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Modern Illustration Process
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MODERN ILLUSTRATION PROCESSES

MODERN ILLUSTRATION PROCESSES

An Introductory Textbook for all Students of Printing Methods

BY
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THIRD EDITION

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"It is also true that a man sees more of things themselves when he sees more of their origin; for their origin is a part of them, and indeed the most important part of them."

G. K. Chesterton
"*St. Francis of Assisi*"

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TO THE MEMORY

OF

G. H. F. CATHERALL

FRIEND OF OTHER DAYS

PREFACE TO THIRD EDITION

During the twelve years that have elapsed since the Second Edition of this book was published there have been, as might have been expected from the progress in the past, very many advances in that branch of photography which is allied with the printing press. Improvements in the fundamental agency—the sensitive surface—still continue and more specialized aids in this respect have been forthcoming. Improvements in the method of colour processes, in offset lithography, in new metal surfaces for lithography, and in apparatus also continue, and best of all, there have been new advances in our knowledge of the fundamental principles underlying the processes and methods involved.

In the text some small deletions have become necessary since the matter represented has, through various causes, become obsolete. Examination of the index will show what subjects are additional, or, being already dealt with, have received further attention. Great care has been taken to give correctly the references to original communications which would naturally be consulted by serious students. The primary aim of this book remains the same. It has been written for the purpose of presenting the principles underlying the processes of picture production in which photography and the printing press are involved, for these principles are important to the understanding of the processes themselves and are of lasting value and the means by which these processes are carried out. To understand these principles should be the aim, and indeed will be the aim, of all serious students who never would be satisfied by mere "use and wont," for only by such study which seeks the answer to the eternal "why?" can real advance be made.

Photography is a great art having many ramifications each with its own purpose. It is often an end in itself, it plays a part in much serious scientific and technical work of many different kinds, and it is a pleasant pastime of the people. Those who practise in one way or another the many applications owe a great debt to Daguerre and Fox Talbot, whose discoveries pioneered the way, and also to many investigators whose labours, often selfless, over many years have yielded such a rich harvest. Especially is this the case with the wonderful work of Hurter and Driffield, which did so much to place our knowledge of the mechanism of the negative making process on a sound basis.

The Author in the preface to the first edition of this book said—"Knowledge that is worthy of the name is founded always upon principles." This was a challenge, and was meant to be. It offered a guiding principle to those young men who had the sincerity of purpose to dig down to the foundations of their chosen crafts. How well the challenge has received acceptance is shown in the literature of our subject, where those who labour in the many fields give the benefit of their work to their fellows. But though there have been many advances in our knowledge of the rationale of processes it has not yet been generally and clearly recognized that an industry does not become really great by processes alone, however good these may be, but by the quality of the men who work them. Far too little care is taken with regard to the selection of the entrants to an industry which has many claims to consideration, and which also offers to those who participate good prospects of material gain. The intake is not what it should be and is still less what it might be.

It is a little more than 100 years since Arago announced the success of Daguerre in fixing the image of the *camera*

obscura, and photography was born. Since that time there has been a continuous advance until the art is widespread and knows few boundaries. Whatever the precise nature of his occupation may be, there are few photographers who cannot share in the proud motto of a famous Regiment and say—

Quae regio in terris nostri plena laboris.

C. W. G.

STOKE POGES
BUCKS
August, 1949

PREFACE TO SECOND EDITION

SINCE the publication of this book in 1933 many advances have been made in the application of photography to the printing press. There have been marked improvements in sensitive surfaces for the camera which have had both a direct and an indirect influence, and in colour photography notable developments have taken place which have contributed largely to the ever-changing face of high-class commercial advertising. The important process of offset photo-lithography has gained by the more general adoption of "deep etch" plates, whilst in colour work correction processes have been developed to such an extent that the offset process may now be regarded as the front rank method of commercial colour printing.

The text, where necessary, has been revised in the light of the advances which have been made. Many new articles have been written, most of which, in order to avoid undue disturbance of the pages, have been placed in the Appendix. The notable things receiving attention have been the after-treatment of negatives and the difficulties in correction methods, the rendering of type faces in gravure, photo-litho plates for offset printing,

three- and four-colour printing processes, and colour photography and publicity.

This book was written with the aim of being a guide for students of printing processes, primarily for those engaged in the work who seek to improve their position in the industry and are taking the only safe road. The aim remains unchanged. But it has never been the intention of the Author to suggest that success can come only by increase in technical knowledge and devotion to that aspect alone, for success in any real and useful sense of the word comes from the exercise of many faculties. The worker in photo-process methods is often placed in the position of an interpreter, and his rendering can be made to show good taste, or the reverse. He does not in most cases originate, he never is himself wholly responsible for what is done, but he can influence and the effect of that influence will be governed by his ability and by the reasonableness of his attitude. One of the most disturbing things in the industry of printed picture production is the lack of good taste which is shown in the selection and treatment of the subjects and which makes much of the pictorial matter so ineffective. There is a failure to appreciate that aesthetic qualities are important, that, to be plain, an appeal to the eye and mind is more likely to be successful when it is pleasant. It is difficult to imagine that a condition of things so unsatisfactory could persist were any appreciable number of producers alive to aesthetic values, or that it is impossible to achieve a better state. To help to bring about so desirable an improvement, it is urged that along with the effort to gain a sound technical knowledge and manipulative ability there should be sought other understandings, perhaps not so tangible, but equally important.

C. W. G.

London, 1938

PREFACE TO FIRST EDITION

THIS book has been written for the purpose of helping students of printing, with whom nearly forty years of the active teaching life of the Author have been identified. It does not aim to give practical details with respect to the manipulation in the different processes. Its object is to inculcate principles, and to state the fundamentals of those methods in daily use for the production of pictures in the printing press, which are of moment to the printer. Largely by reason of its pictorial side has the printing industry risen to its present position, and by its continued adequate treatment of that aspect will it maintain that position unimpaired.

Knowledge that is worthy of the name is founded always upon principles; practice, to be technically and economically efficient, is conditioned by their application, for a practice that is sustained merely by "use and wont" will not in the end be able to face an educated competition.

To-day, numbers of young men are wisely giving to study a portion of their brief leisure after the working day has ended, in order that they may be the better enabled to surmount the technical difficulties of their craft, and to those it is hoped that this book may be of service. The object being what it is, the inculcation of principles, many of which are strange to the reader—although the practices founded upon them may be familiar—the Author has laboured, if anything, the explanations, knowing from long experience the necessity for repetition, and for variation in the approach, in order to make a meaning perfectly clear. This then must be the apology if such be necessary.

C. W. G.

MANCHESTER
May, 1933

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CHAPTER I

THE ORIGIN OF A PICTURE

It is desirable that the student coming, let us assume, to the study of the subject of this book for the first time should understand the underlying idea of a printing process. All printing processes are methods for the multiplication of some kind of picture. No one would resort to the methods described in this book were only one picture of the desired kind required; consequently, we may reasonably start with the picture which is to be multiplied, its nature, and the principles upon which it is produced.

All pictures represent shapes and are on flat surfaces; they are two-dimensional, although they may represent things that have volume and so are three-dimensional. The shape may be simple, as that of an ordinary type letter, or there may be a series of shapes merging one into another as in the representation of a landscape. We may have, on the other hand, a drawing in shading of a plastic object so "like" as to make an observer feel that he is looking at the object itself. All these things are pictures and they depend for their production upon one principle.

They are produced by the regulated *lowering* of the brightness of a flat surface, or, similarly, they may be made by *increasing* the brightness of a flat surface. In the first instance we start with a sheet of white paper and lower its brightness by *black* pigment in accord with the shape we seek to represent, and in the second we proceed from the other end of the scale—we take black paper and use a white pigment. The simplest example of the principle is the finished drawing for a type letter.

The designer of a fount of letters forms a mental conception of what these letters should be in form. He gives this concept reality by making a representation upon white paper, say, for argument's sake, in black pigment, that is, he *draws* the letter as seen "in his mind's eye," and thus the conception has become plain for all to see by this simple expedient.

A PICTURE OF A RELIEF OBJECT

Consider after this preliminary what is done when a draughtsman seeks to make a representation, on the flat, of a relief or plastic object. He may take as the object the white plaster cast shown by means of a photograph in Fig. 1. The contrasts of light and shade—the range—and the gradation will be determined for that object by the illumination, by which is meant the intensity of the source of light and its angular dimensions. The object has no colour, and with suitable illumination—which gives the appearance of relief and the degree of this relief—there will be no black, but white[1] and a series of greys. Now this white and the greys will have *shapes* and so the object presents to the eye an assemblage of white and grey with no pronounced line of demarcation between them—the tones will be *continuous*.[2] The draughtsman with a charcoal crayon has only to produce upon a sheet of white paper these patches of grey as they appear to his eye, correct in shape and brightness, and he will thus have made a representation of the appearance of the object (Fig. 2), the "likeness" of which will depend upon his skill, but given the necessary skill the drawing, if suitably mounted and disposed, may easily pass for a replica of the plastic object. All that has been done has been to rob a sheet of white paper of its surface brightness

[1] For explanation of the meaning of "white," see Chapter XI.

[2] For "continuous" tone and "broken" tone, see Chapter II, pp. 9–10.

Fig. 1. Photograph of White Plaster Cast

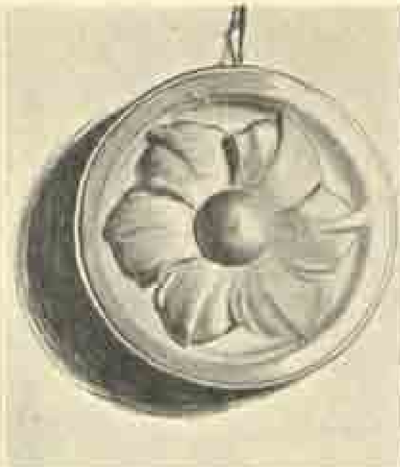


Fig. 2. Drawing of the Plaster Cast in Fig. 1 made with Black Charcoal upon White Paper

Fig. 3. Drawing of the Plaster Cast in Fig. 1 made with White Crayon upon Black Paper

to different degrees—when illuminated in white light—by the application of a black pigment. Conversely, a sheet of black paper may be taken and its brightness may be raised by the application of a white pigment—in correct quantity and relation—to match in tone the parts of the object.

In Figs. 2 and 3 there are shown transcripts of partially made drawings prepared to demonstrate the principles enunciated.

CHAPTER II

THE MULTIPLICATION OF THE PICTURE

THE picture when it leaves the hand of the artist is a finished thing. The student might, however, conceive the pigment as arranged upon a flat surface, say, a block of smooth wood. This surface is now the temporary resting place upon which has been arranged the pigment in form and quantity, and it could be transferred to paper under suitable conditions. The example of the type letter which has been given on page 2 is the simplest that can be taken. If further copies be desired, then fresh arrangements of the pigment would be necessary, which would be a laborious and unpractical plan for multiplication.

In the example taken, the ordering of the pigment is still done by the hand of the artist, and the surface upon which it is so arranged is merely a support. But suppose that the artist alters the surface, say, by removing portions, so that it will no longer hold his pigment, leaving it intact only in those parts where he desires pigment to be held, then the surface becomes the determining agent as to where the pigment shall be. The artist has now only to apply pigment uniformly by some suitable means—the surface determines the arrangement. This is, in fact, precisely the method of the wood engraver. A piece of smooth boxwood is taken and on its surface the artist makes a drawing, say, in simple line. With a steel tool, V-shaped in section, the engraver now removes all the wood where there is no drawing, leaving the parts which have been drawn upon standing in relief. It only remains now for the artist to apply uniformly to the surface pigment in a suitable condition (pigment held in a medium—printers' ink), when those portions in relief

will be covered, and no ink will touch the portions below the surface. The ink so applied may eventually be transferred to paper by pressure, and a replica of the form of the original pencil drawing on the wood will be produced. Here the form of the surface has determined entirely the form of the pigment — we have come to a printing process.

A little thought will show what a great advance has been made by such a plan, when the object is to produce numbers of copies of the artist's drawing. Instead of the relatively laborious operation of repeating the process of arranging the pigment, of drawing, for each copy required, there has been made *once* and for all a matrix available, with suitable precautions, by little labour, for the production of considerable numbers of pictures with the advantage that they are all alike.

The multiplication of copies of pictures then by other means than the hand of the artist resolves itself into the production of suitable matrices. The function of these matrices is to hold or to bear pigment arranged in a definite order and quantity determined when the matrices are made.

Whatever be the method of production, these matrices may be classified as to character according to the way in which the pigment is held. So far as the picture is concerned, by which we mean the rendering of form by the alteration of luminosity of a white surface, pigment alone—be it black or a colour—need be considered, but in practice the pigment alone cannot be used, and for the purpose it is necessary to suspend it in a medium, for which purpose a boiled linseed oil—linseed varnish—is generally used. This forms the so-called "printers' ink," and whenever "pigment," "printers' ink," or "ink" are here employed without qualification, they are to be taken to mean the same thing.

THE FORMS OF PRINTING MATRIX

With respect to the form of the matrix there are three ways and three ways only by means of which the ink can

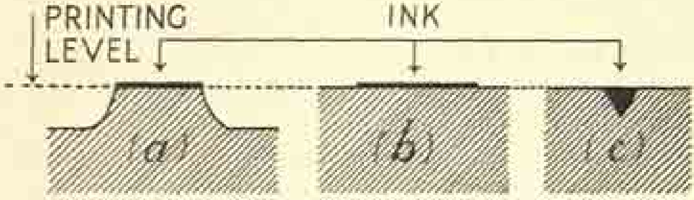


FIG. 4. DIAGRAMMATIC REPRESENTATION OF THE FORMS OF PRINTING MATRIX

be held in an ordered manner. Starting with a *plane* surface of suitable material, the ink may be held by—

(*a*) Cutting away portions of the surface, leaving the parts intended to take the ink standing up. This is a *Relief* process.

(*b*) Forming upon the surface an accepter and a rejecter of printers' ink. This is a *Surface* process.

(*c*) Cutting into the surface, when the ink will be held in the portions so cut. This is an *Intaglio* process.

It will be seen that in the case of (*a*) and (*c*) mechanical conditions determine the holding of the ink, whilst in the case of (*b*) physical conditions alone operate. It will simplify understanding of these three systems if examples taken from well-known methods are given. For the *intaglio* method we have an engraved copper plate used for the production of a visiting card, whilst a forme of type may stand for the *relief* method. For the *surface* method we have a design formed upon the surface of a block of hard limestone, which is lithography. In the last case the stone may be replaced by a sheet of zinc or aluminium—the principle is the same. Still taking well-known processes we have in each class further examples—

Intaglio: Steel engraving, copper-plate engraving (dry point and mordant etching), mezzotint, aquatint.

Relief: Wood cutting, wood engraving, aquatint.

Surface processes are confined to those already mentioned, where the matrix is the lithographic stone (lithography), or the zinc plate (zincography), or the aluminium plate (alagraphy or algraphy). At the present day the term Lithography is applied indifferently to all three, and surface processes are sometimes referred to as "planographic" processes. It may be said that the pictures produced by each method have distinct characters of their own and their value is determined by the connoisseur according to the esteem in which these characteristics are held. In general, it may be said that so far as aesthetic effect and quality are concerned, pictures produced by the intaglio method are held in the highest esteem. Not only does this apply to the older methods, but it still holds sway with the more modern—the so-called photo-*mechanical*—processes where the same principles are utilized, so that it may be said that the attribute which goes by the name of "quality" is largely determined by the form of the ink-bearing surface and hardly at all by the way the matrix is produced. Thus, it may be said, the modern process of *photogravure*, which is an intaglio process, is the best of the photo-mechanical methods so far as the finished picture is concerned.

THE TERMS REPRODUCTION, FACSIMILE, AND TRANSCRIPT

It is desirable perhaps at this stage to indicate certain differences in drawings, because the form of the drawing determines largely the mode of its reproduction. Here it may be said that the term *reproduction* must only be understood in a conventional sense if by that it be sought to convey the idea that any reproduction process ensures a *facsimile*. No *facsimile* of the original is produced by

any reproduction process save in very few cases, and, strictly, probably never. It is better to refer to these as *transcripts*, and only in this sense will the term be used.

If a drawing be made by a mechanical draughtsman, using for the purpose the so-called "ruling pen," each line, though it may differ from its fellows in width, will be equally intense, this being determined by the nature of the tool which controls the delivery of the ink. There is an abrupt break between the line so drawn and the paper upon which the ink rests. Such drawings are, strictly speaking, drawings in "broken tone." If the ruling pen be replaced by an ordinary pen, although it is possible to make each line of equal intensity, in practice, according to the mode of use, they will not be of equal intensity. A freely drawn line will vary in intensity according to the pressure which regulates the flow of the ink, which pressure is governed by the intention of the artist, who relies for his effect in pictorial draughtsmanship upon this variation in pressure. Each penful will carry a different supply of ink, the pressure will vary the width and the supply, and the beginning of a line may be dark, tapering off to something which is quite light, and there is thus produced *gradation in intensity* of the drawn line. In certain mechanical processes employed for the reproduction of line drawings, whilst the mechanical draughtsman's line may be truthfully reproduced in form and intensity, the pictorial artist's line may be correct in form but will not be so in intensity. This often leads, and quite naturally so, to dissatisfaction, but the fault lies with the type of process employed; and in the particular process (line zinc engraving) the fault can only be overcome by handwork afterwards, and then only by the use of a method which alters the line and conveys merely an *illusion of* gradation. When drawings are made in pigment applied

by means of a brush, as water-colour drawings, drawings in body colour, crayon, charcoal, and pastel, the attempt is made to represent the form of an object, something which exists or is created by the artist, by representing the brightnesses of its parts. This is a drawing in shading —there is little or no abrupt transition—and such drawings are said to be in "continuous tone." Incidentally, it may be said that all photographic pictures made from objects in Nature are representations in continuous tone. The form of the drawing ordains the form of the process by means of which transcripts may be made, and in certain processes the procedure which will suffice for making transcripts of drawings in broken tone will not answer for those in continuous tone.

CHAPTER III

MODES OF PRINTING AND SOME MATERIALS EMPLOYED FOR THE PURPOSE

WHATEVER be the mode of preparation of the matrix, whether it be the original method, or the modern means of securing a similar result, say, by the photo-mechanical processes, the matrix belonging to one of the three classes is the same, and will respond to the same treatment. Thus, to secure a picture or print from a modern line zinc etching, the same procedure must be followed as with a woodcut made in the days of Albrecht Dürer, and the stone bearing a photographically prepared image receives and responds to the same treatment when prepared for printing as the litho drawings of Senefelder's time. When considering the printing we are concerned only with the form of the matrix, whether it be intaglio, relief, or surface, and we can ignore, for the time being, the precise manner in which it has been made. This is advantageous, for it enables the student to concentrate upon the study of the essentials of the printing process without his attention being diverted to the rather fascinating ways in which printing surfaces are, at the present day, prepared.

The matrix having been produced, we are concerned with the mode by which its purpose is ensued, the purpose being to enable copies of the original drawing to be multiplied. Bearing in mind that the matrix is a device for holding ink in a particular order and quantity for eventual transfer to paper or other suitable material, we are now concerned with the operations of supplying the ink and its eventual transfer to the desired material. Incidentally, it may be said that there are few materials

which, to-day, cannot be employed as the final support for the ink image—paper, fabric, glass, metal, porcelain, wood, stone, all will respond provided that the substances are in the necessary mechanical condition and that a suitable treatment be adopted.

PIGMENTS AND MEDIA EMPLOYED IN PICTURE PRINTING

We may consider in the first instance the pigment to be used. In the preparation of the drawing the artist seldom employs a pigment alone if the drawing is to have any real durability; even if a stick of charcoal—the simplest of all materials—be employed, the drawing is generally afterwards "fixed" by the application of a resinous solution. Taking any of the forms of carbon employed, charcoal, stumping powder, or chalk, application is by pressure, and the pigment is, so to speak, forced either by the pressure of the charcoal stick, the stump, or the chalk itself, into the fibres of the paper, where it retains a precarious hold, and in consequence the drawing is always liable to damage, as the slightest abrasion will remove some of the pigment. Were the pigment, say, lamp black, to be mixed with water to form a suspension and then while in this state applied with a brush, the particles would enter more completely the felted fibres of the paper and the final result would be much the same—the pigment would not hold for certainty as applied. It is necessary to employ a medium, and that medium may be, in the case of the artist employing a brush, either a solution of albumen or gum acacia. The medium fulfils a two-fold purpose: it renders the application of the pigment easier than otherwise, because the gum lowers the surface tension of the mixture and increases the viscosity (see Appendix, "Surface Tension"), and on the evaporation of the water the gum or albumen

serves as a binding agent for the particles of the pigment. The physical condition of the medium and pigment is of importance, being related to the mode of application. Thus, the mixture of the water solution of gum acacia and pigment, while answering when the application is by means of a brush, would not so easily respond to the application by palette knife as in certain technique in oil painting, when the colour is applied in the form of a paste made by mixing pigment with a vegetable drying oil. We come to the fact that it is necessary, both in the application and in its subsequent retention as deposited or transferred, that the pigment for printing be suspended in a suitable medium, which medium will eventually act as a permanent binder, and that the two be in the necessary physical condition to permit of easy application to the particular form of the matrix employed.

It suffices at this stage to consider only one form of pigment and that, carbon, as obtained by the incomplete combustion of natural gas from the oil wells, the so-called "carbon black." The medium generally used is linseed oil polymerized by heating—the linseed "varnish" of commerce. This medium, which has been used from the earliest days of printing, adequately fulfils requirements. In its simplest form a printing ink consists of a pigment suspended in a medium. We have now carbon black in linseed varnish. The degree to which polymerization is carried determines the viscosity, "thickness," or "stiffness" of the varnish.

THE SOURCE OF THE MEDIUM AND ITS PRODUCTION

It is interesting to note the change which takes place in plain linseed oil produced by means of pressure from the seeds of the flax plant (*Linum usitatissimum*). The raw oil has at 15° C. a density of 0·9321. On heating between

250° C.–300° C. it changes—owing to polymerization—becoming thicker, turning slightly darker, and increasing in density. The polymerized oil now becomes a "varnish." Upon exposure to the air both linseed oil and linseed varnish take up oxygen, becoming thicker, and gelatinize, finally forming a hard but elastic mass—an ideal medium for holding a pigment. A raw oil dries fairly quickly, as does a *thin* varnish, but the thicker varnish dries more slowly. Raw oil could not be used as the medium for printing ink, as upon application it would infiltrate into the paper, leaving an oil outline. This fault is frequently seen with inferior printing inks using oily media, particularly when large-sized letters, bearing a considerable amount of ink, are used. To accelerate the drying of an ink there is added, at the time when the pigment is ground into the varnish, a small proportion of a substance termed a "drier," a lead, manganese, or cobalt compound which behaves as a catalyst; it functions by carrying oxygen to the varnish. Some pigments themselves act as "driers"—some bronze blues, for instance—others as retarders of "drying," amongst which certain blacks are examples. The quantity of pigment to varnish is governed by the intensity of colour required, judged by the amount which the matrix will safely carry for transfer to paper. In some processes, as in the modern offset process, the ink must be particularly rich in pigment because the film of ink carried is thin, and failing richness in pigment the impression would be weak in colour.

SOME PHYSICAL CONDITIONS NECESSARY IN PRINTING

The viscosity required in the ink is governed by mode of application of the ink to the matrix, by the speed of printing, and also by the particular type of machine. An ink for copper-plate printing of fine work is almost a solid,

and one for proofing upon the hand-press, where the ink is applied by a slow-moving hand-roller to the matrix, is far more viscous than an ink which would be employed for the same matrix were it being printed on a fast-running machine. In a cylinder machine the printed sheet is peeled away, whilst on a platen press the sheet is pulled away, and in consequence for the best effects the inks should be different from each other. While there are certain additions made for the purpose of producing particular effects, as substances for reducing or increasing gloss, bodies which mitigate the tendency to "set off"—a troublesome defect which means the transfer of an impression from one sheet to another, when the sheets are piled one above the other after printing—a printing ink remains essentially a simple thing, a pigment suspended in a medium.

The ink, whatever be its nature, must adhere to the agent by which it is applied to the matrix. In certain cases this is simple. No difficulty was found with the fabric- or leather-covered dabber in the early days of printing, but it is not always that the modern composition roller will "pick up" the ink from the slab. In certain cases, as, for example, in the so-called "water-colour" printing, considerable difficulty has been found in this respect. Further, the ink must leave the roller and adhere to the matrix, and finally must leave the matrix and adhere to the paper. These adhesions and transferences are governed by the cohesion between the particles of the medium-covered pigment and by the interfacial tension between matrix surface and ink film, and are not by any means simple problems to explain. The covering of a metal surface with a film of ink is somewhat akin to wetting the surface of a leaf with an insecticide—there must be something present to ensure the "wetability," as the soap or casein with the insecticide. With an ink it

is the nature of the varnish and the pressure of the roller, and it does not by any means follow that an alteration in the medium will mean equally good spreading; in fact, inks differ considerably in the way they will "feed" the matrix.

An important condition determining the inking is the viscosity of the ink itself. Without a reasonable viscosity uniform inking of a surface would not be possible. If the ink were very mobile—the reverse of viscous—it would not remain where placed by the rollers. Viscosity (roughly, "thickness," "stiffness") means that where the ink has been placed by the roller there it will remain. Further, viscosity regulates the flow in the ink duct and so the feed to the roller and thence to the matrix. Since viscosity varies with temperature it will be seen how important is the maintenance of a uniform temperature in press and machine rooms, more especially when colour work is being done.

Considering the material to which the ink image on the matrix is to be transferred it will suffice for the moment to take paper, and paper alone. But paper differs very much in character, from a fibrous material, almost like a fabric, to a material from which all fibrous characteristics have been eliminated by means of a coating of china clay which has been artificially smoothed by calendering. Between the two limits there are many differences in degree and also in kind.

To ensure the transference of ink from matrix to material, contact is the first essential, and beyond mere contact probably a certain amount of extra pressure is needed to *force* the ink into the surface of the material, which, unfortunately in the case of relief processes, is where the ink is free to move and leads to spread of the image. The "spread" is due to delay in ink penetration, which varies with the paper—its kind and surface. The nature of the

ink influences extent of spread—an increase in its viscosity reduces the tendency. This latter presupposes contact. Were the two surfaces *planes*, it would suffice to bring them into contact, and over and above this the minimum amount of pressure would afterwards be needed. But in practice the conditions are not so simple. The matrix is far from flat, and the paper, whilst it may be flat in the sheet considered as a whole, is certainly not so when regarded as a series of minute areas. It is precisely these minute areas that must be considered. If we regard the matrix as an assemblage of fine elements, say, tiny letters in a relief matrix, as in a type forme, and the paper as a series of hills and valleys of the same order of size as the type, it is easy to see that some of the hills may touch the letters and so the necessary contact is made, whilst with others there may be no contact because they meet the valleys, and so the transference of ink is incomplete. It is precisely this condition which makes the printing of the modern "half-tone" block with its exceedingly small elements so difficult upon anything but very smooth paper. The resistance of paper to making contact where areas of small orders of magnitude are concerned is considerable, and is only overcome by great pressure, which has several disadvantages. To avoid this, a paper is employed the surface of which has been artificially smoothed by filling up the pores or interspaces between the fibres with suitable materials, following which it is further smoothed by rolling under polished rollers. But even here this does not suffice for all matrices, and so the paper is given a filling of a white inert body (china clay), and still other papers are made, the so-called "art" papers, which receive a surface coating of inert bodies of finer quality, satin white (aluminium hydrate and calcium sulphate), baryta white (barium sulphate), suspended in casein or gelatine, being employed. The paper is

eventually calendered to produce a surface as nearly a plane as possible, enabling the printer to secure more easily and with less pressure the necessary contact between matrix and material when the transference of ink takes place.

Taking in the first instance for the sake of simplicity—and also because it shows the essentials—the application of ink to the matrix by hand, we may consider the case of an intaglio copper-plate. Here the ink—which is pigment ground in strong varnish—is applied to the surface of the plate by means of a dabber, which is a fairly hard ball of wool covered with leather or fabric. The ink is forced into all the incised portions by rubbing the dabber into the incisions in the plate, the excess being eventually wiped away, leaving the surface of the copper clean, when the plate is ready for printing—for transfer of the ink to paper. This is done by placing the plate on the steel bed of the press (a roller press is employed), placing the paper (which is sometimes damped to soften it) on the plate and covering the sheet with a fine felt blanket, and then applying pressure. The paper is really forced into the incisions by the great pressure, but though the pressure be great, the ink cannot escape, being imprisoned in the engraved cavities, and it is for this reason that intaglio furnishes the sharpest impression of the three systems. The ink is "short" in character, not "stringy," coming away clean from the matrix, and, furthermore, standing in appreciable relief, this effect being enhanced by the fact that the paper has by the pressure been forced into relief.

If we now consider a surface process, we have an entirely different set of conditions. Taking the lithographic stone with its image as the example, we have a varnish or fatty image resting on the surface of the stone, and undoubtedly penetrating the surface. This image will resist water and the stone will absorb water, since by

reason of viscosity, surface tension, and the fact that the varnish image is insoluble in water, and that it rests upon an absorbent stone, we have now a repellent and attractive surface to either ink or water, side by side. If we wish to increase ink on the image we apply that material by means of a roller; if we wish to increase water we apply this liquid by means of a sponge—certain that in neither case will the two interfere. The ink is transferred by pressure to the paper, the stone is redamped, and ink is again supplied by the roller. The surface presents an *accepter* and a *rejecter*. The ink image will not spread, being prevented from doing so by the surrounding water, and it is for this reason that well-printed lithographic work is sharp in character. Other means may be adopted for securing the same effect, as in the Pantone process, where there is a chromium image on a silver amalgam ground, the chromium being the accepter and the silver amalgam the rejecter.

Coming now to the relief matrix, here the conditions are entirely different. The portions intended to hold ink stand in relief, and, when the roller passes over the surface, contact deposition takes place; the ink is held in the ordained manner by the distribution of the elements in relief, this ink eventually being transferred to paper by pressure. Printers as a rule are so familiar with this process—its results are so obvious—that they frequently fail to see the implication. It is not correct to assume that the *surface* alone holds ink, for the sides of the elements hold ink too (since there is no rejecter to confine the ink to the accepter), and an appreciable quantity—if due attention be not paid to the viscosity and the supply of the ink used—is deposited on the sides of the dots close to their tops. This ink is lifted away by the paper and an increase in the size of the elements is shown. A printed dot, therefore, is bigger than the surface of the dot itself, for the ink from the surface and the ink from the

edges are associated in the impression. Moreover, if an impression be studied under the microscope, it will be seen that in the process of applying the pressure, the ink has been pushed out to the edge of the element. This

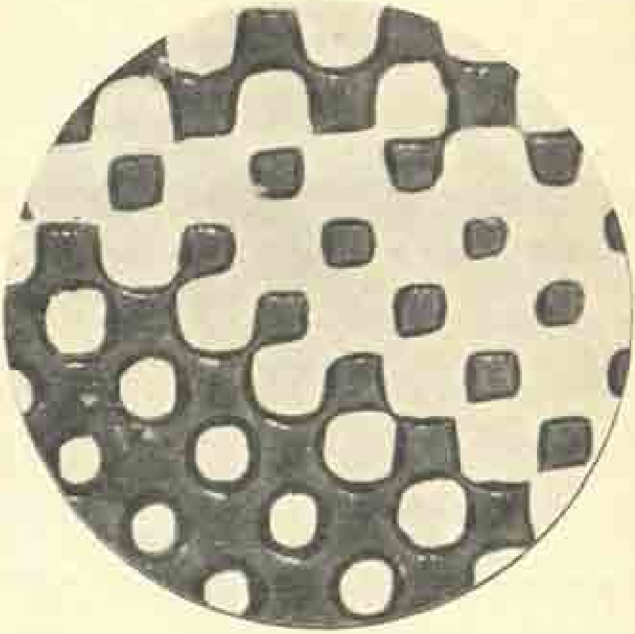


FIG. 5. PRINT UPON COATED ("ART") PAPER FROM A HALF-TONE BLOCK, HIGHLY MAGNIFIED, SHOWING A DARK LINE ROUND THE EDGES OF THE DOTS, WHICH INDICATES THAT THE INK HAS BEEN SQUEEZED OUT TOWARDS THE EDGES DURING PRINTING

is well shown in Fig. 5, where there is represented a portion of a print from a half-tone screen block enlarged.

Of the three impressions, so far as concerns fidelity to the size of the components of the matrix, the relief process is the least satisfactory if rigid considerations be applied. Moreover, it is the one that suffers the most with bad craftsmanship in printing, and cannot fail to do so by reason of its nature.

In an article on "Coated and Uncoated Papers for Half-tone Printing," Dr. Julius Bekk says: "It is impossible to prevent 'squash' or squeezing-out entirely in letterpress-printing, but it is the task of the printer in the interests of the best possible results to reduce it to a minimum."

For the considerations involved, the student is referred to this interesting paper. (See *Penrose Annual*, Vol. XXXVIII, 1936, pp. 99–102.)

CHAPTER IV

THE TRANSFER OF INK AND THE METHODS OF APPLYING PRESSURE

WHEN it has been stated, as in the previous chapter, that printing consists in the transfer of pigment from the matrix to the surface of paper or other material, the process would appear to be simple, more particularly, perhaps, to the student whose everyday occupation is to take part in carrying out the process. In reality it is not so simple as may appear. We are concerned in the first place with establishing perfect contact between the two surfaces, and in no case are the surfaces flat; they are not, strictly speaking, *plane* surfaces. In order to establish perfect contact, pressure is needed, therefore, to force the two surfaces together. If the paper be resistant, as all paper is, then the pressure must be increased over that which would be required were the material perfectly flexible. Moreover, some extra pressure is required to cause the pigment to adhere to the paper over that which would be required were the material a plane surface and quite flexible. The particles of the ink have for each other considerable cohesion, and this cohesion must be ruptured.

It is the pull of the particles adhering to the paper which causes the ink to leave the matrix, but to secure this the ink must be made to some extent part of the paper, and this requires pressure. Now, whilst the resistance to pressure may be the same per unit area with the same class of paper, and the same type of matrix in matrices of different sizes, the total pressure required will depend on the total area involved in each case.

THE SURFACE OF PAPER IN RELATION TO INK TRANSFERENCE

To the student the surface of a piece of paper will be flat, and so far as the sheet is concerned it is so, but when we come to the problem of printing we have to consider *small areas* of the paper in relation to corresponding areas of the matrix, because it is precisely when we come to these small areas that the resistance to pressure is most manifest. This resistance, to be overcome, depends upon two things—the hardness or softness of the material, and the surface to which the ink is to be transferred. (Moreover, differences in pressure occur because the paper is not uniform in thickness, and if a thin area be surrounded by a thick area more pressure will be needed to "bed down" the thin part of the matrix.) The former depends upon the nature of the *material* of the paper, and the latter upon the mode of manufacture which produces a particular finish to the surface. It is to the latter that some attention must be given. A standard of "roughness," of "finish," is not easy to lay down, but for practical purposes we may establish one that perhaps will be easy to understand.

Let us consider a small area, say a square with a side of half an inch. This surface will present rugosities. We may regard it, for convenience, as a small ploughed field, the difference between the height of the tops of the furrows and the bottoms giving the *degree* of roughness. Now, in relation to the width of this field, this difference may be considerable, and we say that the paper is rough. But if we consider the width of a demy sheet of paper the difference is negligible. When we are printing pictures we are not dealing as a rule with inked elements which are large, but with elements which are small—tiny letters, say six point, or the dots in a half-tone process block. If we consider the latter case—where the smoothness of the surface of the paper is an important element towards

perfect and complete transference—we have a large number of small dots. In a half-inch square of flat tone in a 133 line screen block there are 4,356 dots. Each of these is covered with ink, and this ink is to be transferred to paper. Now the tone, if it represents an even patch, will show irregularities at once if the ink from some of the dots does not transfer. When we come to print, if the paper is rough, the chances are that some of the dots will touch the tops of the furrows, whilst the others will meet a furrow or the sides of a furrow; the pressure will not secure contact unless it be great, and so the ink will not be transferred. Hence the patch of tone will be rough, and the effect will be displeasing. Only does this roughness or want of uniformity fail to secure notice when there is used in the making of the block an irregular grain screen instead of the regular half-tone screen. In this case a little lack of regularity is not observed. If it be sought to secure complete transference by extra pressure, then the ink spreads, dot areas are increased in consequence, and there results a flattening of tone. In type printing—the great test of a good printer—the printed face of the type is enlarged, the work is "thickened," an inferior result ensues, and, sometimes, the face of the type is damaged. A similar damage results to the face of a half-tone block. It is perfectly true that blocks are prepared ("deep-etched" half-tone) to stand the heavy pressure required when it is desired to print upon rough papers—which are never intended for very rough material—but such blocks are always specially prepared, and are etched with an extended scale of tone to allow for the inevitable flattening of tones which takes place, and for the best result a very carefully prepared overlay is generally provided. But while this paper would be "rough" towards a 133 line screen block, it would not be rough were it employed for a poster using, say, a 72-point

bold-faced letter. Here the irregularities would not be noticed and, therefore, would not matter; and, indeed, the face of the letter would carry enough ink to fill in the irregularities of the paper.

So far as concerns the material, it is well known that the papers employed in printing show different degrees of hardness or resistance to pressure.

THE MODE OF INK TRANSFERENCE

The transference of ink to paper is effected in one of two ways, either direct to the material—the paper—or to an intermediate surface and thence to the paper. In the latter case, the ink is transferred to a rubber blanket and thence to the paper, when it is said to be printed "offset." We come then to the fact, which is well established, that in ink transference, if there be not two perfect plane surfaces, the surface intended to take the ink must be resilient, and even then the want of planarity must not be too pronounced. Now, a rough surface considered in relation to a small area may be too rough and not sufficiently resilient, but the difficulty is overcome by using the very resilient surface of the rubber blanket, and by this means the range of papers which can be employed for printing small elements is considerably extended. By the use of this intermediate surface many materials can be printed, such as metal, wood, glass, and fabric, which otherwise would be quite impracticable as recipients for the ink picture. A recognition of these before-given simple facts would have saved a great deal of condemnation of the printer for using high surface coated papers by people who do not like this kind of paper. The printer does not use, as a rule, the material because he likes it, but rather by reason of the conditions which frequently obtain. Fortunately, it is not necessary in "surface" methods, as when the offset process is

employed, and the introduction of "deep-etched" half-tone plates—with an increased range of contrast—also now permits the use of papers with a more pleasing surface than has been practicable hitherto.

The mode of transference of ink to paper being by pressure, there is now to be considered the way in which this pressure is effected, and this is a mechanical problem.

It may be stated at the outset that the three types of matrix require different amounts of pressure, but the actual amount in each kind of matrix differs with the circumstances, the particular matrix, the area exposed, the ink, and the paper being the chief determinants.

If the two surfaces—the paper and the matrix—to be brought together were perfect planes, then the laying of one upon the other would ensure contact, and there would only be necessary a degree of pressure sufficient to cause adherence of the ink to the paper, and this amount would vary with circumstances. But the primary supposition—that of perfect flatness—is one that is not met with in practice even approximately, so that the condition is hypothetical. Actually, we have to exert an appreciable amount of pressure to bring together two non-flat surfaces, and generally, it may be said, this will be found sufficient—and often far more than sufficient—to cause the necessary ink adhesion. The additional pressure becomes necessary owing to the fact—as suggested—that the matrix is not flat, and, in part, to a want of accuracy sometimes in the machine or press, though with modern plant of good make this is a minor cause, and may be absent.

THE PRINTING PRESSES

The student who learns to do a thing by the use of apparatus does not trouble himself, as a rule, as to "the why and the wherefore." In the kind of work we are considering he does not see that in a printing machine or

press we have merely a device for producing contact and a certain amount of pressure between two surfaces—he is more often than not likely to assign other *virtues*, other *properties*, to the mechanism, especially if it be of complicated construction. Let us, therefore, start with the simplest device with as few complications as possible, so

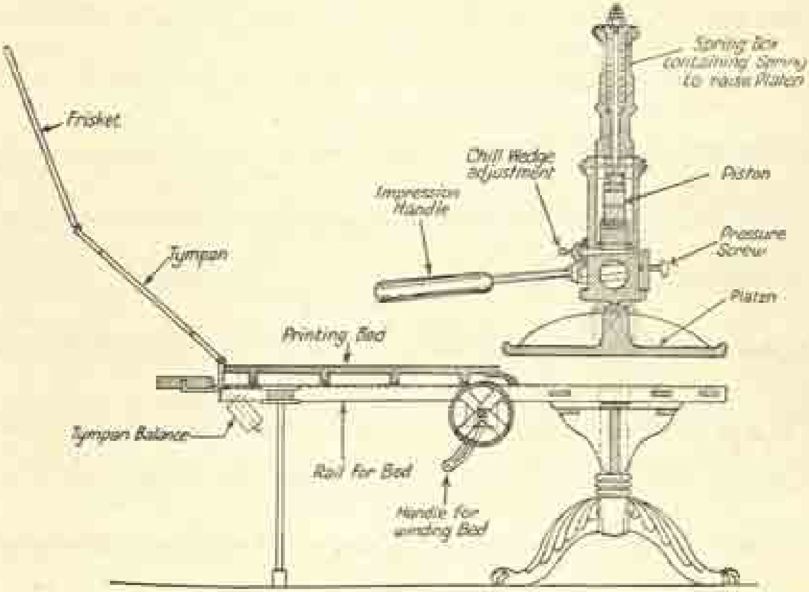


FIG. 6. THE ALBION PRESS

that the principles may be established. It is convenient in the first instance to consider a relief matrix, one where the parts which take the ink are raised above a common level, and with such a matrix the most simple form of device for securing impressions, or prints, is one with which every young printer is acquainted, viz. the simple Albion type of platen press. In an Albion press, Fig. 6, we have two surfaces, the lower the "bed," and the upper the "platen," and when not in use these two surfaces are parallel, and are separated by an interval.

The bed is a solid slab of iron which is supported upon a movable carriage so that it can be moved to and fro on rails from under the platen, and mounted upon the carriage at one end is a hinged frame, which is covered with fabric or parchment, termed the "tympan," and this tympan can be lowered over the bed. The platen is a solid iron plate which is rendered more rigid by means of iron ribbing, the whole being cast in one piece. Normally, it is maintained at a certain distance above the bed by means of springs held in the side frame. Pressure is applied by a lever to a toggle which, acting at the centre of the platen, causes it to travel vertically downwards, there being guides to ensure that there is no lateral movement when on its downward path. When the bed is under the platen and the latter is caused to descend, although it will not travel low enough to touch the bed, the two surfaces should be parallel, and should remain so at each stage in the platen's downward movement.

The tympan in reality consists of two frames, one within the other, and, upon separation, sheets of paper can be introduced. In this way, the tympan may be said to provide an elastic medium for placing between the platen and the matrix. For purposes of explanation we may assume the matrix to be a line zinc relief plate. If it be mounted, it is termed a "block," and to satisfy conditions properly, the *surface* of the mounted plate should be parallel with the back. If it be unmounted, it may be placed upon an iron bed-plate whose upper and lower surfaces are parallel, and sometimes, instead of the bed-plate, there is used one of the special composition boards made for holding plates during printing. We have thus the system very frequently used by photo-engravers—who may not have provided themselves with the more expensive modern proofing presses—for proofing their plates prior to mounting. If these conditions be satisfied,

then when the matrix is in position on the bed and the bed is under the platen, the under surface of the descending platen should be parallel to the surface of the matrix. In practice this latter condition is seldom fulfilled, and, consequently, uniform contact and pressure, which would be ensured when the descending platen reached the paper placed on the inked matrix, cannot be secured. To overcome this drawback there is caused to intervene an elastic medium, viz. the material constituting the tympan, and the degree of elasticity provided will depend—the press being properly constructed and erected, and disregarding a slight lack of uniformity in the thickness of the printing paper—on the departure from planarity of the surface of the matrix or variations in the mount. But, when the necessary conditions have been secured, pressure applied by the platen should cause transference of the ink from the matrix to the paper and a perfect impression should be produced.

The amount of pressure to be exerted by the platen upon the surface of the matrix per unit area, say, each square inch of its surface, is governed by the area of the *upstanding metal* and the total pressure required by the total area of the matrix. Since, however, the amount of metal upstanding in one square inch is not likely to be the same for each square inch, but will vary with the subject represented, although one would expect a uniformity of pressure, in practice the pressure required will vary in the different parts of the surface owing to imperfections in the plane surfaces; and, since undue pressure will cause a less perfect impression in that particular part than should be obtained, we arrive at the necessity for some modification to ensure the proper uniformity, and this is secured by the "make-ready"—the "overlay," or "underlay," as the case may be—which is the pressman's device for securing the proper pressure to each part if a perfect impression

is to be secured. This preparation consists in cutting masks of thin paper which are fixed to the tympan so as to be in register with the particular parts. There are, also, other means of securing this variation in pressure, as chalk, metal, and insolubilized gelatine overlays. Thus it will be seen that, while the descending platen is made to supply a uniform pressure, this is merely the starting point, and that this uniform pressure must be modified to meet the requirements of each matrix and the parts of the particular matrix, because the matrix does not present uniform resistance in each part of its area owing to imperfections as stated.

A fault with the early forms of the Albion press arose through the elasticity of the platen. Owing to the resistance of the matrix at the margins, and the pressure not being uniformly transmitted to these margins, the platen actually bent or "gave," and, in consequence, proper transference of ink was not secured, especially when it was sought to prove matrices of areas relatively large to the area of the platen. To avoid this bending by making the platen thicker would have meant a clumsy construction, and so the difficulty was overcome by strengthening the platen of ordinary thickness by means of the "ribbing." Failing this the pressman could only secure uniform pressure by increasing the thickness of the tympan packing towards the margins, and this was a far from satisfactory method, and one not easy of accomplishment. An interesting instance where the necessity for varying pressure was found occurred when printing upon vellum, the skins of which have not the uniformity in thickness that is shown in paper. It was necessary to make ready in each piece of vellum "in blind" before ink was applied to the surface—generally type matter—and when this adjustment was secured an impression was made. If we now transfer our attention from the line matrix—which

so far has been considered—to type matter, it will be seen that a closely-set page of type will require more pressure than one openly set or one where the type matter varies over the surface considerably, as in a display page. With a "half-tone" matrix the pressure required will be more uniform, and for a given area always greater even than with closely-set type matter. When these surfaces are of very large area it will be seen that the pressure required is considerable and calls for great strength in the build of the press, and, incidentally, demands much exertion on the part of the pressman. To-day these large Albion presses are not used, and other means are adopted, but it is well that students should understand the conditions which did obtain, remembering that the requirements have not altered, but merely the means by which they are met.

Let us consider what would take place were we to seek to produce an impression from a matrix where the resistance was much greater than in any case we have so far discussed. So far the assumption has been made that the matrix would stand the pressure. The stresses considered, in the previous examples selected, have been remote from the crushing stress of the matrix; there has been no likelihood of the matrix giving way or becoming damaged under the pressure required to produce an impression, although delicate type matter might conceivably be damaged, and has been known to be damaged, by careless press work. We may now study, however, what would be the effect were the matrix of that character because of its resistance area being great and the matrix being relatively fragile. A lithographic stone, or the glass plate supporting a collotype film, presents this problem. These are surface processes, and in surface processes the resistance is the same whatever be the amount of image they present, the resistance being the surface independent of what

image there may be upon it. Similarly, in an intaglio matrix. Let us take, for the sake of simplicity, a lithographic stone, and let us assume, in order that we may have the best conditions, that the stone has gone through the planing machine, and that back and front are parallel, an assumption that may be regarded as rather far-fetched. But the stone itself though fairly homogeneous is not entirely so, and, under too great a stress or unequal stress, will often crack, and much loss, if the stone bears a complicated drawing, follows in consequence.

Suppose that it was sought to print from one of these stones in a press of the Albion type, the pressure required for a stone of appreciable size would be very considerable, and presses would have, in consequence, to be extra strongly made, whilst the effort required to produce impressions would be so great that the work would be very exhausting, and the stone would probably give way under the pressure exerted. But is it necessary to apply the pressure to the whole area at one and the same time? Our forefathers decided that it was not, that other means might be adopted for securing the effect, and the "scraper" press is the result of their ingenuity.

In a "scraper" press the pressure is not an area pressure but a "line" pressure. The pressure is confined to a small narrow band at a time, each portion of the surface being treated successively, so that, although the amount of pressure that is applied is that required and is great for the band under pressure at the moment, the total amount applied at that moment is not sufficient to crush the matrix. A similar principle is applied in the printing of collotype plates.

In a "scraper" press, see Fig. 7, we have a travelling bed which rests upon an iron roller of considerable diameter, which roller is caused to rotate by means of a handle. Between the under-side of the bed and the

surface of the roller there is considerable friction, and this friction is sufficient when the roller is rotated to cause the bed to travel. Above the bed, fixed in the "scraper box"—which can be raised or lowered by means of a screw—is the "scraper," which may be, and generally is, a thick bar of boxwood with a blunt V-shaped edge, across

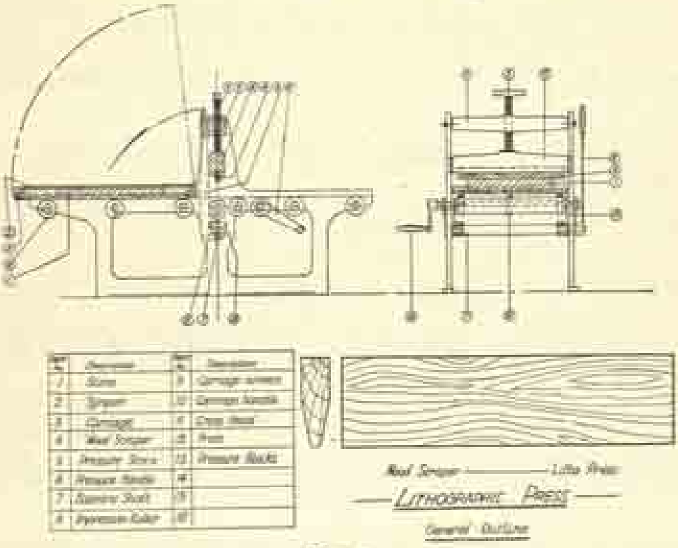


Fig. 7

which from side to side is stretched a band of leather. Attached to the travelling bed is a tympan frame on which is stretched a sheet of zinc or brass, but sometimes leather is used, in which case there is no leather on the "scraper." By means of a lever the roller is raised, and this raises the bed. A stone is placed on the bed and over it are put a few sheets of paper which constitute the elastic medium—as the backing used in the tympan of the Albion press. The tympan is then lowered until it rests upon the surface of the "backing" placed over the stone. The handle is rotated to bring the stone under the scraper, and the lever is raised. This brings the tympan

in contact with the scraper on turning the handle, and the pressman determines by his judgment whether or not the pressure is sufficient—if not he lowers the scraper by means of the screw moving the scraper box. When the pressure is judged to be enough the carriage is brought back, the tympan lifted, and the backing paper on the stone is lifted away. The stone is now rolled up, a sheet of printing paper is adjusted in place, the tympan is lowered, and the bed is caused to travel under the scraper; and when that is done, the pressure is released and the bed is brought back. This operation is repeated when "transfers" are being made to stone from impressions on paper already bearing an ink image. Thus, by this device, the difficulty which would result with large area pressure is avoided.

Where large stones are to be printed, the movement of the bed is effected by power instead of by the sinews of the pressman.

When it comes to the printing of large editions, then for economy power machines are employed. Here the pressure is applied by means of a large diameter cylinder rotating in fixed bearings, and though the mode of application of the pressure is different, the principle is the same. The contact between a cylinder and a plane is a "line" contact, and consequently this system gives line pressure. Actually, however, since there is round the cylinder a more or less elastic packing, the pressure is more than a mere line—it becomes a band of appreciable width—but nevertheless pressure is applied only to a small portion of the total area. Another feature to be remembered is that in these instances of "line" pressure, the stress to which any one part of the stone is subjected is only for a brief space of time.

The scraper is the parent form of "line" pressure. In printing from a relief surface of large size the cylinder is adopted as the means of applying pressure. It would be

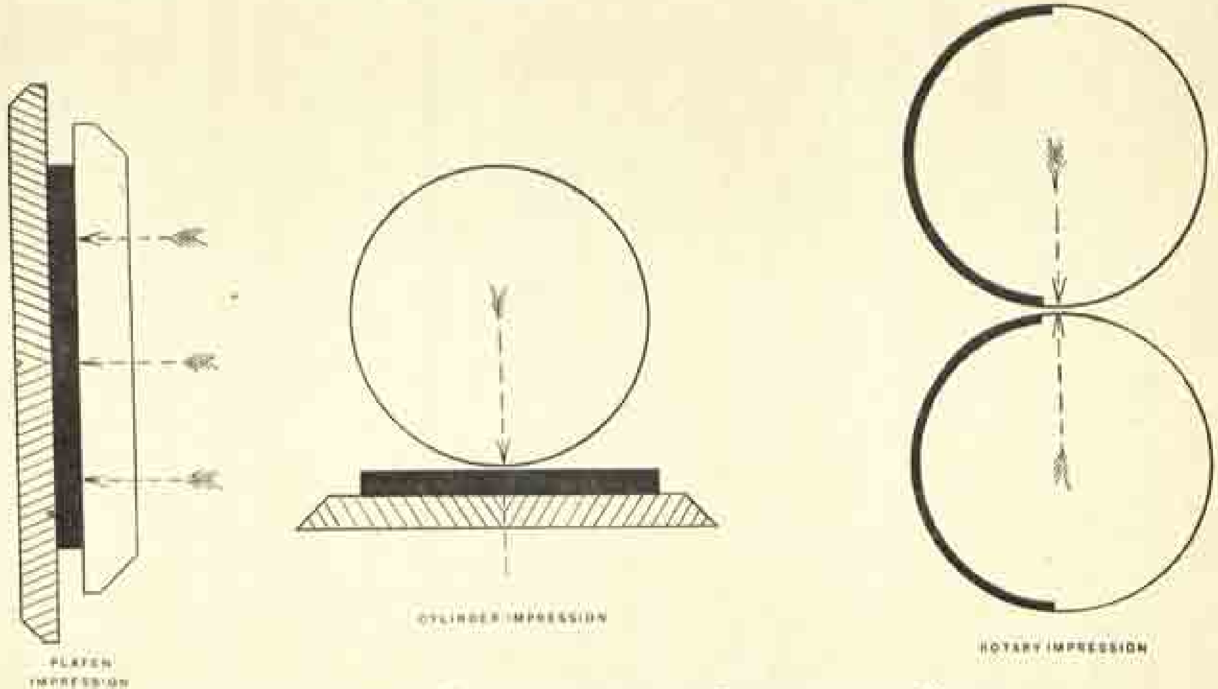


Fig. 8. Diagrammatic Representation of the Principles of the Methods of Applying Pressure in Printing Machines

entirely impracticable to build machines for area pressure sufficiently strong to give the necessary stress, and even were they built the strain produced would break down or damage the matrices, were they photo-engraved blocks or type. Further to this, such devices would suffer from the defect common to all devices of this type, in that the rate of production would be so slow as to be to-day impracticable. With the different method of applying pressure and the mechanism to ensure it there are associated all those devices which, by doing what would otherwise have to be done by means of the human hand with its limitations, determine the economical production of printed matter in modern times.

What is true of lithography and its cognate branches of metal surface printing is true of intaglio printing. In the printing of incised copper plates "line" pressure is used as in the cylinder copper-plate press, and for the same reason. The pressure required is too great to admit of printing the whole of a large area at one time. On account of the elastic pressure—a pressure necessary to force the paper to some degree *into* the incisions to secure the adhesion of the ink—the "line" becomes a band of appreciable width.

In the machine printing of incised surfaces, as in the case of photogravure, line pressure is applied by means of cylinder machines.

In Fig. 8 there are shown by diagrams the principles of the different modes of applying pressure.

CHAPTER V

PAPER AND INK

We may at this stage consider the nature of the two essential materials used in the printing process, the ink and the paper. It is the purpose of the ink when it is applied to the paper to alter the brightness of the latter, for it is in this way that the forms of objects are represented; it is the way in which the picture is produced. We must start with a material which is of uniform tone and we apply to that a body which is uniform in character; for one part must be like another part, otherwise we should not be able to say what would be the result of our application. Although paper has been selected as the material to which the ink is transferred, paper is, as the student knows, not the only material; but the operations with paper are more simple and direct than with any other substance and therefore it is taken. When the term "white paper" is used it does not necessarily mean colourless paper. "White" is frequently used by the printer to denote *unprinted* paper, and in that sense, unless otherwise specified, it will be used in the remainder of this chapter.

SOME PAPER-MAKING MATERIALS

The raw material from which paper is made is principally vegetable fibre. The finished article is a fabric, and more nearly akin to what is generally known as a "fabric" than many seem to appreciate. A fabric, for example, a piece of cotton cloth, has, for the starting point in its manufacture, the fibrous material attached to the seeds contained in the fruit capsule of the cotton plant—the various kinds of *Gossypium*. Similarly, a piece of linen is

formed from the fibres taken after suitable treatment from the stems of the flax plant (*Linum usitatissimum*). From the fibres of the cotton or flax, a continuous thread or yarn is produced by a process of twisting termed "spinning," and from the yarn so produced the fabric is woven. The weaving process is essentially a method of interlacing the threads; yarn in one direction, the warp, is interlaced with yarn in another direction, the weft, and the result in a plain fabric is, essentially, a net-work of yarn which in turn consists of the twisted fibres. In the case of cotton cloth, the finished material is the product of a series of elaborate mechanical operations from the moment the cotton fibre attached to the seeds is received in the ginnery to the time when the finished fabric leaves the weaving shed. To keep the comparison before us, let us consider a piece of fine cotton cloth as merely an assemblage of cotton fibres, the strength of which depends upon the quality of the raw cotton, the nature of the yarn, and the care with which it is woven, whilst the smoothness of the surface, the "texture," will depend on the closeness of the weave and the finishing process to which the cloth is subjected.

THE MATERIAL—PAPER

Paper may be regarded as a fabric produced from fibrous material by a simple process of agitating a mass of the fibres in water, which causes their intertwining or "felting" together, and afterwards draining the water away and drying the drained mass. A material made in this way will not resist fluids, but with respect to the penetrating qualities of fluids into the material, papers may be divided into two distinct classes. We have to prepare papers which will withstand the penetration of aqueous fluids, as ordinary writing ink in the case of writing papers, and a paper of another class, for example

printing papers, which will withstand the penetration of media such as oil or varnish, and the properties necessary are not produced by giving identical treatment to the raw material—the fibres.

In the preparation of the pulp from which the paper is made the fibres are beaten and digested with water in the "beating engine," and it is here that the most important treatment takes place. Pulps for papers required to withstand aqueous fluids are beaten to a certain degree, and then a sizing material, generally resin, is introduced, and the two, the fibres and the resin, are thoroughly incorporated. Pulps intended for the making of printing papers are more thoroughly beaten, and this causes the fibres to attain that condition when they will more thoroughly "felt" in the subsequent stage—this treatment being in addition to the sizing, which may afterwards be given.

In addition the pulp is treated with certain substances which help to fill in the spaces between the fibres. This is termed "loading," and the principal loading bodies that are used are china clay, calcium sulphate, barium sulphate, and starch.

China clay and barium sulphate are also used for coating the *surface* of paper, for which purpose the bodies named are suspended in gelatine for the high-class papers as used in photography, and in glue and sometimes casein for printing papers. The effect of the loading is to make the body of the paper more continuous and the surface to some extent smoother, whilst the rolling with calenders makes the *surface* still more perfect.

THE ULTIMATE NATURE OF THE PAPER USED

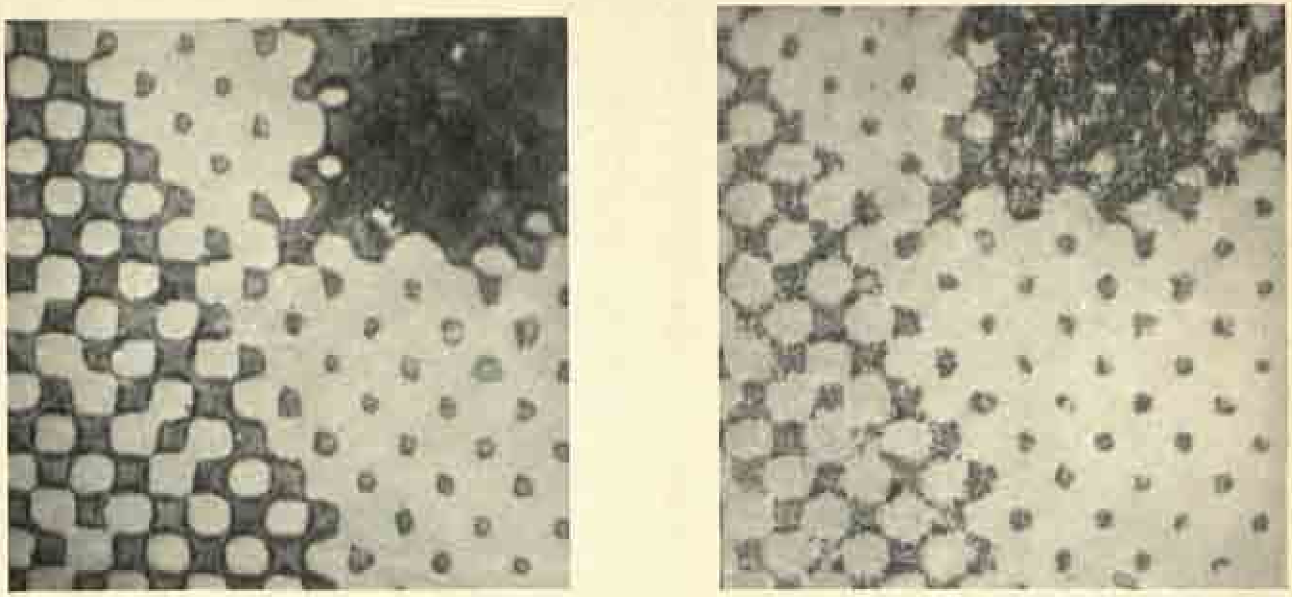
What we have in the end is a felted mass of fibres, the strength of which depends upon the strength of the fibres themselves and the degree to which they are "felted."

This "felting" replaces the spinning of the fibres into yarn and the weaving of the yarn into fabric. Actually, the fibres twist round each other, but although by this process a strong material can be produced, it can never be so strong as the woven fabric. A very large number of fibres are used in paper making, of which the most important is the flax fibre, followed by hemp and cotton (it is seldom that new fibres are used, the source of the material being generally rags), after which we have chemical wood pulp and esparto, while for inferior papers straw and mechanical wood pulp fibres are employed. The fibres of flax, cotton, and hemp in their natural state are too long for the purpose of paper making, but in the process of preparation they are reduced to a suitable length. If they are too long they are unmanageable, whilst when too short the felting will not yield a strong material, as may be seen in "news" stock, for which purpose wood fibres—which are relatively short—are used.

We have in the end a material, compact, smooth, and uniform, the characteristics of which depend upon the materials and the make.

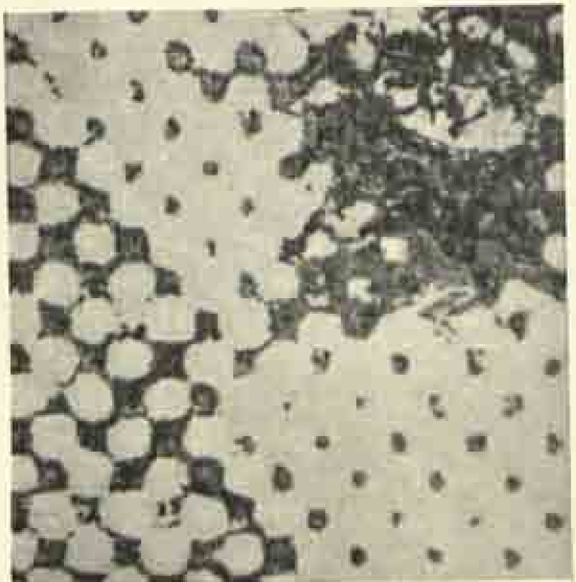
The examples (1–6) in Fig. 9 show highly-magnified (× 35) pictures of half-tone prints upon different kinds of paper. The parts shown are all taken from the same place in the block as near as practicable. As we pass from (1) to (4) we see a gradual deterioration in the form of the dot. This shows in the print a gradual increase in roughness in the tones and a loss in gradation. Example (5) is a print upon a smooth texture paper in character similar to a "plate" paper, whilst example (6) is on the same paper but from a "deep-etched" block.

This material then forms the base of our picture. Its primary purpose is to act as a receiver and scatterer of light, to give a uniform "white" surface, and our pictures are made, as previously pointed out in Chapter I, by

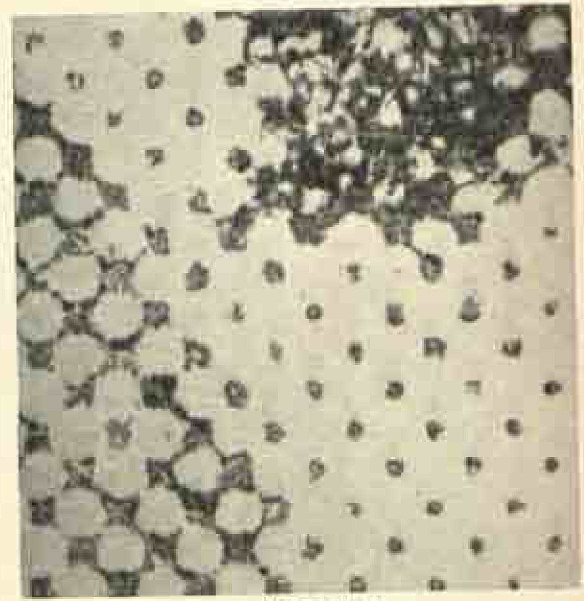


1. "Art"   2. "Imitation Art"

FIG. 9. EXAMPLES OF PRINTS FROM HALF-TONE RELIEF BLOCKS ON DIFFERENT KINDS OF PAPER. MAGNIFIED (×35)

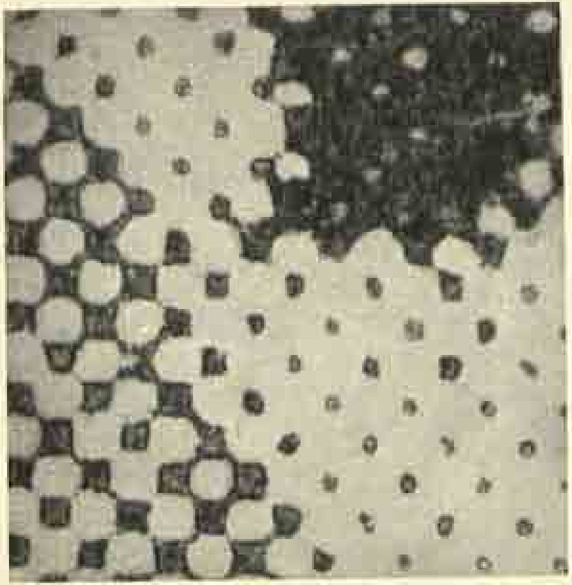


3. "Super-calendered"

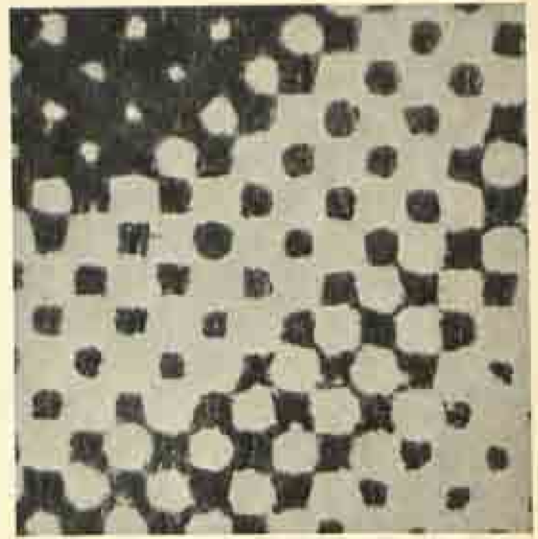


4. "Printing"

FIG. 9 (*contd.*). EXAMPLES OF PRINTS FROM HALF-TONE RELIEF BLOCKS ON DIFFERENT KINDS OF PAPER. MAGNIFIED ($\times 35$)



5. A "well-finished" paper of the "plate" kind



6. Print from a "deep-etched" plate upon the same kind of paper as No. 5

FIG. 9 (*contd.*). EXAMPLES OF PRINTS FROM HALF-TONE RELIEF BLOCKS ON DIFFERENT KINDS OF PAPER. MAGNIFIED (× 35)

taking away the brightness from this surface to different degrees by the application of pigment. This pigment is employed in printing as "ink."

Since the picture is to be formed by the deposition of pigment upon the surface of the sheet of paper, and as some portions of the picture are composed of fine small lines, as in a line print, or dots as in a half-tone print, the particles of pigment must be small in themselves, for were the pigment coarse it would not be possible to represent small gradations, some of which might conceivably be smaller than the particles of pigment themselves. This, then, is the first condition. With respect to the "practical" aspect, it may be observed that all pigments, even though finely ground, are not suitable, for they may be of a "gritty" character, and as such would soon wear away the surface of a fine screen half-tone plate and to a lesser degree a fine line plate. A collotype plate, too, is very susceptible to this kind of pigment, and wears away rapidly under machine conditions. Many pigments of beautiful hue and tone are inadmissible for this reason. Fortunately, to-day, the ink maker has at his command a very large range of pigments of suitable physical character when finely ground, so that the drawback mentioned is no longer a serious objection. Equally, too, the chemical nature of the pigment must be considered, because it might be affected by contact with certain surfaces, as, for example, a copper plate. The pigment must also be of a permanent character when exposed to light. Many pigments, it must be admitted, are faulty in this respect, although the ink maker of repute will always inform the user whether or not this be so. For the purpose of discussion we may take the so-called "carbon black," which is the product of the imperfect combustion of "natural gas" from the oil wells, as satisfying, when properly prepared, all the required conditions.

Examination of the illustrations in Fig. 9 will show how very much the shape of the printed dots differs from what it is known to be in the block. In some cases the irregularity or distortion of dot shape leads to a coarseness in the rendering. Fishenden has drawn attention to this fact in a recent lecture,[1] and the views of a paper expert of known balanced judgment are valuable. The view was plainly enforced that the aim of the paper maker should be to provide papers that will reduce the distortion of "dot" shapes to a minimum.

Examination of the illustration in Fig. 5 shows another disturbing influence, viz. that producing the effect known as "squash." Here we have many influences at work depending upon the nature and the characteristics of the paper, the ink and the machinery—there is no singleness of cause.

The magnified images in Fig. 9 (1) to (6) show well the irregularity in shape of the printed "dot" with different papers.

THE CHOICE OF PAPER FOR THE PRINTED PAGE

All forms of printed matter are pictures and as pictures they depend for their appeal or the impression they make entirely upon their appearance. Since the impression that is sought is to be a good one they should be as pleasing as possible.

It is not by any means easy for the producer to persuade the user—even if the ability to persuade and convince be there—that good appearance is more than half the battle for success. The printed word to be successful must bring—together with literary ability—beauty, comeliness and suitability to its aid. Time was—and not so very long ago—when some of the invitations,

[1] "The Printing Technician and the Paper Maker," *Proc. Tec. Soc. P.M.A.*, XXVIII, 1947.

souvenirs and the like issued by important public bodies in this country were rather sad examples of vulgarity in choice of type, selection of ornament and choice of paper.

It is interesting to note that the two main elements in the printed word—type and paper—have depended for their improvement upon the influence of educated judges of what constitutes good appearance, that is to say, upon those who were not primarily printers but men who judged the success or failure of an appearance by their taste alone. The battle for betterment has not been easy, but the day has passed in all but the very "suburban" section of the industry when the choice of type to be used was allowed to be what happened to be in the "cases" and, as for paper, there was known to be laid and wove, antique, supercalendered, and "art" of different degrees of indifferent or superb glossiness, but the only consideration was that it must print well—that, of course, was important!

The influence of educated designers, supported by printers of taste, judgment and skill, has over a fair span of time succeeded in providing a series of type faces having legibility and beauty, each of which has a suitability for a particular job. Later it became the turn of papers, and some makers of this material have thought it worth their while, as becoming to them and due to the users of paper, to provide the latter with experts whose business it is to select paper for the job and even to arrange for the making of particular kinds.

The choice of paper means far more than selecting something from stock that "will do," i.e. that will "print well." The choice involves questions of kind, of surface, of "feel," of colour, of weight, of "bulk," of strength and the process which will be employed. All these have to be considered in relation to the particular

job. And just as a woman's dress appeals to an educated wearer of taste because of the design, choice of material and colour, so does the printed sheet because of similar virtues. It does not necessarily follow that good taste and judgment in the matter of design carries equal ability in the choice and selection of colour in paper and ink, for some users of print have no taste in colour whatever. Men and women become good arbiters by reason of a natural ability aided by the study of different forms and expressions of beauty in art and nature. They do not become good judges by studying one kind of thing alone, but by taking thought and mental indwelling in the quiet places.

REQUIREMENTS FOR THE PERMANENT APPLICATION OF PIGMENT TO PAPER

Let us now consider the application of the pigment to paper. The form or shape of the pigment patch as applied is determined by the form or shape of the ink-holding areas in the matrix, a line, a square, a circle, or a patch of gradated tone, and this form or shape when applied must remain as applied—it must not alter. Is it possible to apply pigment in its simple state to paper so that it will satisfy this condition? The answer to this question is that it is not possible. A draughtsman uses carbon in the form of a stick of charcoal. Taking a paper having a certain amount of roughness, he can draw upon the paper, and, by its proper abrasion, he can deposit a certain quantity of pigment. Actually, he forces the particles of the charcoal into the fibres of the paper, where it is held. Such drawings are delicate, the pigment is easily rubbed off, and the only way to make it remain where placed is to apply to the surface of the drawing some form of fixation, which may be a solution of a resin in alcohol that is sprayed over the work. If the powder form of black

—the "carbon black"—be taken, it is practicable to apply that to paper to make a drawing by the use of the artist's paper or kid stump, viz. by forcing the powder into the paper, but such a drawing would be liable to damage even more than one made by means of the charcoal stick. Evidently then, the pigment cannot be applied by itself alone with any certainty that it will remain where it has been placed. The course that suggests itself is to form a paint. A paint is a pigment suspended in a medium, a vehicle which enables the pigment to be applied by a brush; and the medium which *naturally* suggests itself is water. We mix some lamp black with water, and we find that it can be applied to the paper by means of a brush. What happens? Some of the water is absorbed by the paper and the remainder evaporates, leaving the pigment dry on the surface, in which state it has no permanency, being readily brushed away, the only portion remaining being the finer particles which, having penetrated some little distance into the paper, remain entangled amongst the fibres. Obviously, there must be some other character in the vehicle if the pigment is to remain; we require something which will act as a binder. We find this quality in several substances—gum arabic, for example, a small quantity of which, when in the form of a mucilage, will confer the necessary quality of holding the pigment during the application by the brush, and of forming a binding material which will remain on the paper when the water has evaporated and the gum has dried. Let us turn now to our matrix and see if we can apply this mixture (pigment—water—gum) to, say, a line block. If we employ a brush we find that we can paint the surface of the block, but we cannot give a satisfactory coating, and when we attempt to transfer this coating to paper the transfer is far from satisfactory. The nearest approach to this kind of printing is that adopted by the

Japanese colour-block printer, who applies to the surface of the woodcut a pigment mixed with rice paste and then transfers the colour to paper.

But printing, as we understand it, means the application of ink by means of a roller, and if we sought to do this with our ink we should find that it would not be picked up properly by the roller, whilst still less would any that did adhere deliver itself to the matrix. This is due to the physical nature of the medium taken. It has little "viscosity," or, to use a homely phrase, "thickness," and so the particles tend to separate or settle out; there is little tenacity or adhesiveness of one particle for another, so that it is not possible to obtain the continuous film which is quite necessary. We try another substance, oil —say, linseed oil. We find that this mixes well with the pigment, takes also reasonably well on the roller, and will leave the roller if it be passed over the surface of the matrix. It has some of the necessary qualities to a certain degree, and so is partially successful, but the viscosity is slight, as also is the tenacity. When we seek to transfer the ink from the matrix to the paper we find that some of it will transfer, but, on standing, the oil leaves the transferred impression, penetrating the paper, and there is shown the design with a more or less semi-transparent surrounding. If we now rub the design, the pigment will come away; if, however, we allow the print to stand, the pigment will not rub away so easily afterwards, because the oil being a drying oil has oxidized and formed a binding medium, but as the greater part has run into the paper there will be little left to form a binder. The mixture is, however, in no respect satisfactory.

We proceed farther and employ a linseed oil product, a varnish, thinking that by its nature it may have the necessary qualities. Linseed varnish, as explained in Chapter III, is a polymerized oil. The pigment mixes readily

with varnish, and takes admirably to the different kinds of roller, forming a uniform film by means of which the pigment can be transferred to the matrix and from the matrix almost wholly to the paper. When the design is transferred to the paper it remains upon the surface if this be hard sized, and the product of pulp well beaten (see page 39), but with soft papers such as antiques, particularly slack sized "bulking" antiques, some of the varnish penetrates whilst the remainder acts as a binder, jellifying, and slowly drying by oxidation to form a hard mass which encloses the pigment and remains precisely as printed. The difference in character of the print can be well seen by examining impressions upon the two classes of paper, that on the hard sized, say a ledger paper or certain hand-mades, appearing to be on the surface where good ink is used, and that on a soft antique more *in* the paper. But all inks do not dry in this way; some inks dry by absorption of the medium into the paper, and some by absorption and by oxidation. As an example of drying by absorption, newspaper inks may be cited. But, generally speaking, the two processes are at work. For intaglio printing (see Chapter VIII), with "doctor" wipe, inks are used in a very liquid condition due to a hydro-carbon diluent, such as Xylol, being employed, and the drying is mainly produced by evaporation of the diluent which is brought about in different ways—by air blast on the sheets or web, and, in some machines, by passing the printed matter over hot rollers.

A printing ink is essentially a pigment suspended in a "medium," the pigment being well dispersed and remaining so. Although linseed varnish is not the only medium used, it is for ordinary printing the best, and we have now to consider how it is that it fulfils the required conditions.

SOME PHYSICAL PROPERTIES NECESSARY IN THE MEDIA EMPLOYED IN A PRINTING INK

It has been stated that linseed oil will not furnish a satisfactory medium for making a printing ink, and the reasons have been explained. Nevertheless, linseed varnish, which is the polymerized oil, fulfils all the necessities.

What, then, are the changes in property produced by the polymerization? In the first place, the material has become thicker or more viscous. A certain amount of viscosity is necessary, and the need for this has been explained, but it is not the only property required in a medium for making a printing ink, nor is it the most important. Place a drop of linseed *oil* upon the forefinger and press it against the thumb, and then separate the two—they come apart easily. Do the same with a linseed varnish and observe the difference—they do not part so easily, more force is required, and between the finger and thumb there will be a thread of the varnish, the length of which will increase if we try different varnishes from "thin" to "strong." The "threadiness" or "stringiness" is sometimes referred to as being the reverse of "short," and it has been explained that some inks, as, for example, photo-lithographic transfer inks, should be "short"; they have, indeed, little of the characteristic property of varnish referred to, otherwise it would be difficult to develop a "transfer" clean. The experiment proves that the oil on conversion to varnish becomes more tenacious; the particles adhere more strongly together. It is this property of cohesion which increases the tenacity that gives the varnish the advantage over oil as a medium. It enables us to produce a film which will remain a film on the inking slab, on the roller, and on the surface of the matrix, for the particles of the ink adhere together. The cohesion of the particles means that the ink image will resist rupture;

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the ink will not, if the cohesion be high, mix with a fluid like water, which is important in surface printing. The design on the stone or metal will not mix with water, so that only the non-design parts are wetted, and when the inking roller is passed over the surface the water rejects the ink, so that the parts which should be are clean and free from ink, and remain so. The property of cohesion prevents the image once transferred to paper—or other substance—from spreading; it remains as printed. The printed image, however, does not remain long in the condition that it is in when first transferred, for the varnish "gels," or becomes semi-solid, and then the mass of the material slowly hardens by absorption of oxygen until, eventually, but an appreciable time afterwards, it becomes finally hard or thoroughly dry. Printed characters after a short time, when the printer passes them for "dry," are really only in the "gel" condition, though they are from his point of view "dry" because they will not smear.

Now all these apparently small things are those which together cause the varnish to form the perfect medium, perfect because it has the properties which enable us to produce the effect we desire. A quality of importance is that the ink should "flow" well, for this determines its behaviour in the ink duct of the press or machine. An ink made with oil would not flow well—it would "set back" in the duct and would not adhere to the rollers—but one made with varnish is the reverse and has the necessary qualities. This good property does not depend upon viscosity. Oil may be made artificially viscous, but it will not have the qualities of a proper varnish, for such a body will still have the "greasy" quality of the oil; it will lack the qualities of tenacity and of adhesion; and when some of these artificially bodied varnishes are used with certain pigments they produce ink which "livers" badly, a fault which many

printers unfortunately have experienced, the ink forming a semi-solid mass like liver, as the name suggests.

THE MAKING OF PRINTING INK

From this varnish we produce our ink. Taking one of a medium viscosity, "middle" varnish, and a finely-divided pigment, we mix the two together, and place them in an ink mill, essentially a trough containing a pair of steel or granite rollers which, by rotating against each other in opposite directions, grind the pigment *into* the varnish until the two are thoroughly incorporated. We can assume that by this operation each particle of pigment has become completely coated with the varnish. In its simplest form this is the completed ink, and for the great majority of cases is all that is required. But, to hasten drying, a certain quantity of driers may be added, as, for example, a resinate or an acetate of lead, manganese, or cobalt. There is no untoward result in this if the ink is to be used quickly, but where with certain coloured inks only small quantities are wanted—for the making of tints, for example—the ink tends to dry in the tin once it has been opened, unless treated with care. It has been stated that linseed oil or varnish dries by absorption of oxygen, in which process it becomes another body. It is the purpose of the "drier" to act as a *carrier* of oxygen to the oil or varnish, but a "drier" is only useful in an ink made with a medium which will "dry" by oxidation, and only certain varnishes will "dry" in this way. Certain pigments by themselves cause the rapid drying of the medium, for instance, some iron blues such as "bronze" blue. In some cases it is found that the paper used contains substances which retard the drying, and then it may be necessary for the printers to increase the quantity of driers; but, generally speaking, it is better that the printer should not tamper with the ink supplied by a reliable

maker, and if any addition be required to meet difficulties when using particular stock, it is wiser to seek the advice of the maker, who will prepare ink suitable. Additions may be made for the purpose of retarding drying, but such retardation generally introduces other qualities which may not be desired. Drying takes place more quickly as the temperature increases, and generally an increase in the amount of atmospheric moisture retards drying. From this it will be seen how important it is to maintain constant conditions in the machine room.

Printing inks taken as a whole, however, are not of that simplicity which the Author has considered to be sufficient for the purpose of explaining certain elementary principles in printing. It is not alone a matter of the oxidation of a polymerized oil and the penetration of the medium into paper. The requirements of printers for printing of the many kinds are to-day only met by an extension in the materials used and by different ways in which these materials are compounded.

The literature of ink making is now fairly extensive and may be consulted by those who are interested in this aspect of the subject. But to the user it is the way that an ink "works" and the final appearance of the printed sheet that matter, and these are conditioned by the physical nature of the ink and its consequent behaviour. It is to this aspect that the main attention of the student should be directed. As an aid to such study, viz. the physical properties of printing inks, the interesting papers by R. F. Bowles should be consulted. See *Penrose Annual*, Vol. XXXVII, 1935, pp. 111—114; and Vol. XXXIX, 1937, pp. 165–169.

CHAPTER VI

THE FUNDAMENTAL PRINCIPLES UNDERLYING MATRIX PRODUCTION —THE NEGATIVE AND THE PRINTING MATRIX

FROM the earliest days when printed pictures were produced until the middle of the nineteenth century, all the methods of making the matrices employed were methods which largely depended upon the hand of the artist; indeed, but for some trifling circumstance, for example, the production of the grain in an aquatint by the use of a resin solution, the making of the grain by the "rocker" in the production of a mezzotint, or the use of a mordant in copper-plate etching, it may be said that the effects produced were obtained by the often laborious hand-work of the artist. It was indeed the fact of this hand-work and the thought directing the hand that gave the results their particular character, their individuality, and their value. All chemical processes, all physical processes, all mechanical methods, tend, and must of necessity tend, to sameness in the appearance of the result even though the subject may vary, and consequently to monotony, however much they be controlled—in the limited way possible—by the user. But those processes that depend upon the hand alone always lead to some surprise in their results—the pictures show the feeling and the temperament of the artist, so that while there may be in two successive subjects done by the same method a general resemblance in technique and in style, there is always a sufficient difference to give a different *interest* with each one. It is the absence of these characteristics that is the greatest drawback to the pictures produced by the modern

illustration methods. When we have allowed that these processes do lead now and then to results having *some* element of beauty, but that their facility tends to the production of much that is worthless (which never would have been produced were more slow and expensive methods the only ones possible), and that the workers themselves so seldom have that artistic insight, feeling, and sympathy necessary to make a picture, it may be said that the results from the pictorial printing press are in the main aesthetically negligible. It is not that the work is produced by mechanical methods (there is no virtue in handwork as hand-work), for the final result alone is the criterion. It is that the work has not those characteristics which make for the aesthetic charm which the hand alone so far has been able to give. Interesting technically, giving in some respects very pleasing results, and extremely valuable economically, modern illustration processes, save to a very limited extent, do not enter the aesthetic field, and it is unwise to claim that they do so enter.

In the majority of cases it may be said that the process of reproduction picture-making was a two-fold process, even as it is to-day; the artist made the picture, and it was reproduced by another, although there were in the past—as at present—artist reproducers who made transcripts of their own work. Largely, reproductions were things in themselves for the collector and lover of pictorial beauty, for the portfolio, or for the adornment of the walls of the home. As time went on, the increase in the number of books published led to a demand for illustrations. This fact made for developments in picture-making processes, but the relatively high cost of any form of illustration did limit their use. If one examines the books published fifty to seventy-five years ago the striking paucity of illustrations, compared with what would be employed at the present day, is manifest.

THE BIRTH OF PHOTOGRAPHY

In 1839 Arago communicated to the Academy of Sciences, in Paris, the success of Daguerre in fixing the image of the "camera obscura" of Porta, and by this discovery the process of photography may be said to have begun. This process was followed in 1841 in England by the Calotype method of Fox Talbot, which, it is interesting to observe, was the first process for photographic negative making, and thus real photography commenced. Three years later there was issued by Fox Talbot the *Pencil of Nature*, which was the earliest book illustrated by photographs. In 1848 Scott Archer made negatives by means of the collodion process, which to-day is the principal negative-making process employed in reproduction studios. In 1851 Scott Archer published the details of his process, from which may be dated the commencement of *modern* photography, although it was not until 1874 that photographers received the first dry plate. From then onwards was a period of remarkable experimental activity, and the eager photographic workers sought every opportunity for extending the use of their methods.

It has been stated already that the use of illustrations in books, by reason of the costliness of the methods, was very limited, and it was only natural that the early photographers should seek to enter the field as illustrators. They were, however, faced with the fact that the only way at the time of producing photographic prints was by the laborious and slow process of silver printing, and when the prints were made it was necessary that they be mounted so that they could be included in the book—a very considerable source of expense. There was also the fact that the prints were known to be of an impermanent character, and added to this there was the aesthetic objection that the prints never harmonized with the type matter. In consequence, although many books were so illustrated, the

activity of the photographer in his craft, so far as concerned book illustration, was confined to the making of photographs, which were used as originals from which another craftsman, another hand, produced the matrix. It was only natural that the ardent photographic experimentalist with the gift of vision should consider this problem from the aspect of processes of illustration then existing in which photography had so far no part. The early worker would naturally study the methods that were being used by the artist multiplier.

This much by way of introduction to the motive which led to the working out of what to-day are the predominant methods of matrix-making for illustration. This book is not intended to be a history of the evolution of these methods, but it has been thought desirable to show that there was an intent from the commencement, with what result all informed printers know. The intention, the aim, was to transfer the camera image to the bed of the printing press in such form that it could be employed for the multiplication of pictures.

THE BASIS OF MODERN ILLUSTRATION PROCESSES

The foundation of the modern illustration method is the photographic process; indeed it may be said that, broadly considered, it is *the* method, for although there is always room, and frequently the necessity, for the intervention of hand-work, the different applications of the "photographic process" are largely chemical and physical operations. Economically, this is generally an advantage; aesthetically, as pointed out previously, the results lose by the fact that they are of the character termed "automatic," for largely the interpretation, if such term may be used, is uniform in character in any particular form of the process.

Considered in relation to ordinary or "pure"

photography, the final print from the matrix may be regarded as corresponding to the print of the "pure" photographer, the only difference being that the print from the matrix is not made by the agency of light, nor is it made, as in the case of the print of the "pure" photographer, upon a light-sensitive material.

Given an original subject from which a matrix is to be produced, the first operation is the making of the photographic negative.

A photographic negative is a record of the light and shade of a subject produced upon a sensitive surface. For this purpose the image of the subject formed by a lens is caused to fall, under suitable conditions, upon the sensitive surface, which changes to different degrees in accord with the different intensities of the light in the different parts of the image. This changed surface is the potential negative, and this potential negative is afterwards submitted to certain chemical operations by which a real negative is produced.

The production of the negative requires certain instrumental means and sensitive material, and upon their correct use, and upon the judgment exercised in these respects, much of the possibility of success will depend.

In view of the importance of the selection of the most suitable sensitive material, this subject will be dealt with in the first instance, and at some length. So far as concerns apparatus, since the book is intended to teach principles and not practice, descriptions of apparatus included in camera systems for negative making will not be given save in outline. For full information in respect to the equipment of studios the student is referred to practical manuals on negative making as recommended in the Appendix, and to the very informative catalogues issued by business houses which supply apparatus.

THE PHOTOGRAPHIC SENSITIVE SURFACE

The sensitive surfaces employed in negative making in a photo-mechanical studio are of two kinds, the "wet" plate and the "dry" plate, and of the dry plate there are three forms—the "ordinary," the "orthochromatic," and the "panchromatic"—the difference being one of spectral sensitiveness.[1] To these may be added a fourth, "collodion emulsion," which still has a vogue in certain quarters because of the fact that it lends itself to special sensitizing for the photography of coloured objects, which work requires an extension of the spectral sensitiveness over and above that which is possessed by the untreated material, and, in consequence, was at one time particularly valuable. It must be stated, however, that the necessity for this material has been very greatly reduced since the improvement of the panchromatic process dry plate, and, because its employment demands special facilities and considerably more manipulative skill than the dry plate, it is now little used.

Since the sensitive surface for the camera to-day means for the vast majority of photographers something which emanates from a factory to be used according to printed directions on the box, photographers are very prone to neglect the study of that article which is the foundation of their daily work. Probably there is no very serious objection to be raised to that attitude so long as the user is properly conversant with the nature of the material he is using, which, incidentally, is far from being the rule. It is suggested that the student of photo-mechanical processes, in whom it is hoped to inculcate a desire to know and understand principles, may wish to adopt another attitude. To this end it is well to select a method for the production of the sensitive surface where the whole of the

[1] In each form there are varieties suitable for particular kinds of work.

work is done by the photographer himself, and this method is found in the "wet" plate—the wet collodion process where each plate is made immediately before its exposure in the camera and at once completed. The wet collodion process is the process which was used by photographers for the whole of their work prior to the introduction of the dry plate, which was first sold by Kennett in 1874, but the dry plate was some time before the public before it displaced collodion in general photography. To-day, although collodion is not—as stated—the only process employed in the photo-mechanical studio, it is so for the majority of negatives, certainly so for what is known as "line and tone" work. For this purpose it has special advantages, technical and economical, although technically the modern process dry plate is a worthy competitor.

A sensitive surface consists of a sensitive substance embedded in a medium and held upon a support. The sensitive substance is silver iodide, bromide, or bromo-iodide, and sometimes silver chloride has been used; the medium is either gelatine or collodion; and the support may be glass in the case of collodion, and in the case of gelatine, glass, celluloid, or paper, all of which are in everyday use. The support fulfils a mechanical purpose, and indeed, to the extent that it is a binder, so does the medium, for the particles of the sensitive salt of silver have no power of cohesion to enable them to form, by themselves, a continuous and homogeneous layer capable of withstanding the different operations, but the medium must not be regarded only in this light, for it may exercise a profound influence on the character of the sensitive surface with which it is used.

A sensitive surface, in order to be suitable, must fulfil two main requirements, both of which depend upon the physical condition of the sensitive body. It must be in the first case in a sufficiently fine state of division to be

able to render the fine elements which may compose the image, and in the second case it must be sufficiently sensitive to enable the negatives to be made without unduly long exposure in the camera. Now both of these depend upon the physical state, the former upon aggregation, the latter principally upon form—on the one hand the particles must be very finely divided and the layer uniform, and on the other, as shown, sensitiveness is largely a matter of crystal size and aggregation. There must obviously be, on the part of the film of the medium holding the sensitive salt, the ability to withstand, as far as may be necessary, the mechanical stresses involved in the operations of negative making, even those induced by a careless negative maker, and the film itself must hold the particles upon which the image has been formed in one and the same place throughout the whole of the process. This first condition is met by both wet and dry films, which are reasonably tenacious, and the "gel" character ensures the second requirement. Obviously, if the particles moved[1] about in the film, negative making would be impossible.

WET COLLODION AND THE GELATINE DRY PLATE

There are two types of sensitive surface, and in each of these collodion and gelatine are used. The first is where the sensitive compound is formed in a layer of the medium after it has been produced upon the support, and the second is where the medium already containing the sensitive salt is applied to the support. In the first case we have the "bath" plate which is represented by the wet collodion process, and the second is the emulsion process which is represented by the gelatine dry plate, and by emulsions in collodion, which were used at one time but are

[1] Strictly speaking, there is reason to believe that the particles do move. (See Appendix, "The Resolving Power of Sensitive Surfaces.")

now, unfortunately, little in demand. In the case of the wet collodion process, the plate is made by the operator at the moment of use, but with the dry plate this is a commercial article, purchasable in different types, ready for use.

CHEMICAL CHANGES LEADING TO THE FORMATION OF THE SENSITIVE SALT

The basis of the wet collodion plate is the "plain collodion." This is a solution of nitrated cellulose—pyroxylene—which, though often confused with "gun-cotton," is not identical—in a mixture of equal volumes (generally) of ethyl alcohol and ethyl ether. This collodion when poured upon glass soon loses the solvents and "gels," and if the alcohol and ether are allowed to evaporate completely, there is left behind a colourless film, perfectly transparent and without visible structure. If, when the "gel" state has been reached, the plate be plunged into water, the remaining solvents quickly wash away, and there results a transparent jelly-like layer. This is the simple film. To the plain collodion there is added an alcoholic solution of an iodide,[1] either ammonium or cadmium, and a *very small* quantity of free iodine by means of an alcoholic solution of that body. This forms "*iodized* collodion," and is the first stage. A film prepared from this collodion will have the iodide and iodine in solution. If a film of this "iodized collodion" at the moment of reaching the "gel" state be plunged into an aqueous solution of silver nitrate there ensues an interchange of the elements, and we have silver iodide and ammonium nitrate as the result; the silver iodide, being insoluble, remains in the form of finely divided particles embedded in the pyroxylene film, and the ammonium

[1] The compounds of iodine, bromine, and chlorine—iodides, bromides, and chlorides—are commonly referred to as "halides."

nitrate washes out into the silver nitrate solution, which is technically termed the "bath." The plate is withdrawn and drained. The sensitive film has been made—this is the second stage. Whilst wet with silver nitrate—hence the term "wet-collodion"—the plate is exposed in the camera, and afterwards the image is developed by flowing over its surface an acidified solution of ferrous sulphate—hence the term "acid development." The plate is then washed, treated with a dilute solution of potassium cyanide—or sodium thiosulphate—and the soluble silver salt formed by the action of the potassium cyanide—or the sodium thiosulphate—is washed away by water, when the plate or negative is said to be "fixed." It is then dried, which is the final stage.[1]

THE DEVELOPMENT PROCESS IN WET COLLODION

Let us now see what has happened during this series of operations, after the formation of the sensitive compound by the interaction of the soluble iodide and the silver nitrate. The plate on exposure undergoes a change, and this change is rendered possible (to a large measure) by the presence in the film of the free silver nitrate, which is often referred to as a "sensitizer"—which may be taken to mean that the silver iodide (or bromo-iodide) has only a *useful* sensitiveness in the presence of *free* silver nitrate. Further, the free silver nitrate eventually supplies the metallic silver by means of which the image is formed on development of the exposed film. The precise change which the silver halide or halides undergo on exposure to light is not known, but we know that in some way the particles are affected and that there are a greater number

[1] In practice a film of silver iodide is only used in special cases. Generally "iodized collodion" means a collodion containing both an iodide and a bromide so that there is formed in the film, as the sensitive body, silver bromo-iodide. Such surfaces are more sensitive than simple iodide and render gradations of the original better.

affected the brighter the part of the image they represent, i.e. where there is a high light there are more affected particles than in a middle tone, for example. We know further that these affected particles will behave differently under certain conditions, as, for example, when the film is developed, from unaffected particles. When over the film there is poured the developing solution, the silver in the nitrate is reduced to the metallic state, and if the conditions be properly adjusted the silver is slowly precipitated as a gentle "rain" of very fine particles. We know that as a first action these particles sort themselves out by some form of attraction exerted by the *affected* particles of the silver halides, and in this way what may be termed the *initial* image of silver is formed. It is further known to be a property of freshly precipitated metallic silver to attract other particles of metallic silver, and the initial image is thus built up until it becomes visible and finally one of practical density, so that there is a useful opacity. If the solution of the developing agent be wrongly proportioned, or be too concentrated, then the attractive force of the halide particles may be insufficient to attract all the particles in the "rain," and the consequence is that they are distributed more or less uniformly over the film, and the image is then said to be "fogged." Although it is not the custom of the photo-mechanical operator (though it was the practice of the wet collodion portrait operator in the early days of photography), he could if he wished increase the amount of density in the image when development ceases (as it does soon) by placing in the developer cup a few drops of a strong solution of silver nitrate, pouring the developer off the plate, mixing the two, and re-applying the mixed solution to the film. Density would soon grow because more raw material for the supply of silver particles had been provided. This was termed "re-development." It is often done now after fixation,

and is then one of the many intensification processes available, this particular process being called "intensification by acid silver." After the development the plate is treated to a dilute solution of the fixing agent, the object of which is to form a soluble compound with the silver halides so that they can be removed with water. Fixing is carried out usually by the application of a solution of potassium cyanide in the case of collodion plates but *sometimes* by sodium thiosulphate, commonly but quite incorrectly known as "hypo." For dry plates sodium thiosulphate is always used since the finely divided image is attacked by cyanide.

When potassium cyanide is employed there should for safety be added sodium sulphite to reduce the *cyanate* frequently present as this acts as a solvent of silver and attacks the materials of the image. After sufficiently long application of either agent the plate is washed with water to remove the products of the decomposition which takes place by *osmosis*, which is the passage of liquids and/or other substances through a membrane, the membrane here being the film of gelatine, collodion on paper.

Welborne Piper found that "fixation" was more rapid if there was added to the sodium thiosulphate about 25 per cent of its weight of ammonium chloride. The increases in the rapidity of fixation is probably due to the conversion partially of the sodium salt to the ammonium salt but not entirely. Objections have been taken, though the reasons are not stated, to the use of this solution for gelatino—bromides of silver prints.

Recently there has been introduced a proprietary agent (Amfix) for which is claimed rapid and safe fixation for plates and films and that the products of the fixation are rapidly removed by washing.

The density of the image in the collodion plate is never

sufficient in the photo-mechanical negative for *broken*-tone subjects, so that we must have recourse to an intensification process (see page 81) by means of which the opacity of the image can be increased. There are many such processes, but for details the reader is referred to the textbook on processes. It may be said, however, that for continuous-tone negative making the so-called "density processes" are not employed, for there would be a loss of gradation, the "acid silver" method being used.

The mode of application of the developer is interesting. The plate is held supported upon a pneumatic holder or held by one corner—an inferior way—and the developing solution is flowed over the surface, the aim being to avoid spilling any solution over the margins. To ensure easy flow the developer contains alcohol, so that it may possess a similar surface tension (see Appendix, "Surface Tension") to the "bath" solution which moistens the surface of the plate, for without this admixed alcohol there would probably be partial rejection and, in consequence, unequal development. The reason why this mode of accomplishing development is adopted, rather than the more obvious one of using a dish, is to conserve the "rain" of silver particles for the image. Were a dish used, more solution would be required, development conditions would be altered, and, were the sides and bottom of the dish not chemically clean, the silver would soon be deposited on these and the image would receive less. Beginners generally overlook the fact that the amount of silver is very small, and do not take simple precautions, such as masking off superfluous white or light paper margins to a drawing when exposing the plate, to ensure that the amount available is at its greatest. If the margins of the plate were affected, silver particles would be attracted to these and, in consequence, there would be less deposit upon the image.

Where the negative is a "half-tone" dot negative, there

are other methods, known as "clearing" or "cutting," which are processes where a solvent of the image material is used for reducing the size of the dot, and when this is done the dot formation is altered, often to advantage, but too often with a loss of gradation

Here the student's attention is drawn to several very important features of the wet collodion process. In the first place the film is extremely thin and porous. This means that the action of chemicals is not retarded, and the washing away of one set of chemicals before another is applied is rapid. Secondly, the film material is inert; it does not form compounds of a chemical character or of a physical character—adsorption—with the bodies with which it comes into contact. The *sensitive halides* are not themselves affected by the developer, and the fact that the film of nitro-cellulose is very thin means that the image is practically on the surface; indeed, in the case of a dot image, if the surface be viewed in an oblique light, the dots, in the form of little cones, can be seen standing up in relief. Most of the characteristics described are features of value in the wet collodion plate.

THE PHOTOGRAPHIC DRY PLATE

We may turn now to the gelatino-bromide dry plate, which is, as before stated, a commercial article marketed in a number of types having the same form but different characters. In the case of the gelatino-bromide surface the sensitive agent is either silver bromide—though seldom pure silver bromide—or bromide and iodide, the latter being about 10 per cent of the whole. In certain cases, as for photo-mechanical purposes, silver bromo-chloride is used. The normal spectral sensitiveness of the "ordinary" surface is replaced by surfaces having an extended spectral sensitiveness, and thus we have the "orthochromatic" plate which has in addition to the

normal blue sensitiveness a sensitiveness to the yellow-green and slightly to the yellow spectral region—which increase is produced by the addition to the emulsion, before coating, of a minute quantity of an eosin compound, generally erythrosene—and a "panchromatic" plate where the band of spectral sensitiveness extends into the red, produced by the addition to the emulsion of a carbocyanin compound. It may be observed that though considerable improvements have been made during recent years in the dry plate, the *ideal* with respect to spectral sensitiveness has not been quite attained. For a plate to be perfect in this respect its curve of sensitiveness should be identical with that of spectral luminosity, for only then can colours be rendered into monochrome in proportion to their brightness. The most perfect plate to-day has still an exalted sensitiveness to the more refrangible—the blue—end of the spectrum, and the practical means of overcoming the defect is to employ a correction filter of yellow (see page 382) on the lens when the negative is being made. The *medium* is gelatine, which exerts a great influence on speed and character of the emulsion. The *support* is glass, celluloid, or other film, and paper.

A gelatine emulsion is prepared by the addition, under suitable conditions of concentration, temperature, and rate, of a solution of silver nitrate to a solution of gelatine containing a soluble alkali halide, either ammonium or potassium bromide; and if the emulsion is to contain silver iodide this is produced by decomposing some of the already formed silver bromide by the addition of an alkali iodide, in which case the physical condition of the silver iodide just formed follows that of the silver bromide. The emulsion is then digested at an elevated temperature, following which it is cooled, additional gelatine added, and the emulsion allowed to set. In some cases precipitation of the silver salts is effected with a solution of ammonia

nitrate of silver. The set emulsion is then broken up, washed in water to remove the products of decomposition, remelted, a small quantity of potassium bromide and alcohol added, and the emulsion again heated. After this it is filtered and may then be used for plate coating.[1]

The result of this treatment is to produce a highly sensitive form of silver salt, and according to the treatment so will be determined the speed and the gradation-giving character of the emulsion. Emulsions, for particular purposes, are frequently blended to produce a plate of desired character. Contrary to an idea prevalent amongst many photographers, speed is not an isolated function, that is to say, it is not possible to produce plates of widely different speeds having the same character, for speed is largely a function of the character of the emulsion.

Our knowledge of the fundamentals of the wet collodion process, although it is much the older method, is largely empirical; while the knowledge of the practice, through long years of effort and use, has become sound and complete, our knowledge of prime causes—the cause of sensitiveness, speed, and the nature of the latent image—is practically nil. A very different state of things obtains with the dry plate, upon which a large amount of accurate research has been carried out by different investigators.

THE DEVELOPMENT PROCESS WITH THE DRY PLATE

Some knowledge of the mechanism of the development of the image in a wet collodion plate has been offered (see page 64), and with the explanation now to be given of what occurs in the corresponding process with the dry

[1] This is a very simple outline of the way in which a gelatino-bromide emulsion may be prepared. In practice, the production of emulsions of different types demands considerable knowledge, judgment, and experience, and the precise methods are not published.

plate, the student will be able to compare the two processes. With respect to the "sensitiveness" or "speed" of a dry plate—the two, although closely related, are not necessarily identical (see Appendix, "Sensitiveness and Speed")—in spite of the large amount of careful work which has been done on the subject of the latent photographic image, the amenability of the silver salt to its formation, and its nature when formed, we have not, as yet, precise knowledge.

Reference is made later in the text (see page 73) to the fact that grain or crystal size and crystal aggregation have considerable influence upon "speed," and it is probable that the gelatine content, or the way in which the gelatine is associated in or about the complex, has, too, its bearing upon the same quality.

The wet plate developer has the general formula

Reducer + Restrainer + Alcohol

whilst in the dry plate solutions, where phenolic compounds are used, the formula is

Reducer + Preservative + Accelerator + Restrainer

water in both cases being understood. In connection with the composition of the wet plate solution it may be said that, practically, it is always the same with regard to components. In a dry plate developer this is not the case, but, speaking generally, it may be said that though the composition may be changed, the reactions are similar in character.

Of reducing agents, three are generally employed, pyrogallol, metol, and quinol. The agents pyrogallol and quinol are frequently used alone, but metol seldom so; pyrogallol and metol are used together, whilst metol and quinol in conjunction form one of the most frequently employed combinations. These agents by themselves will develop the image in an exposed plate, but the process is so slow as to be of no value from the "practical"

standpoint. To accelerate the action, the three agents are used in an alkaline condition, the alkalis employed being the hydrates or carbonates of potassium and sodium —caustic potash or caustic soda, or potassium or sodium carbonates.

The three reducing agents named do not keep well in aqueous solutions, and they change very rapidly when made alkaline. Since in practice it is necessary—or a great convenience—to employ a stock solution, means must be found for "preserving" the aqueous solution. If the liquid be slightly acidified the solution will keep well, and that is shown by the avoidance of discoloration, but when the solution is made alkaline for the purpose of development, discoloration rapidly takes place, with the result that the gelatine film becomes stained, and that is a practical drawback. As far back as 1882, Berkeley showed that sodium sulphite had the property of preventing discoloration to a very large extent, even in alkaline solution, that whatever coloured substance was formed it was kept in solution by the sodium sulphite, and that staining of the film, to anything like the extent ordinarily known, did not ensue. The result has been that this agent is now universally used as a *preservative*, and in consequence plates can be developed without the gelatine becoming stained. But sodium sulphite has another action of importance. Whenever a silver halide is reduced by a phenolic developing agent to the metallic state, there is always associated with the silver image a stain body varying in quantity with the amount of silver, and to this the name "stain image" is applied. This "stain image" is a perfect replica of the silver image and reinforces it. To the extent that it does reinforce it is an advantage, and is regularly made use of in practical negative making. But it is a disturbing element. It can be controlled, however, by the sodium sulphite. According

to the amount, so will the quantity of "stain image" vary, and if sufficient sulphite be present, there will be only the slightest amount of stain, and the colour of the image will be the normal neutral grey of the silver. High sulphite contents, as required to produce these neutral grey images, always tend to give "fog" owing to their producing (due to the solvent action on the silver halides) an excessive amount of soluble silver salt in the gelatine film, which is acted upon by the developer. (For a full consideration of this phenomenon see Mees and Piper, "On the Fogging Power of Developers," *Photographic Journal*, Vol. LI, 1911, page 226.) In consequence, high sulphite contents are avoided and a certain amount of "stain image" is accepted. This does not mean, however, that the gelatine film will be stained *generally*, for that is not the case.

Sodium sulphite is, then, a preservative and a stain preventer.

The part played by the soluble alkali bromide is that of a restrainer, and it has also the valuable property of preventing "fog," *that general reduction of silver which produces a veil* that has earned that name. There are very many excellent plates on the market that will not develop particularly high density in a negative, without giving "fog," and, though some "fog" is admissible, leading as it does only to a slight reduction in contrast, generally its presence is to be deprecated.

We know that when a sensitive surface of silver bromide receives sufficient exposure, some of the crystals are affected in such a way that they become capable of being developed whilst others do not. The criterion as to whether or not a particular crystal has become by exposure developable, appears to depend upon what takes place at minute spots on the surface of the crystals, which spots are termed now the "nuclei." Since the crystals are,

from the standpoint of small things ordinarily appreciated, almost unbelievably small, the "nuclei," which are only a part, are smaller still.

As to the nature of the "nuclei," only by hypothesis can we at present make suggestions, but we can say at least that the prevalent hypothesis has good experimental evidence for its support. It is well known that the gelatine plays an enormous part in determining the speed and other properties of a silver halide emulsion. Sheppard has shown ("Photographic Gelatine," *Photographic Journal*, Vol. LXIV, 1925, p. 380, Communication 240 from the Research Laboratory of the Eastman Kodak Co.) that the increased sensitivity in high-speed emulsions is in the first instance due to small chemical differences in the emulsifying gelatine which do not affect the grain size distribution, that the "sensitivity centres" are due to the gelatine, and that this property has been traced to the presence of small traces of organic sulphur compounds, isothiocyanates (thiocarbimides) and thiocarbamides, and, specifically, allyl mustard oil and allylthio-urea. The thiocarbamides interact with the silver halides, forming *nuclei* of silver sulphide, which is the material of the "sensitivity centres."

No conclusions have been reached as to what occurs when the surface, and consequently these centres, receives that amount of light which is represented by "correct exposure." We know that light is capable of decomposing silver bromide into bromine and silver, and it may be that by this light action silver particles add themselves to the "sensitivity centres" of silver sulphide; indeed, that has been suggested as their function (Sheppard, Trivelli, and Loveland, *Studies in Photographic Sensitivity, VI, The Formation of the Latent Image*, Communication 228 from the Research Laboratory of the Eastman Kodak Co.), viz. to "collect about them the silver atoms produced by

the photo-chemical decompositions of silver bromide" (*Monthly Abstract Bulletin*, Research Laboratory, Eastman Kodak Co., Aug., 1925, page 489).

The whole subject is extremely difficult, but it would appear that we start with silver bromide containing "sensitivity centres" of silver sulphide, and that these are increased in size by the accretion of silver specks formed by the decomposition of silver bromide in amount according to the different light intensities; thus the centres increase to different degrees according to the amounts of silver, and these form the *nuclei* which are the *developability* centres.

RECENT INVESTIGATIONS INTO THE NATURE OF THE LATENT IMAGE

An account of the most important work done in the causes of the formation and the nature of the latent image up to 1929 is given by Dr. Rawling ("Recent advances in our knowledge of the Latent Photographic Image," *Photographic Journal*, Vol. LXIX, 1929, pp. 471–478), and since that period the research has been carried forward. A summary is given by Prof. N. F. Mott in the 12th Hurter and Driffield Memorial lecture (*Photographic Journal*, Vol. LXXXI, 1941). Prof. Mott, together with Dr. R. W. Gurney, has advanced a hypothesis which is finding considerable acceptance. Agreeing in general with the accepted view that the latent image consists of silver atoms coagulated about a *sensitivity speck* which Sheppard and his immediate collaborators assume to be silver sulphide (and later Clark, some colloidal silver), they propose a new way in which this can be formed. It may be taken that the primary process of forming an image is that electrons are set free within the grain which is in harmony with the effect of *photo-conductance*, which is the increase in electrical conductance in many

substances that takes place when the substances are illuminated. Coblenz had shown that the photo-conductance of silver bromide increased as the wave-length of the incident light was decreased from 5000 Å. It reached a maximum at 4600 Å, and fell to zero at about 4200 Å.

Toy, repeating the experiments but with extremely thin films of the halide, got rid of the maximum whilst the relative effect became greater towards the ultra-violet. It was found that there was great similarity between absorption and conductance curves. The photo conducting electrons are able to move more freely in the silver bromide crystal lattice, and in so moving are caught in the sensitivity specks which thus acquire a negative charge and the field formed within the grain attracts positive silver ions[1] with the result that the speck increases by the addition of silver atoms until it assumes such a size that it will be able to induce development. Prof. Mott states that "the essential part of the theory is that two processes are involved in the latent image formation, a movement of electrons followed by a motion of ions," and it is pointed out that "even at the temperature of liquid hydrogen photographic surfaces are sensitive to blue light though the sensitivity is much reduced." It was shown by Berg (*Trans.* Faraday Society, Vol. XXXV, 1939, p. 445) that a blue sensitive surface at 90° K (absolute) reached its maximum density only after an exposure 10,000 times longer than that necessary at 293° K (absolute), though the sensitivity for lower densities is reduced by about 10 only. And pointing out that ionic conductivity is not possible at 90° K., Prof. Mott goes on to say that "the electrons released by the light at low temperatures are stored up in the grain and released when the surface is warmed up prior to

[1] An ion is an atom or group of atoms having an electric charge.

development," and that "more striking evidence of the two processes is provided by the fact that a surface exposed to blue light at low temperatures can be bleached by red light at the same temperature *provided that it has not been warmed up between the two exposures.* If there be no warming up, only electronic movement is involved, the exposure to red light frees the trapped electrons and gives them a chance to return to their original positions in the halide ions (see footnote, page 76). Once the surface is warmed up, however, ionic movement takes place and no bleaching can occur at low temperatures where ionic movement is impossible."

Prof. Mott applies the hypothesis to the explanation of many photographic phenomena such as reversal or solarization[1], the Herschel and Clayden effects[2] and to the phenomena involved in the complicated subject of reciprocity—law failure in photographic exposures—(see page 93), and this aspect has been considered by Webb and Evans (Eastman Research Laboratory Communication, 687 and *Photographic Journal,* Vol. LXXX, 1940, pp. 188–192).

The Author strongly urges students of photography to study carefully the Report of Prof. Mott's lecture.

MECHANISM OF DEVELOPMENT IN A DRY PLATE

Let us now consider the question of development. We know that the photographic image differs from the unexposed silver bromide, in that the former is affected

[1] When a sensitive plate is exposed to a wide range of light intensities for a gradually increasing time there is an increase in the densities produced on development and these diminish almost to nothing. By prolonging the exposure it is possible to obtain a positive. This is reversal or solarization.

[2] The "Herschel effect" is the destruction of the latent image when it is exposed to red or infra-red radiation. When a sensitive surface is exposed to an intense light for a brief period, say 1/50,000 second, the plate's sensitiveness is lowered so that it does not "fog" if exposed to the light afterwards. This is the "Clayden effect."

by the developer, and that the latter is not. Strictly speaking, we should say that the unexposed silver bromide is not affected in a reasonable time. We know that certain reducing agents will affect both. A "well-balanced" developer is one that will not affect unexposed silver bromide in the time taken to develop an image in the same surface when exposed. When the developer is applied to the film, the well-known principle that action does not take place between a solid and a liquid operates, and, before any effect takes place, the bodies between which action is desired must be dissolved; hence the silver salt must pass into solution. When it does it is ionized. But the product of the solubility is small, and, therefore, there is only a very small amount taking part in the subsequent change. We have, however, a certain potential. Under the action of the reducing agents, the silver ions lose their charge, and we have then silver molecules in solution; equilibrium will be established unless the silver molecules be taken out of solution, and such a removal would be facilitated by the presence of a nucleus. This nucleus is provided by the portions of the silver salt which have been changed by light. Upon these the silver is precipitated, and the equilibrium is then upset, more silver bromide passes into solution, and the cycle of changes is repeated until eventually the image is fully developed. The fact that the solubility of the silver bromide is very low indeed gives the reason why the development is limited to particular grains. When, as in the case of high sulphite contents, or, as in the early days of photography when ammonia was used as the alkali, and used in excess, there was a solvent of the silver salt of appreciable power, the amount of silver salt in solution was excessive, it was not localized, and general reduction—in other words, "fog"—was produced.

During development, upon application of the developing

solution, silver bromide from the sensitive surface passes into solution and is ionized when action takes place with the reducer. Addition of the soluble alkali bromide supplies an additional common ion, and the effect is to reduce the ionic concentration of the silver salt; there is, therefore, less available for the reduction by the developer, and so the process is slowed up.

The influence of the soluble bromide in restraining development differs with the reducer. Upon rapidly acting agents as, for example, metol, amidol, "Rodinal" (Reiss, *Der Entwicklung der Photographischen Bromsilber Trockenplatte und die Entwickler*, 1902, p. 91 *et seq.*), the action is less pronounced than with a slow-acting body, for example, with quinol, pyrogallol, ferrous oxalate, and glycin. In a quinol developer with caustic alkali, potassium bromide has little action save in large quantities. With amidol the effect of potassium bromide increases as the concentration of the sulphite is reduced. (Bancroft, *Trans.* 8th Inter. Congress, "Applied Chemistry," 1912.)

The velocity of development is affected by the temperature. At low temperatures development becomes very slow until it almost ceases when the solution approaches 0° C., but different developing agents are differently affected, quinol being particularly sensitive to temperature reductions. On the other hand, development becomes rapid as temperature rises much above the normal temperature of the air, and at higher temperatures "fog" ensues, whilst eventually the gelatine softens and finally melts. To prevent this softening, where it becomes necessary to develop at high temperatures, the addition of sodium *sulphate* to the solution is recommended, which agent produces its effect by reason of its action on the gelatine.

Developers differ in the way in which they cause the exposed plate to behave. Eder showed many years

ago that, broadly speaking, developing agents might be divided into two groups. In the first group the members develop the image gradually tone by tone, the high lights first making their appearance, being followed by the other tones in the order of their relative brightness. The agents in the second group cause all the gradations to appear simultaneously, and after this the different tones gradually acquire densities to correspond to the different degrees of brightness in the object. In the first group we have pyrogallol and quinol, which owe their power to hydroxyl groups, and in the second, amidol, metol, and paraminophenol, which develop by reason of their amino groups.

Density in developed surface depends upon time of development, increasing with time until the maximum density the surface is capable of yielding is reached. Contrast, therefore, increases with time of development, provided that "fog" does not supervene. But, generally speaking, when "fog" supervenes, it increases at a rapid rate as development is continued, and consequently there is an increasing element acting as a reducer of contrast.

It has been stated upon page 66 that the density of the image upon wet collodion after development in broken-tone subjects is never sufficient, and that recourse must be had to intensification. Similarly, sufficient density is seldom, if ever, obtained in continuous-tone negatives, and the same process must be applied. The choice of the process is important. Further to this, in practice, reduction and intensification, or a reversal of the procedure, intensification and reduction, are necessary parts of the process of screen negative making—by wet collodion—for the production of printable negatives.

If, however, there be no "fog," then since contrast depends upon difference between the lowest and highest

tones, and as the latter increase with further development (to a *limit*), then the more prolonged is the development, the greater is the contrast. If development be continued beyond the limit, then "fog" may supervene with resulting lessened contrast. In the special case of line images on dry plates, unduly prolonged development is to be deprecated, leading as it does to impairment of line. This impairment is lessened or avoided by the use of thin films with a substratum "backing."

INTENSIFICATION OF DEVELOPED IMAGES

The intensifiers in general use for wet collodion broken-tone work are lead ferricyanide, followed by the application of an alkali sulphide, and cupric bromide, followed by the application of silver nitrate. For wet collodion continuous-tone work (principally used for collotype) they are silver nitrate with acid ferrous sulphate or acid pyrogallol, and mercuric chloride followed by ammonia. Frequently mercuric chloride is applied after partial intensification with the silver nitrate and acid pyrogallol.

On gelatine dry plates for broken-tone work (line and screen negative making), acid metol and silver nitrate, or mercuric chloride followed by ammonia or ferrous oxalate, or mercuric bromide followed by silver cyanide, are used. The two latter can be applied after the former, and then very great density can be secured. For gelatine dry plates for continuous-tone work, acid metol and silver nitrate are used where it is important to control the amount of the increase in density and to control gradation—the latter being variable by the proportions of silver to metol. In addition, for chromium intensification, potassium bichromate with variable amounts of hydrochloric acid, followed by metol quinol developer, is used (*never* amidol as originally proposed), and also mercuric chloride, followed by ammonia or ferrous oxalate.

Intensifiers are sometimes divided into two classes. Certain methods are named "density-giving," and it might be thought from this that the remainder were *non*-density giving, which would be absurd, because they would not be, in that case, intensifiers. The division is purely arbitrary, but what it means is that some of the methods give a great increase as compared with others, as, for example, the lead ferricyanide solution—which gives a mixture of silver ferrocyanide and lead ferrocyanide, both of which are converted to black sulphides by the application of the alkali sulphides, when the gain in density is very considerable. Because of this property they are unsuitable for continuous-tone negatives, for the increase would be so great that there would be a loss of gradation. For the careful control of gradation an intensifier is required which gradually increases the deposit, the effect of which increase can be seen and which can be stopped at any moment. No other intensifier but physical intensification with "acid silver" will give this advantage, though, on the other hand, if considerable increase is necessary, the operation is tedious, and, moreover, even considerable deposits produced by this method are liable to "print through." But it is unequalled when the gradation and density must be entirely under the control of the operator.

THE DIFFERENT TYPES OF DRY PLATE

Dry plates of different types come into commerce, and should be chosen according to the character of the work for which they are to be used. From the standpoint of the photographic operator, whose business is to make negatives of different types of subject, the properties of importance are the spectral sensitivity, the range of contrast possible with a particular sensitive surface and the capacity to register intermediate gradations, and the last

two properties are not identical. Many emulsions will render an extended range, but not intermediate gradation. The ability to give high contrast depends upon the property of the emulsion to give great density combined with an absence of deposit for the lowest tone—in ordinary language, great density combined with "clearness" or freedom from "fog."

It is very important that plates should possess a high resolution (see Appendix, "The Resolving Power, etc."), for the reason that this property largely determines the ability to render fine detail, which is so important in line work.

There are other properties desirable in practice, such as a reasonable rapidity of development and fixation. The former is governed by grain size and aggregation, and by the hardness of the gelatine, which controls the speed of entry into the film and the diffusion in and out (osmosis) of the developer. Grain size and aggregation again control the rate at which the silver salt is converted by the potassium cyanide or sodium thiosulphate into a soluble salt so that the plate may be "fixed" by the action of water.

Thickness of the gelatine film determines the speed of washing, because osmosis, or the rate of diffusion of a soluble salt in and out of the film into the surrounding water, takes place more slowly with a thick film than with a thin one, and this is a matter of importance, for in a photo-mechanical studio the work must be done nearly always in a very limited time. In consequence, plates made for the photo-engraver—the so-called process plates—are nearly always made with a thinner film than those plates made for other kinds of negative making.

Excluding collodion processes and considering gelatine emulsions, the present-day range of sensitive surfaces includes the following kinds—

Ordinary, with limited range of sensitivity—from the

near ultra-violet to 5400 Å (see p. 344), viz. to the beginning of the blue green.

Orthochromatic, with an increased range of sensitivity—from the near ultra-violet to about 5900 Å, viz. extension to the green and *very slightly* to yellow. (The term "isochromatic" sometimes applied to these surfaces is a misnomer.) It is not strictly correct to say that the "ordinary" surfaces are without sensitiveness to green and to yellow. What is meant is that such sensitiveness as may be found is of no practical value in negative making.

Panchromatic, with a further increase in sensitivity, broadly from the near ultra-violet to about wave-length 6700 Å, viz. extension to yellow, orange, and red.

There are, in addition, particular kinds of plates and films for special purposes, as, for example, *radiography*. A plate of particular interest is one sensitive to the "infra-red," where the sensitivity is that of the *ordinary* followed by a gap and then a band of sensitiveness from 7000 Å–9000 Å. A plate of this character is used in the preparation of the "black printer" (see p. 446) in four-colour work. (See *The Modern Masking Method in Correct Colour Reproduction*, Kodak.) The subject has been fully discussed by Tritton, F. J. (*Penrose Annual*, Vol. XL, 1938, pp. 126–128).

For "Sensitivity and Dark Room Illumination," and "Reduction of Sensitivity: Desensitization," see Appendix.

The support is glass, celluloid or other film, or paper. There are advantages in each kind. Glass is undoubtedly the most easy and convenient to use, but it is the most expensive of the three, and it suffers by presenting the defect of reflection halation at the maximum. In dry plate work the "glass charge" represents a serious item in the cost of a negative as against wet collodion, because the glass is only used once, whereas in wet plate work the film, after use, is cleaned off and the glass used again

perhaps a dozen times, so that the "glass charge" on the negative would be only one-twelfth of what it would be were a dry plate used. For many reasons films have come to be used, and, more recently, paper, both of which are very much cheaper than glass. Both show less reflection halation than glass. But they are not by any means too easy to use, the difficulty being their support and maintenance in a flat condition in the dark slide. For this purpose several methods are in vogue: (*a*) The film—or paper—is placed in the carrier with a sheet of glass at the back which takes off the pressure of the spring and gives a certain support. (This is not a good way.) (*b*) The film—or paper—rests upon a sheet of glass and a card is placed behind, allowance being made for "register." This maintains flatness, but it is necessary that the glass be clean and free from flaws as the least defect will produce a blemish in the negative. This system does keep the film flat. (*c*) The film—or paper—is rested upon an adhesive supported on a slab of glass. This adhesive is a thin film of a very firm jelly akin in physical character to the jelly used on "copying" trays (the old "Hecktograph"), and remains in good condition for a considerable time, or a two-sided coated material is attached to glass, and takes the film or paper on the other side. Similarly, glass is coated with a "tacky" varnish to hold the film, and these are good and convenient plans. (*d*) The provision of a pneumatic cushion in the dark slide upon which the film—or paper—rests. This is the best plan, but the arrangement is an expensive one to provide. The system (*b*) is not admissible in very many instances in half-tone screen negative making, for the simple reason that the glass will not allow the film or paper to be brought near enough to the ruled screen. Both film and paper negatives have the advantage that they can be easily cut up, which is of importance where "flats" (see Fig. 39, page 295) are

to be made up. The wet collodion plates lend themselves readily to stripping for this purpose.

The operator faced with the differences in plates must learn how to make a selection. The student, with advantage, may start *de novo* and consider what is required in the negatives, of which he is called upon to make three kinds, (*a*) broken tone, in the form of line subjects; (*b*) broken tone, in the form of "screen" negatives; (*c*) continuous tone. Pencil drawings will be considered as (*b*) or (*c*). In (*a*) the object is to produce a negative in which the parts corresponding to the lines are clear or free from any deposit, whilst there is a sufficiency of density to yield the opacity to protect the coating underneath during the process of printing the resist.

It is observed that in the study of the subject, it is always desirable to assume no deposit in the parts representing the lines. Resist printing is not so simple as it may appear with respect to requirements. In general it may be stated that the greater the sensitiveness of the coating that is used for the resist, the greater should be the density in the negative in the parts representing the whites. In consequence, negatives for bichromated albumen or fish glue require greater contrast than did negatives for sensitive bitumen coatings.

The pure photographer coming to the study of the subject for the first time would find that a negative, to be suitable for the production of a black and white print on bromide of silver paper—with perfectly unaffected whites—would have to be very dense in the whites, whilst for slow chloride of silver (gaslight) paper the necessity for this condition would not be so great. At first sight it would appear to be merely a question of the relative inertia of the two surfaces, and, as between the bromide and the chloride papers, it is so. When preparing a print upon these papers no part of the surface, which in the final

print should be white—to meet the requirement previously assumed—must be affected by light, for if it is it will be "greyed" upon development, and that greyness will remain. But if the negative were being used to print upon bichromated fish glue, a resist for photo-lithography, or for a relief line engraving, any slight change in the surface under an opaque part would not matter for the reason—precisely given—that so long as the coating below remained unaffected, i.e. soluble, it would wash away on development, and in the end the result would be just the same as it would have been were the top layer of the resist unaffected. This will explain to beginners why often, with negatives far from opaque in the whites, satisfactory prints for photo-mechanical purposes can be made.

We have, therefore, the requirement that in the negative there must be a certain range of contrast. Since "range" is a matter of difference between clear and opaque (since there cannot be a ratio between two quantities, one of which is zero, we assume there is some opacity in the clear parts, and for this the opacity of the film will suffice) it would appear that there might be an appreciable opacity —sometimes called "veil" or "fog"—in the parts that should be clear, provided that there was a suitable increase in the opacity of the opaque parts. The student should not be led away by any notion of this kind, for the contrary is the case. It is not easy of explanation, for it is not alone a question of inertia, which requires that the equilibrium of the sensitive compound be *upset*, at which stage the action may be said to start and by further light to continue; it is that the film should not be subjected to so weak a light that it can recover, which by the very principle of inertia it will tend to do, but print making appears to require that the process of insolubilization should proceed *quickly*.

There is yet another thing. Whilst the bichromated coating upon zinc will remain unchanged in the dark for a *reasonable time*, on copper that time is much less, and were the necessary exposing time to be long, the reducing action of the copper would cause the coating to become partially insoluble, leading to "scumming" in the prints. For this reason it is not possible to prepare, in the early part of the day, a supply of coated metal to be used as required, for even if kept long in the dark the coating would change. It is found that if the surface of the copper be silvered (see Chapter X), this scumming may be prevented so far as it may be due to the action of the copper, but this is used only in gravure.

DRY PLATES FOR PROCESS WORK

For many years dry plates have been available having qualities which made them suitable for "line" and "half-tone" negative making. These plates—"process plates"—are characterized by the property of yielding considerable contrast compared with even the "slow" type of "ordinary" dry plate.

A comparison between wet collodion and gelatine plates shows that there is considerable physical difference. The image material in a wet collodion negative is, practically, on the surface of the thin collodion film, whilst in the gelatine plate the image material is in the body of the film. This gelatine film is, compared with the collodion film, one of appreciable thickness. The dots in a screen negative are not, in the first instance, viz. after development, sharply defined flat discs of uniform density, but show a vignetted edge or "fringe." This "fringe" is removed by "cutting"—a solvent process—which is followed by intensification, when dots of fairly uniform density result. With a surface image the "fringes" can be removed before any serious loss of density has taken

place in the remainder of the dots. But when all the dots are diffused in the body of the gelatine film, serious loss of density ensues on "cutting," more particularly in those representing the darker tones of the original. These differences are of importance and a comparison would indicate the advantage of the wet plate. The wet plate image is more amenable than the image in gelatine to those processes of intensification which confer considerable increase in density—lead ferricyanide and cupric bromide—for reasons soon discovered in practice.

The process plate, however, became a valuable aid. A further advance was the introduction of one with an extended sensitivity, and known as the "Process Panchromatic." During recent years great technical progress has been made by the use of emulsions having increased contrast factor. The plates now have thinner films than the old type process plate—a great advantage in many ways. Because of this thin film the dots show less "fringe," are better in "cutting," and high density processes for intensification can be utilized. In addition, printing down on metal for resists is more easily accomplished. The "wet" plate has been used for line negative making from the earliest days of "process," and for halftone since the introduction of the screen. A technique of excellence has been evolved by *skilled* operators and consequently there has been a certain lack of enthusiasm in favour of change.

During the last few years improvements in kind and in extension, in the variety of the sensitive surfaces for the engraver, have been made, and these retain the properties mentioned above because the necessity for them is basic. We have now the "process plate" in two speeds, one very slow and giving great density and contrast and the other with practically the same properties but having greater speed, which can be employed for line and for

half-tone with the ruled screen. Further to this there is a slow panchromatic plate specially made for the production of half-tone screen negatives, if need be, and a plate which is suitable for colour work. In addition there is provided slow emulsion process film (emulsion coated upon a flexible safety base) and another similar but panchromatized. It is often necessary to provide stripped negatives for different purposes, and there is now available a non-colour sensitive emulsion coated upon a flexible film and mounted—for use—upon a base. The finished negatives can be stripped from the base, wet or dry, and transferred to the final support chosen.

It will thus be seen how the sensitive material manufacturers have laid themselves out to meet the needs of the process worker. But more than that. Each packet does not contain certain sensitive materials behind which are mystery and silence, as was the case not so many years ago. The sensitive material is *ab initio* the product of a research laboratory admirably equipped and served by a highly skilled staff. Before a packet of material is bought the would-be buyer can read the laboratory report issued, can see the sensitivity curve of the particular material, and can learn about "resolving power" and sensitometric curves and study the time and temperature chart for development and the approximate "gammas" obtainable. If the process photographer fails now he fails through ordinary manipulative skill or inability to follow plain statements in terms and language that he should understand, or, perhaps because he thinks that he knows better and selects the wrong material for the job. Such photographers, alas, do exist.

The question is sometimes asked how do these sensitive surfaces for process negative making compare as regards speed with wet collodion. Well, the speed of wet collodion is by no means a constant (depending as it does upon the

particular salts used in the collodion and the free iodine present, the strength of the "bath" and its acidity), and information that will be reliable is proverbially difficult to give when the question is addressed to one who is informed and honest. But, roughly speaking, the process sensitive surfaces are 10–20 times as speedy as the wet plate.

From time to time arguments are advanced against the use of dry plates in lieu of wet collodion; these had justification once, but no longer have the same value. Sensitive gelatine emulsion surfaces of many kinds, with *supports* in different forms—glass, film, and paper—are now made, each suitable for a particular purpose or purposes. No such variety in "means to an end" exists (nor is practicable) with wet collodion. In many houses where progressive ideas on photographic processes prevail, the gelatine emulsion surfaces have found a welcome, and their use is extending. It may not be practicable in a particular place to abandon the use of collodion, nor is the discard necessary, for the dual working is a matter of organization. The extended use of gelatine would have many advantages beyond those of a *technical* character and its employment would not entail—as sometimes argued—economic disadvantage.

For half-tone negative making of the screen negative in which the continuous tones of the subject are translated into broken tone, the type of dry plate that *rightly* should be employed is not the same as for original line subjects, although this is a feature in the selection of material that is very frequently overlooked. The idea that a screen negative is one where there are dots and clear spaces should not hide the fact that the negative should be a good *rendering* of the tones of the subject in so far as it can be produced, and consequently the sensitive surface should be one capable of responding to gradations—it

should be able to register these gradations. It must not reduce or get rid of gradation more than can be helped, even though apparently gradation is rendered by only two tone elements, black dots and clear spaces. The word "apparently" is used advisedly, for the dots are not always purely opaque elements of different sizes, but vignetted dots, and the final effect—the gradation in the resist—will vary with the time of printing. When collodion is used (and for good originals of neutral tone it is a very good process), a collodion most suited to line work (which might be a plain iodized collodion, though in general practice the use of a bromo-iodized collodion obtains) is not the best collodion for half-tone work. It is better for this kind of original that a collodion which contains an increased proportion of soluble bromide—a "softer" working collodion, to use a common everyday term—should be employed, for in this way more perfect gradation is secured. To aid the rendering of gradation, it has been a Continental practice to employ a bromo-iodo-chloride collodion with a very small amount of free iodine and a sensitizing "bath" only very slightly acid.

The negatives in continuous tone which the photo-mechanical operator is called upon to make may be those which are *indirectly* required for the production of half-tone blocks and for photogravure, and *directly* for collotype, and this section, it may be observed, is an important one, calling frequently for the exercise of considerable skill. With respect to the negatives required for half-tone block-making, screen negatives cannot be made of objects in relief (see Chapter VII), and the reason for this limitation will be given. In consequence, that large section of the work of the half-tone block-maker which includes the rendering of subjects of a pictorial character, as landscapes, architecture, and objects which might be found within the walls of the Victoria and Albert Museum, and

also that large section of subjects that are called "Commercial," such as may be wanted for catalogue illustration, both require the work of the pure photographer, who will make a continuous-tone negative and from that a print which will become the original from which the screen negative will be made. It is true, but it is a "counsel of perfection" simply because it involves extra trouble, to say that the half-tone blocks would be better were they made from transparencies than from prints. This course, however, is not always practicable, or, indeed, desirable, for the reason that very many prints are "worked up" or "finished" by the air-brush artist before they come to the negative maker. This working up is frequently done upon photographs that would be worthless without it for the purpose of good block-making, and in that sense the original may be said to have been made not by the photographer, but by the air-brush finisher. In that class of work, where at each stage the best practicable has been done, the work of the air-brush artist is important; indeed, its use may be said to have considerably extended the scope of the photo-engraver, even though this extension has been at the expense of the wood engraver, whose extinction for certain kinds of work it has practically determined. It is desirable that the student should understand something of the reasons for this change.

PHOTOGRAPHY AND THE RECIPROCITY LAW

The Reciprocity Law lays down that if a light of certain intensity, I, acting for a certain time t produces a certain effect, then if the light be reduced—or increased—the same result will follow if the time be increased—or reduced—in proportion; in other words, when It is a constant, the effect is the same.

The question as to whether or not the law $It =$ a constant held true for different values of I and t for

photographic sensitive surfaces has attracted the attention of scientific photographers for many years. In the classical researches of Bunsen and Roscoe (*Philosophical Transactions*, 1863, pp. 145, 153) these investigators based the conclusions at which they arrived on their researches into the darkening of silver chloride when exposed to light of different intensities and gave as the result the law which is termed the Reciprocity Law, according to which the photo-chemical effect or blackening is the product of the intensity into the time of exposure, "time" being the reciprocal of the intensity, and vice versa. They decided that equal products of the intensity of light into the time of insulation (exposure) corresponded within very wide limits to equal shades of darkness produced upon chloride of silver paper of uniform sensitiveness. And furthur that *photo-chemical induction* does not exert any prejudicial effect with the intensities of light such as are employed in the measurements under consideration. Photo-chemical induction is not unknown in photographic processes. It means that the action of light once started continues in the dark. To this is due the so-called "continuating action" in carbon or autotype printing which is of considerable value sometimes in the process.

Abney some years later (*Photographic Journal*, 1893–94, p. 302) examined the subject. He disagreed with the conclusions of Bunsen and Roscoe, and found by experiment that the effect produced upon a photographic surface by a given intensity of light and time of exposure depends upon the actual values of the intensity and the time, and not simply upon their products.

VARIOUS INVESTIGATIONS UPON THE RECIPROCITY LAW

Since the experiments started many workers have made investigations—Jones, Hall, and Huse, Briggs,

Twyman, Hervey, Webb and others. The general conclusion is that for the gelatine dry plate at least the conclusions of Bunsen and Roscoe strictly speaking do not hold good. The volume of work done has been considerable, but it is beyond the purpose of the Author of this book to give the matter in its full detail, and the student should consult the original papers.

THE WORK OF SCHWARTZSCHILD

A brief note of this work is given by the Author in spite of the limitations imposed upon himself because it has aroused considerable attention and has a more or less practical bearing upon photographic negative making, viz., when slow plates are used in light of low intensity.

Schwartzschild (*Photographisches Correspondenz*, 1899; p. 171) as the result of experiments corrected the expression $E = It$, where E stands for the effective exposure or photographic effect and I and t intensity of the source of light energy and the time of exposure respectively, to $E = It^p$, p being a constant which he thought to be independent of the *actual* intensities and the photographic material. From the practical standpoint it means that with poor illumination and material of a low degree of sensitiveness the Schwartzschild effect takes place, but it was shown later that this held strictly *only* for poor illumination. It becomes really a part of the reciprocity effect, i.e. that the exposure with a weak light even if prolonged in proportion to the visual brightness does not produce the same effect as a proportionately shorter exposure with a bright light. The fact that this effect may come into play was well known to the older race of photographers, who made allowance for the weak light, especially when they were using small lens apertures. They had not then highly sensitive plates and the lenses

were often such that small apertures were necessary when photographing objects with many planes widely separated. Considering now Schwartzschild; if at F.8 the exposure was 1, then with F.22 when the illumination on the plate would be much weaker the exposure should not be 8 times as long, but taking the average figure of value for slow plates the exposure should be $1\frac{3}{8}$ as long.

MODIFICATION OF PHOTOGRAPHS BEFORE THE TRANSCRIPT IS MADE

Examination of a photograph of any natural object will show at once that the tones are rendered in a manner which is not found in a picture produced in any other way. The tones are smooth and continuous, and there is nothing that we have come to associate as having been made by the work of the hand. In consequence of this, should it be found necessary to add anything to a photograph, the added work must be of the same character; otherwise it will show, and there will be a conflict of style of such nature as to be inadmissible. In a large branch of photographic work, particularly that which comes under the head of commercial, a certain amount of hand-work in the direction of modifying tones is quite necessary for the simple reason that much of it is done under conditions which preclude all possibility of obtaining good negatives. Further to this, there are cases where the object itself is of a very rough character, and the photograph must be "smoothed up" to meet the taste of the buyer of photo engravings. These cases occur particularly with photographs of machinery, and a little imagination on the part of the reader will give the reasons why the defects are what they are. Added to this there is the fact that it is frequently necessary to emphasize some part of the object, as some feature in a machine, in order particularly to

draw the observer's attention to that part. Now, the photographer's power of giving the *kind of emphasis* that an engineer, say, might require to be given to a certain part of the machine, is practically negligible. It was not so, however, with the wood engraver, who could give within reasonable limits whatever *kind* of emphasis was

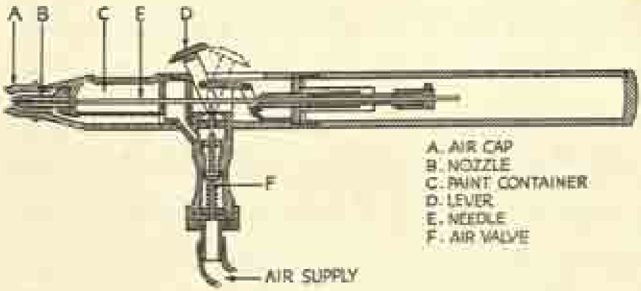


FIG. 10. SECTIONAL REPRESENTATION OF THE AIR BRUSH OR "HANDPIECE"

wanted. Further to this, if the photographer provided even a poor photograph, the wood engraver could use that photograph as an original, and, so long as all the features were there to guide him—the quality of the photograph did not matter—he could still produce a wood engraved block satisfactory as a catalogue illustration. Not so the photo-engraver, who was very largely dependent upon the *quality* of the photograph for the production of quality in his block. The obvious suggestion was to apply the art of the finisher, but, unfortunately, this was not possible for the reason that the work of the brush always proclaimed what had been done.

It was, however, by the invention of the air brush that this limitation was removed.

The "air brush" (see Fig. 10) is a device by means of which a jet of air blows a spray of finely-divided liquid colour upon any surface against which the pen may be

directed. By means of a needle—controlled by the forefinger—working in the orifice or nozzle of the "pen," the opening is varied, and thus the amount of colour, whilst the distance at which the pen is held from the surface determines the area over which the colour is spread. It is possible by this device to cover surfaces with a perfectly even or evenly-gradated film of colour. Greater or less intensity is produced, not by an illusion, but really by reason of the fact that there is a greater or less quantity of pigment deposited. In this respect the shading which may be produced is like the shading in the continuous tones of an ordinary photograph. In consequence, modifications upon the photograph can be made by the draughtsman using this instrument without such work showing in the reproduction, and thus a valuable tool has been placed in the hands of the photo-engraver. To-day in all high-class catalogue work, save for a limited class of object where the work does not lend itself, the excellence of the block work and photo-lithography is largely due to the employment of the air brush in preparing the original photograph for the screen negative maker. A further advantage in the use of the air brush is that by its means the range of the contrast in the original can be increased to allow for the reduction in the range which occurs with the use of the ruled screen for the translation of tone. *Strictly speaking*, the work of the fine etcher should be entirely eliminated in the etching of plates prepared from properly worked-up originals, because the *necessity* for such correction has been avoided by the extension of scale in the original.

Although the great majority of originals that are "worked up" are so treated for the block process and for photo-lithography, in both of which processes the screen is used, the method is also employed for other processes as collotype and photogravure, regard being paid to the

character required. With collotype, where the work is done by the collotype producer *ab initio*, the laterally reversed negative required is made suitable for the purpose, and any modification that may be required is done by the usual processes of retouching and masking on the negative, processes which in the hands of skilful workers may lead to a considerable improvement. The same may be said of any negative not made for the process which, nevertheless, it may be desired to use. Such a negative is reversed by the process of stripping (see page 104), and may be re-reversed after use if the owner of the negative desires this to be done. It may be found desirable, however, to produce a print from the negative, to "finish" this by means of the air brush, and from this original to make a new negative for use. Often, too, the negative must be reproduced because the original negative available is not of the correct size. In the case of such reproduction, it is always better to work from a transparency of the original than from a print as the intermediary. The range of contrast can be better, the grain and surface defects of the print are not reproduced in the second print, and, further, the transparency gives another opportunity for modification. But it is more difficult, and it is much to be regretted from the standpoint of good technique that the easier course is chosen.

Similar considerations apply to photogravure. In this process the printing of the gelatine resist is by means of the reversed transparency. Generally in good gravure work the transparency is treated for the purpose of improvement. In photogravure, and still less in collotype, there is not the power of modification of the final matrix that there is in the case of the half-tone plate. In recent years as gravure has become more used, the technique for modification of the matrix has been extended, but the power is not so great as in the block process. Moreover,

such methods add greatly to the cost, which is a serious objection. In collotype there is no power save that which can be exercised by a skilful printer. Consequently, these processes may be said to be in a particularly strict sense "photographers' processes," and in such processes the rule is always as expressed by the phrase, "get it in the negative," which means that whatever is done is done by the negative maker—the purely photographic work must be sound, and only by so doing is the best produced.

PHOTOGRAPHIC TRANSPARENCIES

Reference has been made to the necessity for *transparencies.* A transparency is a photographic positive upon a transparent or translucent support. Transparencies are used as the first stage in the reproduction of negatives and in one case in photo-mechanical photography, viz. in photogravure, in lieu of negatives (as stated previously), for the production of the carbon, or gelatine resist, which must be a negative print. The transparency, as any other positive, may be the exact counterpart of the negative, and to ascertain whether or not it is a counterpart there is one simple test, viz. by superimposition, if the transparency be the same size. If the finished positive be superimposed upon the negative, the two should, when examined by transmitted light, present one uniform grey tone. But this does not mean that a transparency which fails to fulfil this test is a bad transparency, but only that it is not a perfect counterpart. Transparencies, like negatives, are good when they yield by their use the result desired, and it may easily be found that a transparency with a reduced or extended scale of contrast is the better for the purpose contemplated.

If the transparency be desired for the reproduction of a negative, and the negative is to be as the original, then the transparency should be the counterpart of the original

negative. Transparencies are usually made upon dry plates either "by contact" or "in the camera," but the dry plate is not the best means. All development processes where silver salts are used *tend* to an increase in contrast and a loss of gradation, and it is a good test of photographic skill to make a positive that is really an exact counterpart. The better process for the purpose is the carbon process with a particular technique, but it is more difficult, takes longer, and is therefore not so often used.

Many photographers are familiar with transparencies only in the form of lantern slides, and it would appear that they carry their ideas of what a transparency should be into their work should they be called upon to make transparencies for other purposes. There is also an entirely incorrect idea that for the purpose "slow" and "vigorous" dry plates, that is, plates giving "brilliant" images, should be employed; indeed, the second idea arises from the first. The use of these plates nearly always leads to a loss of gradation, a thing to be guarded against by any good workman, unless there is a particular reason for desiring such loss. In photography one may extend or compress the scale of contrast, but no process can *introduce* gradations, although they may be, however, quite easily lost. It is quite true that in certain cases vigorous transparencies are sought, as, for example, by many workers in photogravure, but there is no necessity for the loss of gradation, and a photographer who asks for very vigorous slow plates in order to produce vigorous transparencies should be recommended to continue his studies in practical photography. In general, it may be said that a plate should be used having the same scale of gradation as that employed for making the original negative.

The operator who has to make negatives for collotype plate making will soon find if he works in consultation with the printer—who finally handles the plates—what

range of contrast he must aim to secure, and experience is the only guide. It may be said that negatives to suit the process should be what the pure photographer calls "soft," and there should certainly be no areas of clear glass even if these areas represent "blacks" in the original subject, be it a flat surface, or deep shadows in a subject in relief. If the range[1] in the negative be more than may fairly be said to be represented by the term "soft," then the negatives must be masked to reduce the contrast and the content of alkali bichromate in the film should be above the normal, following the usual system with bichromated gelatine when continuous-tone negatives possessing great contrast are to be printed.

The effect of printing strong contrast negatives on the collotype plate is that by the time the lighter tones are printed the darker tones are overprinted—the gelatine has been rendered *too* insoluble. The effect is to lose gradation in these dark tones, and in those places where the gelatine has been quite insolubilized no ink may be taken or it may not adhere—there is apparently no holding quality. The reason for this is not easy to understand, but the fact remains. It is not an isolated case, for even in the bromoil process of pure photography, if a bromide print with very deep darks be converted, these parts may, and indeed often do, refuse to take ink—the gelatine has been *too much* tanned or insolubilized by its union with the chromium compound.

In the negative making both for gravure and for collotype it may be said that a plate having a long scale of gradation should be used, and that will generally mean a rapid plate. Many operators like to use slow plates because by their use less care is necessary in judging the exposure necessary, and they are apt to judge negatives and to proclaim them "good" merely because they are

[1] It is now the practice to seek definite figures for the range.

"brilliant." Students in practical photography should be on their guard against imbibing such heresies. There is no reason why negatives on rapid plates should not be brilliant. Moreover, there are many causes for a lack of brilliance which will produce the defect whatever be the plate used, and against these the student should train himself to be on his guard.

COLOUR SENSITIVE PLATES

A question of some moment arises with photographers as to whether or not "ordinary," "orthochromatic," or "panchromatic" plates should be employed. If the subject be one devoid of strong colour, the ordinary plate may meet the requirement sufficiently well, but better negatives could be made on panchromatic plates with a suitable correction filter, and "suitable" does not mean always the ordinary "yellow screen"—a yellow filter (see Chapter XII). When the subject is one with brilliant colour, the use of the panchromatic plate is a necessity, otherwise the negatives are simply less good than they might be, and the absence of proper colour values in the rendering merely means work for the transparency maker, the retoucher, the finisher, and the fine etcher at the later stages if the customer is to be satisfied, and this is bad and uneconomical photography. For the orthochromatic plate with its less correct rendering, there is not, or should not be, any use in the professional studio now that panchromatic plates are available. All plates for whatever purposes should be "backed."

BACKED PLATES

The student may properly ask, since this is the first occasion when the term "backed" has been used, what is the meaning of this word and what is the purpose of the "backing"? A backed plate in its simplest and commonest

form is a plate which is covered on the back or glass side with an opaque medium which is in optical contact, i.e. one where there is no air space. Such a medium in the form of a paint may be applied by means of a brush (which is generally the method employed by photographers who buy unbacked plates and back them themselves—a practice which, because of its risk and inconvenience, more especially with panchromatic plates which have to be manipulated in almost total darkness, is falling into desuetude). The object of the backing is to absorb the light which passes through the film and the supporting glass, and so prevent one form of halation. The cause of this defect and the necessity for this backing are explained in the Appendix (see "Halation"), observing that there is no case in photography where the negatives made upon backed plates are not better than those made upon plates unbacked.

STRIPPING PLATES

The terms "stripper," "stripping," and "stripping plate" have been used, and appear to call for explanation.

Ordinarily a collodion film adheres very slightly to glass and is easily damaged. To avoid the difficulty the glass is "edged," which in practice means that on the margin of the glass before it is coated there is applied a solution of india-rubber in benzene, and the solvent, when it has evaporated, leaves a thin layer. This suffices to keep the film from slipping off during the operations of negative making, but the film may be damaged by a rough touch in the parts where there is no india-rubber. However, it is a convenient method because it permits the film to be "turned" for reversing or to be stripped for making up a "flat," which means a number of different negatives all transferred to a sheet of glass. A further precaution is to give the glass a *substratum*, and this may be a very

dilute solution of rubber in pure benzene or a solution of albumen or gelatine in water. This leaves a film of the substance upon the glass, and with substratumed glass the adhesion is relatively tenacious and the film may even be gently rubbed without suffering damage. In certain processes, as in collotype, where the attempt is made to bring two rigid surfaces—the plate and the negative—into perfect contact, as required for exposing, the negative may quite easily be broken, and to avoid this damage stripped films are often used. These films have the further advantage that they can be easily cut with scissors when it is required to assemble and mount a number of negatives together for exposing together on one collotype plate. When collodion is used, stripped films are made by coating the glass with talc and edging with rubber before coating with collodion. When the negative is finished, it is levelled and coated with a solution of gelatine, which is allowed to set and is then dried, and the surface is afterwards coated with plain collodion. Any work necessary is now done upon the negative, and the film cut through and pulled away from the glass.

At one time certain dry plate makers supplied "stripping" gelatine plates, which meant that the glass was talced and was then coated with collodion before the emulsion was applied, the collodion ensuring that the film would eventually leave the glass. When the negative was finished, gelatine was applied as in the case of the collodion. Few, if any, dry plate makers supply these plates now, for the introduction of celluloid-coated films of different types has obviated the necessity, but there are still "stripping" plates obtainable. These are plates, the glass of which has not received the usual *gelatine* or other form of substratum for ensuring that the emulsion film will adhere throughout the operations of making the negative—development, fixing, and washing. Such plates have their

uses, as, for example, in certain technical work where it may be desired to remove a background completely and leave clear glass or to insert another, and in the very common practice of "floating in" titles or names of places made on a separate negative into a little transparent panel cut out of the negative it is desired to title. This cannot easily be done with an ordinary plate, but is simple, given the necessary "knack," with stripping plates. In some cases it is desired to strip negatives made upon ordinary plates as a whole. Such cases occur when an unreversed negative is to be laterally reversed, or often when the glass has been cracked. This is done by coating the negative with plain collodion and then immersing in a solution of alcohol and water containing hydrofluoric acid. The acid dissolves the immediate surface of the glass, and the film no longer adheres. A piece of paper is squeezed to the film, lifted up, and laid flat. A fresh piece of paper is now laid on the film and squeezed, and, on raising, the film may be caused to adhere to the second paper. The film is now similarly transferred to a second piece of glass which has been given a coating of gum or starch mucilage. If the film is not to be reversed then the second paper is omitted.

Stripping films were at one time often made by coating the negative film on glass with gelatine and enamel collodion before the acid treatment. The object of the collodion in all these cases is to counteract the tendency to stretching.

MULTIPLICATION OF IMAGES—"STEP AND REPEAT" SYSTEMS

A problem in negative making which arises in connection with each of the three different types of matrix—intaglio, surface, and relief—is the method to be adopted for the multiplication of images. To produce economically large

numbers of copies of any design, a postage stamp or a box label, for example, requires that a number of replicas be assembled upon one sheet so as to reduce the number of runs at the machine. This requirement has been satisfied in the past mainly by the method of the lithographer for the simple reason that the class of work for which it is required was mainly done by lithographic printing. The method was to produce, from the original stone or plate, transfers to the requisite number, to arrange these with the necessary margins upon a sheet of paper, and eventually to transfer these images to stone or metal, after which the operation of multiplication was purely the routine of the machine room. Tedious but simple for monochrome work in one printing, it became far from simple where colour work was concerned, for it meant that each one of perhaps 50–100 images must register accurately with each one of the 50–100 images upon each sheet of transfers, when there were possibly half a dozen or more printings.

This problem has been now simplified by the introduction of what have come to be known as "step and repeat" systems, which derive their name from the operation involved in producing the final multiple. These systems involve photography. A single image is repeated step by step until the requisite number are produced upon one plate. The required image of a postage stamp is repeated 120 times, producing a multiple negative containing 120 separate negatives, and from this may be produced a zinc relief plate or a photo-litho plate on zinc or aluminium. If photogravure be required, then, instead of projecting a positive, a negative is used. The work can be done with a very high degree of accuracy with respect to the predecided position of the images. The principle is to project, by means of a camera system, an image from the master negative or positive (and this image may bear

any relation in size to the master, reduced, enlarged, or same size) on to a plate sufficiently large to take the desired number of images. The plate can be accurately moved any desired interval after each exposure in a straight line so as to produce a row of images, and it can then be raised and another line of images produced until the plate is filled. After this the dark-room work necessary to convert the exposed plate into a negative—or positive—is carried out. If it be colour work, when one negative is made, the next "master" of the colour set is placed in the camera and the repeat negative produced. In consequence of requirements this apparatus is very accurately made, and there need be no fear that the different images in, say, a set of "stepped-up" three-colour negatives will not be in register the one with the other.

Originally applied to the production of negatives, the principle has now been extended to apparatus for "printing down" multiple plates, so that a single negative can be placed in the apparatus and printed—with perfect accuracy as regards position—the requisite number of times, say, for example, upon a bichromated albumen (which is afterwards inked up and developed) or a fish glue coated plate. This system is also used particularly when very large plates are wanted for stepping up already stepped-up negatives, for there is a limit to the size of photographic plates which can conveniently be made or handled. When stepping up on wet collodion, it is necessary that the work be done quickly or the surface of the plate may dry, when the soluble salts in the film will crystallize out, and the structure of the image will be destroyed. It is in cases like this that there is a limitation in negative making, and to be able to "step up" a negative which itself has been stepped up, and so produce a great number of images upon a plate which can go to the machine, is a great economic benefit.

THE APPARATUS FOR NEGATIVE MAKING

At this stage the student should have obtained a reasonable knowledge of the nature of the sensitive materials used for the purpose of negative and positive making, and the way in which images are formed upon these surfaces by the action of light, followed by the

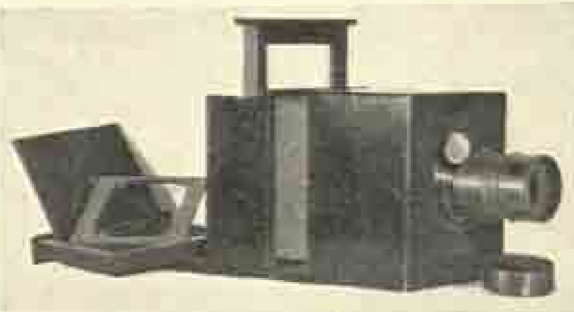


FIG. 11. A SIMPLE CAMERA OF EARLY TYPE, WITH LENS AND REMOVABLE FOCUSSING SCREEN AND DARK SLIDE "WITH INNER FRAME" TO TAKE SMALLER-SIZED PLATE

subsequent chemical processes carried out in the photographic dark room, by means of which these images, latent or hidden in the surface after exposure in the camera, are rendered visible and permanent. Since it is the function of these surfaces to render permanent in a certain form the images they receive, the mode by which these images are formed will now be considered, in other words, the camera system. The principal component in the system is the camera, with which is associated the objective or lens. Essentially, the camera is a device for supporting a lens at a certain distance from a sensitive surface, with a provision for preventing any light from reaching that sensitive surface other than that passing through the lens. A line through the mechanical centre of the lens to its focal point is the principal axis of the lens, and the sensitive surface should be so supported that

it is, in its normal position, at right angles to the axis. Since images are formed correctly at the principal focal point when the object is so far away that the light received by the lens is in the form of parallel pencils, and at other focal points, termed conjugate focal points, when the object is nearer, there must be the means, within limits, for altering the distance of surface to lens to suit circumstances. The photograph (Fig. 11) represents then the bare essentials of an outfit showing the camera, lens, and plate-holder (single) or dark slide. In Fig. 12 is shown an additional picture of the lens—in the camera it is fixed in a rack and pinion focussing tube—which is a simple achromatic combination of an early type consisting of two elements—a flint glass double concave cemented to a crown glass double convex, this combination being mounted at one end of a tube, whilst at the other end is placed a circular aperture or "stop," which limits the diameter of the pencil of light that enters the lens and, consequently, determines the brightness of the image. In this camera, focussing is done roughly by moving the back to and fro, the finer adjustment being made by moving the lens by means of the rack and pinion. Simple as it is, the student would do well to commit this form to memory and to avoid the error of imagining, as some do, that there is a mystery in the camera.

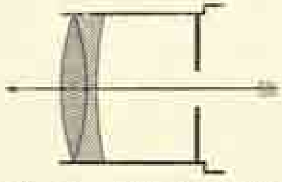


FIG. 12. THE SIMPLE ACHROMATIC LENS USED IN THE CAMERA SHOWN IN FIG. 11

The lens is mounted on the camera in a rack and pinion focussing tube

It would be possible to omit the lens and put in its place a plate bearing a minute circular aperture to occupy the axial position. By this simple procedure an image of objects in front of the aperture would be formed on the sensitive surface and excellent photographs can be taken in this way.

But it would not suffice for our purposes. Although there are several reasons for this limitation, it is enough to say that with "pinholes," as they are termed, there would not be enough light passed to meet the requirements in our particular kind of negative making. We employ lenses *primarily* because, passing more light than pinholes, they give more brilliant images and therefore the exposures are briefer, which is necessary. A lens in its *simplest* form is a portion of a transparent refracting medium bounded by spherical surfaces, and its function is to receive light proceeding from the object and to converge that light so that it falls upon the sensitive surface. If we consider any luminous or illuminated object as an assemblage of luminous points of different degrees of luminosity in colinear relation to each other, then, if the lens receives light from these points and transmits the light to positions on the sensitive surface which are in the same colinear relation, there will be formed an image like unto the object, save for the fact that the brightness is never the same since all the light sent forth from the object points is not received by the lens. But in practice a simple lens will not do this, and we come therefore to a more complicated device in which, by means of several lenses placed in certain positions to each other, the optician has been able to overcome the main defects of the simple lens and to produce an instrument which will form an image sufficiently like in form to the object to satisfy necessities. The simple lens is, however, the easiest to understand, and is indeed quite satisfactory where the photographer does not require critical images, and is, moreover, cheaper.

The requirements of the photographic process call for two classes of image formation, the production of an image of a flat surface, as a drawing upon a flat surface—the sensitive surface—and an image of an object in relief

upon a flat surface. In this second case we have the projection of the image of a solid object upon a flat surface, which is a more difficult condition to satisfy. The optician is able the more easily to satisfy the requirements of the

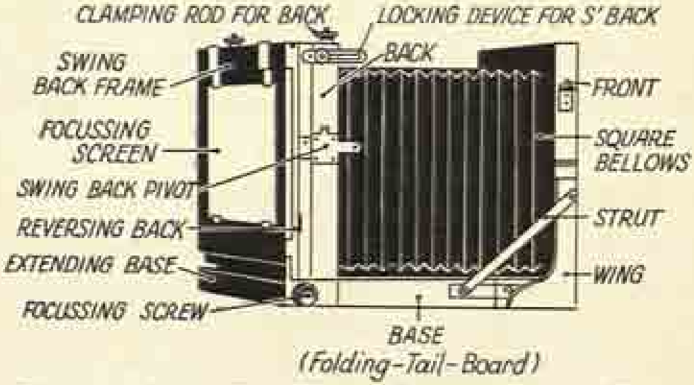


Fig. 13. A Square Form Modern Portable Camera—Heavy Form, Back Focussing

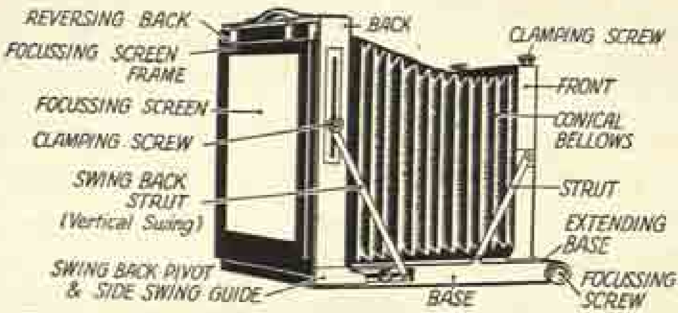


Fig. 14. A Square Form Modern Portable Camera—Light Form, Front Focussing

former, and since the photo-mechanical worker deals in the main with flat originals, he is in a better position generally than the pure photographer.

But though the simple camera of Fig. 11 suffices to explain the requirements for making *a* negative, it will not meet the requirements of *all* negatives, and in practice we come to something more complicated. For "copying,"

and photo-mechanical negative making is generally copying, the requirements in practice are more complex than for a camera intended for general work. The cameras shown in Figs. 13 and 14 possess all the essentials for ordinary negative making, and could be used for certain kinds of negative making for photo-mechanical purposes, but not for all. In the modern camera—the designs vary considerably—there are means for altering the position of the lens in relation to the plate (rising and falling fronts), and for altering the angular relation of the plate to the lens (swing backs), and for altering the distance of plate to lens (focussing device). In the camera shown in Fig. 13 the lens is fixed and the plate moved. Although this camera is essentially a portable camera, it has the same focussing movement as a camera intended for purely copying purposes, and this movement is essential in the latter form of apparatus, for the reason that in copying work we have nearly always to make an image to a definite scale, for which purpose the lens must be at a definite distance from the object and the sensitive surface then moved to the posterior conjugate for that distance, when the image will be "sharp." But if we can allow the lens to be moved, it is possible to construct a camera of a more compact character, and since this is a great advantage in portable apparatus such a plan is followed, although there have been for years cameras where focussing can be done from both back and front. When focussing by movement of the lens we alter the size of the image, but when the object is large in proportion to the image, any movement of the lens to and fro produces so trifling a difference in size as to be of no moment. In Fig. 14 is shown this front focussing camera. A modification of this type provides for movement of the back and the front.

Although in the operations of the industry particular kinds of apparatus are employed for negative and positive

making, the simplest form of apparatus will be sufficient to make plain the operations essential to the production of the record. The sketch, Fig. 15, represents the "lay-out": (A) is the original to be photographed on an easel; (B) is the camera containing the image-forming lens (which camera is shown in detail in Fig. 13) and the focussing

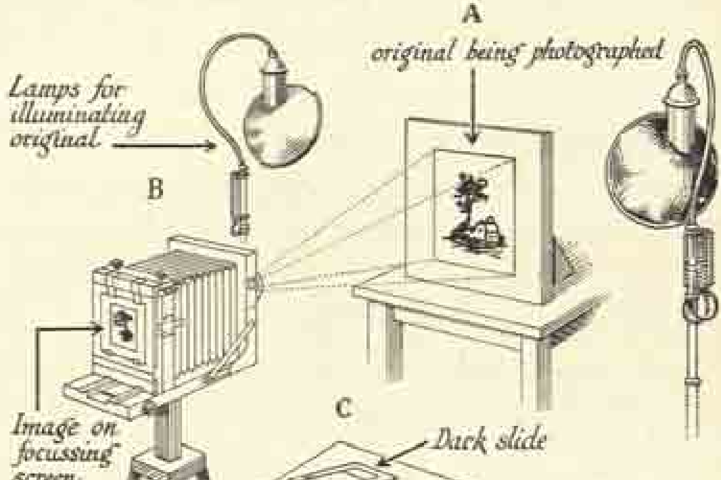


FIG. 15. "LAY-OUT" OF APPARATUS FOR MAKING A SIMPLE PHOTOGRAPH

(The electric glow-lamps may be used in places where there is no daylight)

screen upon which the image is, in this case, formed; and (C) is the container or "dark slide" holding the "sensitive surface" in readiness. Two sources of artificial light are also represented. When the image has been properly arranged to the required size, the dark slide replaces the focussing screen, and upon withdrawal of the protecting shutter the image falls on the sensitive surface and produces its effect, it being understood that the sensitive surface occupies exactly the position held by the focussing screen prior to the "exposure." The surface of the original is evenly illuminated either by daylight or,

more generally, by the artificial light from a pair of high amperage arc lamps. The original, in the majority of cases which come to the illustration studio, is a flat surface—pictures, drawings, photographs, or frequently a carpet or other fabric, or a piece of linoleum. If, however, the object be a nature subject in relief—it may be that the camera is used out of doors to photograph a scene—the system is, in its essentials, the same. This procedure would give a negative which might be employed for the making of prints by a process of *pure* photography, or it could be employed in certain matrix making processes, as, for example, the surface process of collotype or the intaglio process of photogravure. *But* for the relief processes, *if the subject were in continuous tone*, as a portrait, a landscape, or a drawing in shading, it would be necessary to add a further element (ruled screen) to the camera system in order that the continuous tones of the subject might be translated into the necessary broken tone with which the relief processes alone can deal. As will be noted in the succeeding chapter, with the half-tone process for certain types of subject—objects in relief—it is necessary to make an ordinary negative and from that a positive or print, from which is produced the kind of negative required for the process. In this case the positive or print occupies the position (A) in Fig. 15.

One advantage—common to all photographic systems—of the process of negative making is that the size of the negative, as compared with the original, can be adjusted to requirements, viz. to the size desired for the finished matrix. Moreover, it has been found possible to enlarge or reduce one dimension only while maintaining the other—a proceeding of value in certain instances, as, for example, designs for the roller of the calico printer, or labels for different purposes.

In a photo-mechanical studio, whilst the larger portion

of the work is the photography of flat surfaces, a considerable quantity of the subjects undertaken are those in relief. For this purpose cameras after the pattern of Figs. 13 and 14 are used, and although the precise form varies the essentials are the same. In some instances the

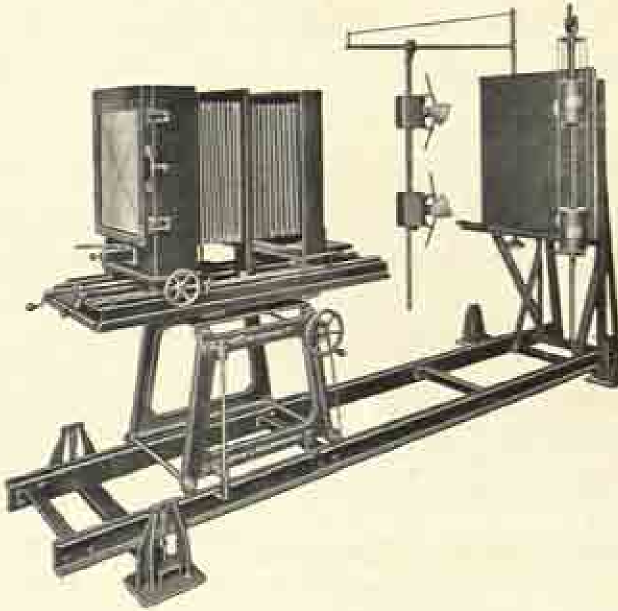


FIG. 16. THE COMPLETE UNIT FOR NEGATIVE-MAKING FROM FLAT SURFACES CONSISTING OF CAMERA UPON ANTI-VIBRATION STAND, THE EASEL OR COPY BOARD, AND THE ARC LAMPS (HUNTER-PENROSE) [1]

studio type of apparatus is employed, and the greater rigidity it possesses (owing partly to its greater bulk) is an advantage. The sensitive plates or films are held in dark slides, the double "book form" being principally employed, though with studio cameras the single slide is

[1] Certain improvements dictated by experience have been made in this equipment. The focussing screen has been hinged. The stand is now constructed as a low girder model. It has several advantages, one of which is that it can easily be stepped over—a help in crowded studios.

often preferred. But for the straightforward routine of photo-mechanical negative making, special apparatus is used of ingenious construction and of a high degree of accuracy, which apparatus has been evolved as the result of a long experience of the particular requirements.

The exposures of the sensitive plates being in this kind of work relatively long, special precautions must be taken against vibration, all the more necessary because studios are so frequently placed in the heart of large cities and the consequent shaking owing to the traffic presents difficulties. To meet these difficulties the practice now generally adopted is to mount camera and easel upon an anti-vibration stand, and in the construction of these stands considerable ingenuity is shown. Further to this it is now usual to support the arc lamps used for illumination of the "copy" on the same stand, and thus the whole outfit is one unit. Since negatives and positives are made by transmitted as well as reflected light, the easel is removable, being replaceable by a box-like arrangement known as the "transparency holder." The lamps are capable of being swung round to illuminate a white screen placed behind the transparency holder, which screen becomes the source of illumination to the negative or positive in the holder. (See Fig. 16.)

The normal position of this camera is with the focussing screen parallel to the easel, and this position is maintained by reason of its support running on lines which are at right angles to the easel. But since so many of the negatives must be laterally reversed, the camera is mounted upon a turntable so that it can be turned to bring the focussing screen at right angles to the easel, reversal being effected by means of a prism on the lens. A reversing prism (Fig. 17) is a prism silvered upon its hypotenuse and mounted in a metal box of such construction that one face of the prism can be brought close to the front combination

of the lens. In Fig. 17A is shown a prism and a lens combined. Prior to the use of the prism, a plane mirror

FIG. 17. THE REVERSING PRISM

FIG. 17A. A LENS AND REVERSING PRISM MOUNTED TOGETHER

silvered upon the surface and then polished and eventually held in a mirror box so that the surface of the mirror was at an angle of 45° with the lens axis, was employed.

Mirrors are, for the same aperture lens, cheaper than prisms, but their use presented constant difficulties owing to the tarnishing of the silver surface. Moreover, since it is not practicable to polish the surface of a mirror to

FIG. 18. THE BACK OF THE CAMERA SHOWN IN FIG. 16, SHOWING THE SCREEN GEAR AND CIRCULAR SCREEN IN ALUMINIUM HOLDER IN POSITION

anything like the same degree of accuracy as the hypotenuse of the prism, the results are inferior to the latter with respect to accuracy in the image definition, for faults in the reflecting surfaces impair the performance of the lens.

In Fig. 18 is shown what is known as the "screen gear." This is the arrangement by means of which the

ruled screen employed for the translation of continuous tone into dots (see page 167) is held. The essential requirement is that the screen must be held absolutely parallel to the sensitive plate during exposure. An index must be provided for showing the operator the distance of the

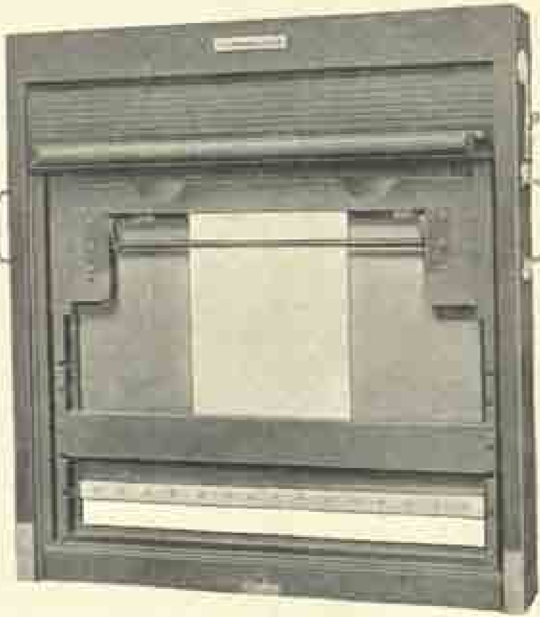


FIG. 19 THE SINGLE DARK SLIDE OR PLATE-HOLDER USED WITH THE CAMERA SHOWN IN FIG. 16

A plate is in position showing how it is held by means of the adjustable bars

screen from the plate. The screen in position in the illustration is a circular screen. Circular screens were introduced for colour work where the component negatives of the job must have particular crossing angles to reduce pattern (see page 387). Originally, separate screens were employed, but it is much more economical to employ a circular screen in a mounting with a divided edge so that the setting may be to the particular angles necessary,

and, moreover, the time that would be lost in changing screens is avoided.

In Fig. 19 the dark slide is shown, which is always a single slide. The different sizes of plate are accommodated by means of adjustable bars. The shutter is always of the roller-blind type, and may be completely removed from the slide, thus permitting focussing in the camera, which is occasionally required.

THE LENS

The lens or objective is an essential part of the photographer's equipment. Its purpose is to form upon the sensitive surface employed an image of the object to be portrayed, an image of the kind which is suitable for the process employed. This is the photographic record and may be a negative or a positive.

In its most simple form a lens is a portion of a refracting medium bounded by spherical surfaces, the medium in the case of a photographic lens being glass of certain physical properties. The simplest form of lens which will form an image is the spectacle lens. From such a simple element consisting of a single piece of glass the wonderful construction embodying complicated mathematical calculations and highly skilled and specialized workmanship have been evolved. Each form of the final instrument, each finished lens, is primarily adapted for certain kinds of photography. Lenses for the photo-engraver's studio are essentially lenses for copying and generally originals having a flat surface as pictures of some kind.[1]

Advances in lens design have been made possible by the production of a special series of optical glasses.

[1] Where there are objects in relief to be finally represented by most forms of photo-mechanical process (see Chapter VII) the primary negative is a matter of pure photography and would ordinarily be made in a studio attached to the process studio. The print or transparency in the case of renderings by any form of the "half-tone" process would then be passed to the process studio for the making of the special kind of negative.

These were made possible by the researches of Professor Abbé and manufactured by Schott of Jena. Great success in this respect has followed the work of Chance Bros. of Birmingham. The new glasses—new compared with the material at the disposal of the lens makers in the early days of photography—are chiefly remarkable for the great variety in refractive index, in spectral dispersion, in freedom from colouring and, what is also very important, in stability as regards their behaviour towards light, air and moisture.

A brief reference to important forms of lens specially designed for process negative making may be helpful to the student. The requirements in a lens for the photo-engraver's studio are an image free from distortion, uniform illumination over the field, and critical definition. Further to this, where the lens is to be used with colour screens (see page 113) the images must be identical in size, and for this purpose the corrections must be of a particular order.

THE "BLOOMING" OF LENSES

When a pencil of light falls upon the surface of a lens, of this incident pencil a portion is reflected amounting to about 8 per cent. Some is absorbed, the amount depending upon the particular glass and the wavelength of the light and the remainder is transmitted and forms the image. The loss by reflection is not very important with camera lenses, but the reflections do lead to a lack of brilliancy in the image. With such instruments as binoculars or periscopes where large numbers of surfaces are traversed, the loss is important and the lack in brilliancy of the image is noticeable. To combat the faults recourse is had to the operation of "blooming," which means the production of a non-reflecting or at least a lower reflecting film upon the glass-air surface. The result is to increase

the transmission and to reduce the other drawbacks of a reflecting surface.

The "blooming" film must be of such a thickness that interference[1] takes place between the light reflected at the air-film and film-glass surfaces.

The thickness of the film is important. The refractive index of the film is determined by the choice of material. Silica has a high refractive index but can be used with dense glasses. The metallic fluorides cover the whole range of optical glasses. The methods employed are three in number, two being chemical and one physical. The chemical methods produce the film out of the glass of the lens by dissolving away some of the constituents to the depth required. In the physical process the film-making material is evaporated on to the lens surface in a high vacuum. In the chemical method the oxides combined with the silica to give the glass its character are dissolved out by means of dilute acid, or a later plan is to suspend the lens above a dilute solution of hydrofluoric acid, but this method is not applicable to all glasses. The chief advantage of the physical method is that a material can be chosen to suit the refractive index of any glass without reference to its chemical composition. The film can be easily removed. In the chemical method the surface of the glass is used and the film can only be removed by polishing away some of the glass.[2]

[1] If two trains of light waves following each other are in step, viz. have their troughs and crests coincident, they reinforce one another. If they are out of step and the troughs and crests do not coincide, they are said to "interfere." If the waves be generated by a white source and they are out of step colour is produced and the precise hue will depend upon the degree by which they are out of step. The simplest case of interference is with the soap bubble, where the light reflected from one surface of the transparent film interferes with that from the other and as the thickness of the film varies the hue varies because of the difference in step. If the crest of one coincides with the trough of another there is complete interference and extinction results.

[2] The Author is indebted for this account of the "blooming" process to Twyman, F., *Prism and Lens Making*, pp. 152–155 (Adam Hilger Ltd., Camden Town.)

With camera lenses there is a reduction of "flare," but it does not appear to have been demonstrated that there is a material improvement in the images produced by the lenses in process studios by the "blooming" film under the conditions in which the lenses are used.

It should, however, be recognized that when it is desired to avoid loss of light by reflection in any optical device all glass and surfaces should be "bloomed."

THE CONSTANTS OF A LENS

The constants of any lens to the photographer (or other user), whatever be its design, are the principal focal distance[1] and its aperture. Both are of primary importance to the user, and the student should understand what the terms mean.

PRINCIPAL FOCAL DISTANCE

If a positive lens be placed in the path of a parallel pencil of light, say that proceeding from a very distant source—the origin—the pencil being on the principal axis of the lens and parallel with it, then an image will be formed on the axis on the other side at a position due to the particular lens. Now the distance between the origin and the focal points is the principal focal distance of the lens. There are two foci, the one on the object side being the *anterior* and the other the *posterior*, and the positions from which distances are measured are known

[1] The term "focus" if used instead is slang and misnomer. Focus is the point or position where convergent rays meet after refraction with a positive or real image forming lens, and with a negative lens the point from which they diverge. With real image forming lenses we are concerned with *distance*, which with *length* connotes two positions, the origin of the light (parallel pencil) and the focus. In the first instance and as a fixed property of any lens the nearest point at which a sharp image is formed, indeed *can* be formed. The distance between this point and the origin is the *principal focal distance*.

"Focal length" is equally wrong with "focus," implying as it does that a point has magnitude. A *point* is merely a position; it has no magnitude, no length, width, or thickness.

as the *nodes*. The distance of the posterior node and the focal point is the principal focal distance of the lens. No image can be formed *nearer* to the lens than the one spoken of, but if a pencil of light *not parallel* be taken then an image will be formed and it will be further away from the node than the one in the first instance. The two distances are spoken of as *conjugate focal distances*. If the source of light, say for simplicity's sake at a great distance, is caused to approach the lens its image will recede and the position of the image (and its size) will depend upon the distance of the source. In all cases cited the image will be real and inverted. Lenses used by the photo-engraver and his camera are positive lenses.

The brightness of the image given by any lens depends on several things, the glass, the number of elements, and their reflecting surfaces, and the aperture. The aperture, an opening in the lens through which the light can pass, is expressed as the ratio of the opening to the principal focal distance and is known as the F value. The opening may be regarded for simplicity's sake as the "stop" or diaphragm. The stop is the fixed ring introduced by the lens maker, but the aperture may be made smaller by the introduction of diaphragms withen a certain range. This is the mechanical aperture, which may not be the true aperture. In a simple single lens such as that in Fig. 11 page 109 used as shown, the mechanical aperture would be the true aperture, but if the lens were reversed it would not be so. When a lens has a combination *before* the diaphragm there is admitted a condensed pencil of light, and it is the diameter of this pencil at the plane of the diaphragm that is the aperture. This is the *effective* aperture, and it is this aperture which when divided into the principal focal distance gives the true aperture ratio —the real F value—for example, F4 or F8 as the case may be.

THE EFFECT OF DIFFRACTION[1]

Diffraction has been made use of by Tritton, F. J. (see *British Journal of Photography*, Vol. LXXXIV, 1937, pp. 513, 514) when copying screen plate colour transparence such as Dufay, the effect being, when a very small aperture is used in making the copy negative, to give results in almost continuous tone, thus removing a difficulty (see Production of Pattern, p. 387) when colour block negatives are made by use of the regular cross line screen. When a lens is computed the aperture which will give the best definition is known, that is to say, when the resolving power (see p. 406) is at its best. With this aperture the normal (viz. those which affect definition) aberrations of the lens are at a minimum. To reduce the aperture further will mean that diffraction may begin to show its harmful effect upon definition. It is to be regretted that this is not more widely known and appreciated, and that so many operators use very small apertures under belief that sharper images will result. This does not apply to process operators except when making negatives of line drawings, but it is a practice with many photographers who make negatives of objects and scenes in relief, particularly when there are planes at different distances, in the hope that these will be brought into sharp definition on the image plane which is the routine procedure.

Here any effect of diffraction would not be observed since critical definition is seldom required in this kind of negative. Years ago the reverse was often sought.

Methods for the determination of the principal focal

[1] The term *diffraction* is applied to a phenomenon when a light wave print is prevented from coming to a focus. It occurs *always* when a wave of light passes a sharp edge or through a narrow slit or is reflected from a surface having *fine* ridges as in the case of a grating made for the purpose of producing a spectrum. The wave, instead of coming to a focus, is spread. This interferes with definition in the case of a lens aperture, but the effect is only noticeable when the aperture is relatively small.

distance of a lens and its aperture are given in the Appendix.

MEANING OF APERTURE

Between the lenses in the mount there is fixed a ring by the lens maker. This the full mechanical aperture and cannot be altered. It is desirable to use the word "stop" for this ring. But there is provided the means for varying the aperture within limits by the introduction of metal plates—through a slit in the mount—having openings which bear a definite relation to the principal focal distance of the lens and are designated as to size by their F ratios. These plates are preferably known as *diaphragms*, though in everyday speech they are called *stops*. They are sometimes spoken of as Waterhouse stops or diaphragms from their introducer, Major-General Waterhouse. Ordinarily the openings are circular, but with lenses for negative making with the ruled screen square openings or square with extended corners or other shapes are provided. Instead of the metal plates there is often provided an *iris* diaphragm. Here we have a series of metal vanes which come together (forming a more or less circular opening) by an external ring—a great convenience. With lenses made for process work both systems are provided.

MARKING OF APERTURES

Apertures are marked with their F values. Illumination diminishes as the aperture is reduced, and the necessary exposures are directly proportional to the squares of the F values. If we take the exposure required with F. 8 as unity then the exposures with other apertures are easily found. Thus—

Aperture . . .	F.8	F.11·3	F.16	F.22·6	F.32
Squares . . .	64	128	256	512	1024
Exposures . . .	1	2	4	8	16

The decimal point in 11·3 and 22·6 is usually omitted, so that we have 11 and 22.

The exposure with a smaller stop, say F. 4—if present—would be $\frac{16}{64}=\frac{1}{4}$, or in other words, if we take F. 8 as the standard then the relative exposure with any other stop x would be $\frac{x^2}{8^2}$. The brightness of the image is the inverse. It is sometimes the custom to mark the stop with the F value.

It is usual in Britain and the U.S.A. to make the stops of such size that the exposures bear a simple relation 1: 2: 4: 8: 16. The practice to-day with the best lenses is not to make the diaphragms smaller than F. 32.

PURPOSE OF VARYING THE APERTURE

Taking the simplest case where the object is flat, viz. is in one plane, as, for example, when copying a drawing, the first effect to be noticed when the aperture is reduced is that there is a reduction in the brightness of the image. If the lens does not define well—if, for example, there is spherical aberration[1] (see Appendix)—then there will be an improvement in the definition.

If for any reason the illumination is not uniform, if the margins of the image are less bright than the centre, there will be a gain in the equality of the illumination by a reduction of the aperture. When the principal focal distance of the lens is relatively short to the size of plate to be covered, inequality of illumination will always be seen. If the principal focal distance of the lens is less than the diagonal of the drawing it may easily be seen, but such lenses are not likely to be part of the normal

[1] It is possible that the modern process operator may never have to use a lens having marked spherical aberration. With such lenses the final focussing should be done with the actual stop to be used in position.

equipment of the studio. Where the lens of less than the normal principal focal length is used for reductions, inequality and poor marginal definition will not be so obvious.

If the object is one of relief, as when making negatives in pure photography from which prints on transparencies are required as the starting point of the photo-engraver, and there is much relief, then if one part of the object be shown sharp on the focussing screen then parts nearer or further than this in the object will be unsharp. It is usual to take a good average and then reduce the aperture until sufficiently good definition is produced. The student should remember that in such work "pin-point" definition is seldom desired save for technical purposes or advertizing—certainly not for pictorial work. In this latter respect the student would be well advised to examine some of the best work in our leading exhibition and see the definition attained for this has undoubtedly been sought.

The foregoing gives some of the effects produced by aperture variation, and these constitute the answer to queries which arise in everyday practice in the studio or field. But a full examination of the effect of aperture changes involves the study of lens aberrations, for a brief account of which the article in the Appendix should be studied, for the close study of lens aberrations is beyond the purpose of this book. The process operator has to deal with the instruments provided by the optician who applies his knowledge in the science—and the art—of lens making. He seeks to cure as far as may be, to sacrifice in one direction when necessary in order to gain in another—such constitutes the art—and in the main he succeeds in reducing the effect of the aberrations to a negligible stage. The products are wonderful and should be appreciated.

MOUNTINGS OF LENSES

It is important that the combinations of the lens be held rigidly, for their position in relation to one another determines whether or not the corrections will be effective. A lens depends in the first instance upon complicated and accurate calculations, and the figures of value must be adhered to in the instrument. The photographer should never take a lens apart even to the extent that he could do, which, very fortunately, is very small.

The mount consists of a cast tube to which a projecting hood is often attached, and this may be detachable, though to-day any hood that is present is generally an extension of the metal cell. At the back of the mount there is a thread to permit the mount to be screwed into a flange which can be attached to the camera front or "lens board." The different parts of the mount are shown in Figs. 20 and 20A.

Generally the metal used is hard brass, but aluminium and its alloys have been used for small lenses. This has been in many ways a mistake for weight is only of moment with the larger lenses and these are seldom carried about.

Moreover, the aluminum mounts were seldom satisfactory, corrosion being an unpleasant feature with some of the alloys, and another marked drawback is the tendency of the threads in some cases to wear.

In the case of some modern high-grade lenses to secure accuracy stainless steel has been selected for all parts of the mounting, and owing to the sensitive nature of the lenses it has been found necessary to secure the elements by springs on their seatings.

Lenses are attached to cameras by means of metal flanges, and when several lenses are used in a camera the flanges of the largest are fitted to the lens board and smaller lenses are attached by means of metal adapting

rings. These (as well as lens caps) have now been for many years fully standardized.

SOME POPULAR LENSES

In Figs. 20 and 20A are shown two lenses of the well-known "Cooke" type, which are largely employed in process houses. In each case one portion of the mount has been removed to show the optical construction.

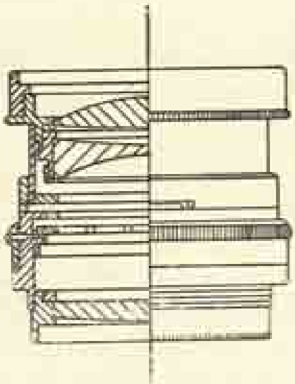


FIG. 20. THE COOKE LENS—SERIES VB

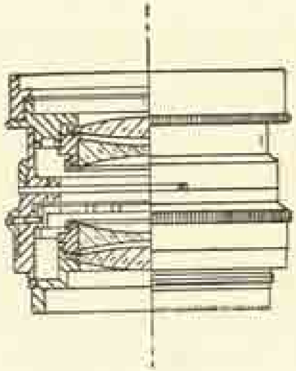


FIG. 20A. THE COOKE LENS—SERIES IX

The lens Series VB is a triplet comprising a double convex collective and a double concave dispersive lens in front of the diaphragm, and a weaker double convex collective lens behind the diaphragm. The lenses are simple uncemented elements, the collective being of dense barium crown and the dispersive of light flint.

The lens is corrected for a field of about 45°. The chromatic correction is such that, when focussed visually, the copy, illuminated by arc light, will be in focus on the photographic plate.

Owing to the "secondary spectrum" present with lenses made of the usual types of glass, the image through a red filter will focus slightly long, and that through a

blue or green filter slightly short, of the visual focus. It is for this reason that for three-colour work the Series IX has been designed to bring the foci through the red, green, and blue filters much closer together, and therefore the component images much more equal in size.

The construction is that of four simple uncemented lenses, those on the outside being of double convex, and therefore collective, of dense barium crown, and those on the inside double concave, and therefore dispersive, of

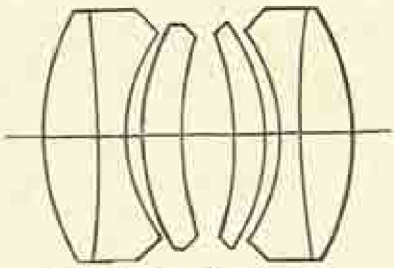


FIG. 21 ROSS PROCESS LENS

special telescope flint, which reduces the "secondary spectrum."

Series IX is symmetrical, which has the advantage that the lens need not be reversed when enlarging, whereas with the Series VB the front of the lens should always be toward the longer conjugate, or the larger of the two—image or object.

The field of the Series IX is 45°–48°.

Messrs. Ross have recently introduced a new type of lens for the process studio. The optical elements are six in number and are practically as shown in Fig. 21, and the glass-air surfaces are "bloomed" (see page 122). The mount shown in Fig. 21A embodies a number of departures, especially the large iris scale. In addition to the iris, provision is made for Waterhouses diaphragms which can be made of different shapes, and these can be rotated through a definite angle. Provision is also made

for colour filters. This lens is provided in different apertures and in different principal focal distances—

F. 10	9½	13	18	21	25	inches
F. 12·5	30	31	42	48	-	"

The resolving power of these lenses is high, which makes them valuable for copying fine line drawings.

With respect to the optical construction of this lens the patent specification B.P. 592,144 (1946) says: "In

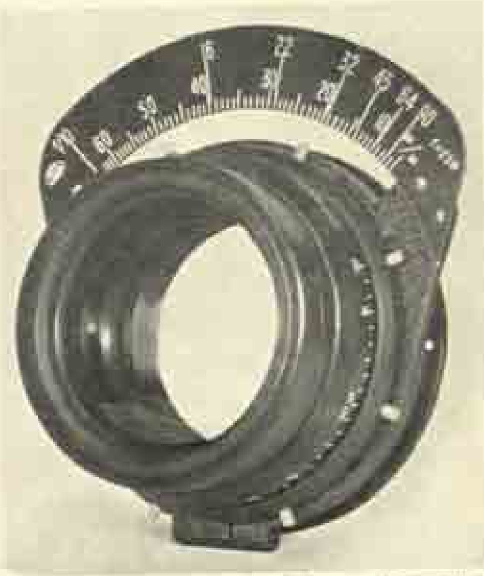


FIG. 21A. "BLOOMED." THE OPTICAL ELEMENTS ARE ALMOST INVISIBLE

carrying the invention into effect according to one form the objective consists of six individual lenses, three on each side of the diaphragm. Each combination on the two sides of the diaphragm comprises a positive meniscus lens and a doublet formed of a double convex lens and a double concave lens. In each combination the double concave lens lies towards the diaphragm and is cemented to the double convex lens, the power of the cemented

surface being collective, whilst the meniscus lens is disposed adjacent to the double concave lens with its concave surface towards the diaphragm."

TYPES OF CAMERA UNIT

In Fig. 16 is shown a photograph of the complete camera unit (referred to previously) of one of the best and most recent types of apparatus for photo-mechanical negative making.

This type of apparatus is extremely compact, but it is not the only one employed. In some studios which are on the ground floor of a building fortunately situated with respect to the absence of vibration, the camera and easel are mounted upon separate stands which run on wheels in sunken "railway lines," and this enables both camera and easel to be moved about by a system of junctions in the railway lines as circumstances require. In some map-making establishments, where very large negatives are so frequently made, the camera is replaced by a room which contains an easel to hold the plates instead of a dark slide, and the whole operation of plate preparation is conducted in the camera room. For details of such a system the student is referred to an article by Douglas, "Photo-reproduction Methods and Processes, Survey of Egypt." (See *British Journal of Photography*, Vol. LXVII, 1920, page 511.)

The type of camera room described is also employed by the establishments which set themselves out to make large negatives for photolithography, apart from those required for map making. A modification has been constructed by Messrs. Hunter-Penrose which has the advantage of an external body of process camera form. The back of the camera fits up against the wall of the room inside of which is the sensitive plate holder. There is fitted a travelling copyholder which takes the form of the

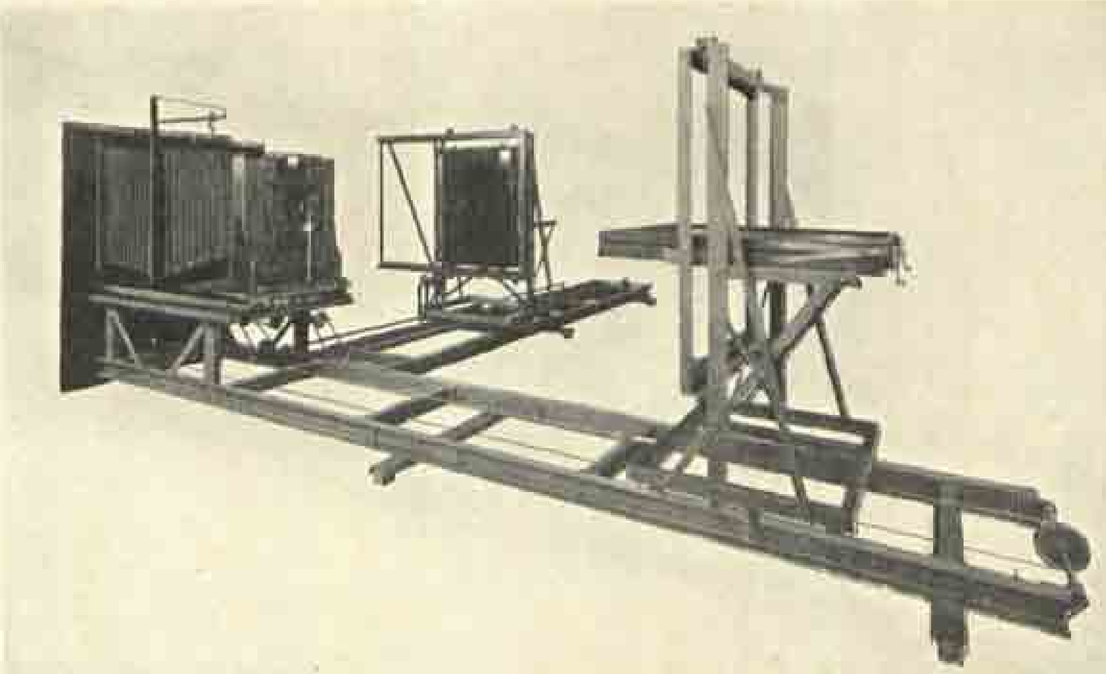


FIG. 22. DARKROOM TYPE CAMERA UNIT WITH SPRING-BACK COPYHOLDER, FOR WORK IN DIRECT AND PRISM POSITIONS (HUNTER-PENROSE)

well-known glass-fronted pressure frame holder. This form is valuable since with it the drawing on manuscript can be made quite flat. Fig. 22 shows the general arrangement of the external system. In the particular case provision is made for making reversed negatives by means of the prism by having another copy board on runners at right angles to the main pair. A holder for transparencies

FIG. 23. VERTICAL AUTOMATIC FOCUSSING PROCESS CAMERA (PRISM TYPE), WITH ARC LAMP EQUIPMENT (HUNTER-PENROSE)

may be provided to take the place of the copy board. By a system of cords and pulleys both copy boards can be adjusted for distance from the inside of the room. To prevent vibration, shock absorbers are provided and the girders come close to the floor.

Further to these, vertical cameras—direct or prism—with or without automatic focussing device, are employed, and these have special value, especially where space is important.

It has become the practice, in order to facilitate work, to adapt to the ordinary camera system a scaling device so that lens to copy board and focussing screen to lens can be adjusted by simple measurement for a predetermined size of image.

The camera represented in Fig. 23 is a complete unit. It is suitable for screen and continuous-tone negative making up to 15 in. × 15 in. The camera back is fitted with a circular ruled screen of sight size 15 in. diameter. This screen can be used for colour negatives at any screen angle up to 11 in. × 9 in. in size. The image range permitted with this apparatus is from $\frac{1}{8}$ scale reduction to $1\frac{1}{2}$ diameters enlargement. The focussing system is automatic with accuracy to a predetermined scale. The lens (an Apotal of 30 cm. principal focal distance) is fitted with a suitable reversing prism. There is a radial diaphragm indicator and an internal lens shutter operated from the back of the camera.

The copy holder is the face-up spring-back book pattern type which can be moved by hand wheels at the back of the camera in four directions for adjustment of the image on the focussing screen.

When required, this apparatus is fitted with a transparency holder with independent illuminant for copying by transmitted light. The arc lamps are mounted on arms which are automatically adjusted with the copy holder.

Vertical cameras are particularly valuable when space is limited. In addition to their normal use for copying, vertical cameras have considerable value for the photography of certain aspects of small objects in relief, as, for example, jewellery and other ornaments, coins and medals (direct or from their plastic casts) for catalogue illustration, natural history objects, and many other small articles where *arrangement* is of importance. The display

of these items is very much easier upon a horizontal surface than upon a vertical surface. Moreover, the lighting (which is often both from above and below) is more readily controlled.

In some forms of the illustration process, negatives made without any idea of their being used in the process may be employed if they are of the correct size and have the proper range of contrast necessary for the particular process; but frequently the demands of the matrix process are such that an original negative must be reproduced of a different character to satisfy requirements. It may be said, however, once and for all, that in photo-mechanical illustration processes, as in pure photography, the quality of the final result depends very largely upon the quality of the negative. Considerable as are the powers possessed by the skilful photographer for modification, there is no questioning the old dictum "get it in the negative," where excellence of result is the criterion of value. Neglect of this wise advice always leads to loss of time and consequently to an increase in the cost of production.

THE PREPARATION OF THE MATRIX OR PRINTING SURFACE

Having now considered the different aspects of the sensitive surface and the process of negative making, we come to the preparation of the matrix.

Whatever be the nature of the final matrix, its production depends primarily upon a change in the solubility of certain bodies, and it is to this question of a change in solubility that the student's attention is now directed.

THE PROBLEM OF "SOLUTION"

What is the nature of a "solution," and what is meant by *solubility* and *insolubility*? A solution is an intimate or homogeneous mixture of one substance in another. There may be a solution of a gas in a liquid, a liquid in a

liquid, a solid in a liquid, or a solid in a solid. In all these cases, given suitable bodies, solutions can be formed. To the one there is given the name *solvent*, and to the other *solute*. Thus, in the intimate mixture formed by dissolving sugar in water, the dissolved substance—the sugar—is the *solute* whilst the water is the *solvent*.

In modern photo-mechanical processes we are concerned with one solvent, viz. water.

Let us for the purpose of explanation consider the behaviour of water towards two simple substances, common salt (sodium chloride) and plaster of Paris (calcium sulphate), both of which we introduce into a relatively large volume of pure water. On stirring the mixture, the salt quickly disappears, forming a perfectly transparent mixture, actually colourless. On stirring the liquid mixture of plaster of Paris and water, an apparently uniform milky liquid is produced, but on allowing this mixture to stand, the liquid quickly becomes clearer, and, finally, if sufficient time be given, the water becomes quite clear, the white particles of the plaster falling to the bottom. If now the liquid be stirred, the phenomenon repeats itself, and if some of the clear liquid be suitably examined it will be found to contain no calcium sulphate. Actually, however, careful tests would show that a trace had passed into solution, because there is no substance absolutely unaffected by water. We say that the common salt had dissolved, had passed into solution, that it was *soluble* in water, whilst essentially none of these things had happened to the plaster of Paris. We say that it was nearly *insoluble*. So from the standpoint of the behaviour of water we say that the plaster was *insoluble*, but that with respect to its own behaviour it did form a *suspension* in the water. Now between a body dissolved and a body *suspended* there is one great difference. Let us imagine that the common salt solution and the plaster of

Paris suspension be placed in two tall glass cylinders. After a brief interval a great difference in appearance will be observed in the cylinder containing the plaster, but no difference will be noted in the salt solution. The former quickly clears, leaving in the upper layers practically only the most minute particles, all of which eventually settle. A careful test of the different layers of the salt solution would reveal no difference in the composition. We therefore say that the composition is *homogeneous*, whilst at any given interval the composition of the different layers in the liquid in the cylinder containing plaster and water would differ, and this difference would persist until the whole of the particles of the plaster had fallen to the bottom. Prior to this the layers of liquid would differ, and the whole contents would be *non*-homogeneous; but whatever be the lapse of time, the common salt solution would remain the same.

Now, there are different kinds of solution, and to this difference the student's attention is directed.

If we dissolve some common salt, some sugar, and some sodium carbonate separately in water, we obtain perfectly clear solutions—ordinary *solutions*. Here, it may be explained, the particles are suspended and move about in the water, but they are so small (less than $5\mu\mu$) ($1\mu = \frac{1}{1000}$ of a millimetre and $1\mu\mu = \frac{1}{1000} \times \frac{1}{1000}$ of a millimetre) that they cannot be seen by any ordinary magnifying arrangement. These particles continue to move about, they cannot be seen, and they do not settle out. It is only when they are above $250\mu\mu$ that they can be observed by the microscope. If we take some china clay (the fine white material from which porcelain is made), mix it into a creamy mass with water, and then pour this thick liquid into a large volume of water, a turbid mixture results, and in time the particles settle (when larger than

$100\mu\mu$) whilst the water above the sediment is clear. It behaves as did the plaster of Paris, and is merely taken as another example of the same phenomenon—the particles form in the water a *suspension*, and the body so suspended is called a *suspensoid*. It is a case, primarily, of the size of the particles. Now between the solution and the suspension exist many intermediate stages, and of these the *colloidal* state is one. In the case of a colloidal solution, the particles are larger ($5\mu\mu$–$100\mu\mu$) than in a true solution and smaller than in a suspension, but these particular colloidal solutions—which may exist in solid or liquid form—possess valuable properties and are of wide application, for many important industries depend upon the attainment of the colloidal condition, the dry plate industry, for example. Milk is a colloidal solution of butter fat; the rubber as it flows from the tree, the *latex*, is a colloidal solution; white of egg is a colloidal solution. There is a certain property of colloidal solutions which differentiates them from ordinary true or non-colloidal solutions. If we take starch and boil it in water we obtain a solution which is colloidal. If we mix with that some common salt solution, we shall have an ordinary solution and a colloidal solution together. Now, if we pour some of this combined solution into a clean grease-free bladder—an animal membrane—and then suspend the filled bladder in clean water, the particles of sodium chloride will pass through the membrane, but the particles of starch will not. It was Thomas Graham who first discovered this (1861), and he termed bodies that would, when in solution, pass through an animal membrane *crystalloids*, and bodies that would not pass *colloids*. Whether they pass through the membrane or remain in the bladder is purely a question of the size of their molecules. In this case the fine particles of the common salt freely pass through the membrane into the surrounding water, whilst the

larger colloidal particles do not pass but remain within the bladder.

COLLOIDAL BODIES USED IN THE PHOTO-MECHANICAL PROCESSES

In the printing industry we employ many typical and important colloids. In photo-mechanical photography we may say that all the processes depend upon colloids, and it is desirable that printers should have at least a speaking acquaintance with the more important substances.

If we speak of a colloid we speak of a body which does not form a true solution; it behaves, that is to say, differently from the way in which a crystalloid behaves, for example, a solution of common salt as compared with a "solution" of glue. As stated, all bodies that, when in solution, will not pass through an animal membrane, are termed *colloids*, although in other respects they may be quite different, as, for example, a solution of glue and a solution of gold in the form of "purple of Cassius," both of which will not pass through an animal membrane. It is a question of the size and condition of the particle in solution. For example, particles in the colloidal condition bear either a positive or a negative electrical charge and they have certain limits of size, between $5\mu\mu$–$100\mu\mu$. The old distinction of colloid and crystalloid has been broken down since it has been found possible to prepare bodies, formerly classed as crystalloids, in the colloidal condition. We are concerned with two things, the influence of the *colloidal condition* as in photography, where the dry plate is largely a product of such state, and the use of certain bodies which are colloids, and we must not confuse the two things. It has been observed that the matter is sometimes put as if all colloids could be used by the photo-mechanical worker, and against any such supposition the student must be on his guard. Important bodies used are colloids, but not all colloids can be used.

The "colloids" we employ are—

Starch	Transfer Papers
Gum Arabic	Lithography
Albumen	Photo-engraving and Photo-lithography
Gelatine	Photography and Photo-engraving
Gelatose (used in the form of fish glue).	Photo-engraving

If we regard as the most important that which cannot be substituted, then gum arabic and the gelatines (including gelatose) are the chief bodies, and of these the gelatines are the more necessary.

In photo-mechanical processes we are concerned with the behaviour of certain bodies under particular circumstances. These bodies are gelatine, gelatose (as fish glue), and albumen (white of egg), which are used in conjunction with alkali bichromates, and this fact is expressed often by saying that we employ "colloids in conjunction with alkali bichromates." But while this is true in intension, it is not true in extension, for since the processes were introduced, the term "colloid" has been considerably enlarged so that it is no longer true to suggest—as might be done—that any colloid could be used, because such is not the case. What we must understand is that the bodies *we do use* are colloids.

Coming now to the application, we will take, in the first instance, gelatine and an alkali bichromate. It is not correct, as sometimes is done, to say *alkaline* bichromate, because the bichromates have not an alkaline reaction. A bichromate is a compound of chromic acid and a base, and as the base we use some of the metals known as the alkali metals, thus, potassium, sodium, and the radical ammonium, which behaves as a metal. It is a property

of a mixture of gelatine, gelatose, or albumen to form bodies which, under certain conditions, viz. when in an ordinarily "dry" state, are sensitive to light, and the change which occurs, and upon which nearly the whole of our matrix-making processes depend, is that before the action of light they are *soluble* in water, whilst they become by the action of light *insoluble* in water. This is the simple principle to which the student's attention will now be directed.

The substance gelatine—of which an inferior form is ordinary *glue*—does not exist in nature, but is formed from certain naturally-occurring bodies—animal tissues (hardening and non-hardening), skin, sinews, bones—by the action of hot water, by what is termed a process of "hydrolysis," or "hydrolytic cleavage" (see Appendix, "Hydrolysis"), which is a chemical change or decomposition which is effected with the addition of the elements of water, viz. oxygen and hydrogen. If, for example, a piece of calf-skin, dehaired and defatted, be digested in hot water for a sufficient time, the substance produced by the change—gelatine—passes into solution. If this solution be now filtered and allowed to stand until quite cold, it will change from the liquid condition to the semi-solid, the "gel" state, provided that there be sufficient gelatine present (3 per cent to 5 per cent). If this "gel" be allowed to form in thin layers and then be dried, it will form a clear, transparent mass of solid gelatine. If properly prepared from suitable clean material, gelatine is a neutral transparent body without taste or smell. Under ordinary conditions it contains from 14 per cent to 16 per cent of water, and in clean dry air is perfectly stable. In a closely confined space it is not quite stable, being liable to the formation of a mould, especially in impure and unclean air, and decomposition sets in. It is not a perfectly simple entity but a complex substance, showing

in different specimens considerable variation, though for the purpose of this discussion it may be regarded as one substance.

If, during the process of manufacture—the digestion—the operation be not carefully controlled, a further cleavage takes place and there is produced "gelatose;" and because the process of cleavage is a continuous one, all samples of gelatine contain variable quantities of gelatose. In certain cases this process of cleavage is actually allowed to proceed far beyond the gelatine stage, and a gelatose is definitely produced. This takes place in the process of the manufacture of "fish glue," which is produced from fish-skins and bones. This body is very largely used in the photo-mechanical processes, and the outstanding difference between the resulting products is that while the solution of gelatine will form a "gel," the solution of gelatose forms a thick and viscous liquid depending upon the concentration, and the gelatine is then said to have passed into the "continuously soluble" condition. If the process of cleavage be carried still further, "gelatone" is formed, and this body is of no value for our purpose—indeed, its presence is a distinct drawback.

THE PROPERTIES OF GELATINE

If a piece of gelatine be placed in *cold* water it does not dissolve. Water is absorbed in considerable amount, the gelatine swelling in the process. If, now, the temperature of the water be raised to a little above blood heat, the swollen gelatine dissolves to form—if it be good gelatine—a *clear* solution and a *colloidal* solution. If the amount of gelatine dissolved be equal to between 3 per cent and 5 per cent, depending upon its quality (the proportion of contained gelatose being *one* of the determinants), then upon cooling, the gelatine solution will "gel." On the temperature being raised again to about blood heat a liquid

once more results, and this alternate cooling, setting, and re-liquefying may be carried on until a stage is reached when the "gelling" will no longer take place. If, instead of plain water, we employ a solution of a pure alkali bichromate, the solution will be absorbed, and if the gelatine is removed and dried in the absence of light, there will result a *clear* yellow mass (provided the concentration of the bichromate solution has not been too high, but semi-opaque if it has been so), which will be a solid solution of the alkali bichromate in the gelatine. If, now, the mass be placed in plain cold water, the bichromate will diffuse out, and on the temperature of the water being raised the gelatine will dissolve. This shows that the mere presence of the bichromate does not change the property of the warm water to dissolve the gelatine—a fact of great importance. If, however, we take some of the dried bichromated gelatine and expose it to daylight, a change takes place; the colour changes from a bright yellow to a dull orange. Let us assume that we have allowed the change to proceed to completion. We now place the mass in cold water and we notice that very much less bichromate diffuses out into the water, the reason for this being that a large quantity of the bichromate has been used up to form a compound of a complex character with the gelatine. We notice that the gelatine swells very slightly, and that if we touch the surface it feels hard and has lost entirely its "sticky" character. On the temperature of the water being raised to a point even far higher than we did in the previous case, the gelatine will not dissolve, so that we say that the gelatine has lost its power of swelling and that it has become insoluble in hot water. If the exposure had been less than the time indicated, it would have been found that a portion only of the gelatine had been rendered insoluble and the remainder would have passed into solution. The insoluble gelatine produced is proportionate to the amount of light

received (actually, time of exposure × intensity of light), a fact of considerable importance.

If, instead of taking gelatine, we take gelatose or albumen, the effect will be the same; both will, when mixed with an alkali bichromate and in the *dry* state, yield sensitive substances, substances which will resist, after sufficient exposure to light, the action of hot water, because they have been rendered *insoluble* in that liquid. *Gelatone*, however, does not form an insoluble body when exposed with an alkali bichromate.

These bodies furnish the majority of resist images but not exclusively. Resists are obtained with a resin in conjunction with an alkali bichromate or chromate. This has given rise to a useful process termed "cold enamel," or "cold top." The light insolubilized resin forms the resist. The process is of special value for relief plates on zinc.

The processes in which resin is used are frequently referred to as cold top or cold enamel: They are largely used in the U.S.A., and the present writer saw it employed in Germany 20 years ago.

An interesting contribution on the subject is that made by C. D. Hallam and R. S. Cox in "Cold Enamel" (*Photo-Engraver's Monthly*, June, 1939). Here shellac in aqueous ammonia is used with ammonium bichromate as the sensitizer. The metal is coated in the usual way and exposed, when it would appear that the film is more sensitive than that of bichromated fish glue. The image is developed with methylated alcohol and etched in the usual manner. Since there is no strong heating the zinc retains its original character.

The use of resin later attracted the attention of Smethurst, who investigated its behaviour as a resist and gave the results of his detailed experiments in a series of articles (*Photo-Engraver's Monthly*, January, pp. 5–7,

February, pp. 37–39, and October, pp. 254–255, 1942). It appears from Smethurst's work that the *kind* of resin is very important and to this ingredient as well as to the other agents used the author pays particular attention and gives a working formula with precise details of the method of use in the final article of the series.

Smethurst sums up and gives his views as the result of working the process of resin printing. Later still, the subject was to prove of interest to Erich Loening of the Kodak Laboratory, Harrow. Finding the process of Smethurst the most reliable of any employed he still felt that the process was not perfected and was far from satisfied with the raw material, and proceeded to investigate the different kinds of resin as to suitability. Loening is of the opinion that the irregularities found can be more or less overcome by a controlled hydrolysis by which a more reliable final solution can be prepared. The process is, however, one for the manufacturer who would prepare the material for the engraver's use. (See "Notes on Cold Top Enamel" *Photo-Engraver's Monthly*, July, 1948).

Recently there has been introduced to the photo-engraving industry a new substance, polyvinyl alcohol, or P.V.A., to take the place of the classic gelatose and albumen in resist making. This body is easy to use and has several advantages, especially with zinc, since the heating of this metal in the preparation of the resist is unnecessary. Many houses are now using P.V.A. to the exclusion of gelatose and albumen.

CHAPTER VII

THE RENDERING OF LINE AND TONE BY PRINTERS' INK

In Chapter II it has been explained, very briefly, that there is a distinction between drawings, that in some drawings the forms are represented by lines and in others by patches of pigment of different intensities shading the one into the other. To the former the term "broken" tone was applied, whilst the latter were called "continuous" tone. It was further explained that in many "broken" tone drawings the lines were of uniform intensity—as in an engineering draughtsman's production—whilst in the pictorial artist's drawing this was by no means the case, for the lines were frequently of different degrees of intensity, and even the intensity in an individual line varied from one end to the other, so that this type of drawing partakes of the character of "broken tone" and "continuous tone." But the distinction remains, and it is an important distinction which the student should understand or he will not be able to appreciate the difference between processes, why certain methods are necessary, and why, so frequently, the transcripts of drawings made by the photo-mechanical worker fail to give satisfaction, inasmuch as they do not render properly the appearance of the original.

For the purpose of explanation, however, we may take as one example of the "broken" tone drawing, the line drawing of a piece of mechanism as produced for the workshop of the engineer, and an artist's drawing of a landscape in washes of black pigment upon white paper may stand as representing a drawing in "continuous" tone. Both of these are to be represented by some form

of photo-mechanical process. The artist's pen drawing, where lines represent the forms of objects but the lines are of varying intensities, may conveniently be considered later.

At the outset it is observed that the engineering drawing is of all drawings the most easy to render. Indeed, it may be said that if rigid canons are applied, it is the only case where a *facsimile* is possible. In all other cases there is some form of compromise; we accept what is an illusion for the real thing, and the greatest illusion of all is in the prints produced by the process most used, viz. the "half-tone" type-high block method.

Two problems confront the producer—the rendering of form and the rendering of the line, or of the tones in their relative intensity. The first is a matter of shape and the latter of shape and intensity. In both cases the size of the transcript may be varied—may be to any scale. In practice "any scale" must be interpreted reasonably, for with any enlargement beyond a certain scale errors would be introduced. This degree of enlargement, however, would seldom be called for, observing that the error when present is due to the optical instrument—the lens of the camera.

Truth to tone is a much more difficult matter. The sensitive surface employed in making photographic negatives is capable of rendering a certain tonal difference, a certain contrast of light and shade. It may be capable of rendering the tonal difference—the contrast—but be faulty in the rendering of intermediate gradations. Provided that the range be not too great, no difficulty is experienced, certainly so far as the range in drawings is concerned, for the maximum possible with black pigment and white paper is less than can be rendered by any sensitive material readily obtainable. So far as concerns intermediates, that problem presents little difficulty with

the materials in use. Difficulty is far more likely to be found by the careless selection of material. In all photographic copying processes there is a great difficulty in maintaining through a *series of operations* slight differences in tones, more especially the lighter tones, which tend to run together and the differences to be obliterated. This fault, however, can generally be corrected by hand-work, and no process for tonal rendering is probably as good as it might be if there has been a too rigid adherence to the automatic method, a thing not likely in any good reproduction studio of to-day. When the subject from which the transcript is to be prepared is one in nature, then difficulties may present themselves. The contrast may be within the range possible on the photographic surface, or it may be greater and to different degrees with different subjects. Now, finally, since the contrasts, whatever be the subject, are represented by pigment upon paper, which has only a limited range, it is not profitable *from the point of view of the reproducer* to consider the question of rendering contrast greater than can be finally rendered by his pigment upon his paper, since if produced in the negative it could not be rendered in the print. Very many subjects are photographically rendered by a compressed scale, and it is a matter for the taste and judgment of the photographer at which end of the scale, light or dark, the compression shall be.

In the rendering of apparently great contrast by materials which actually have a limited range, the photographer is at a decided disadvantage compared with the artist, because, whilst the former has to take the subject to some extent as he finds it, the artist, by a skilful disposition of the light and of his drawing, can *suggest* a far greater contrast than actually exists.

Returning to our line drawing, we have, in the first instance, to produce from the original a photographic

negative to the scale desired, and this scale may be varied at will. From that negative a print is made upon the sensitive surface, and, finally, that surface is converted into a form usable in the printing press. The most usual process which would be employed would be either the surface process, photo-lithography, or the relief line block. There would be no reason, save that of cost, to prevent the surface process, collotype, being employed, and, for a similar reason, that of photogravure, but in the latter case the printing upon the sensitive surface would be done by means of a positive. The processes that would be employed are described in Chapters VIII, IX, and X.

So far, the work has been quite easy and no difficulty in rendering occurs. The photo-mechanical worker has only to make his negative and surface line for line like the original, and the straightforward printing process will give replicas of the original to any number so long as the printing surface lasts. But it is quite otherwise when an attempt is made to render tone. There are certain processes where the rendering of tone is simple and straightforward, and of these the most interesting is the obsolete process of Woodburytype (see Chapter VIII), of which it may be said that no other photo-mechanical method gives a comparable result for quality of rendering. Next to this we have photogravure and after that collotype. In all other cases the effect is produced by an illusion. Since in these instances the illusion depends upon one and the same principle, it is desirable that this principle be stated and explained, and its applications given in their simple aspects and their many ramifications.

ACUITY OF VISION IN RELATION TO PICTURE-MAKING PROCESSES

All pictures produce their effect primarily by the influence which they exert upon the eye: they commence

the effect by the process of *seeing*. Now the eye is an optical instrument, and it is subject to imperfections, as are all optical instruments that have so far been constructed. Amongst the defects is one that is to us of considerable moment, viz. a lack of "resolving power" (see Appendix, "The Resolving Power, etc."). If we consider a series of black lines of perfect construction separated by white spaces, the lines and spaces becoming smaller and smaller in width, eventually a stage will be reached when the eye will be unable to differentiate between the lines and spaces; it will not be able to see the difference between the one and the other, but the two will apparently merge, and they will then produce a shade of grey. The stage when this effect will be reached will vary even with individuals with good eyesight, and there will be marked differences when these observances are compared with those of individuals having bad eyesight. The degree of fineness which the individual can detect, and the difference, is a measure of that person's "resolving power" or "visual acuity," and the distance is the "visibility distance."

When testing the resolving powers of lenses a fine cross line screen is used as the object, and critically focussed images are examined optically at different degrees of obliquity and the number of lines resolved both horizontally and vertically are given for the image. In one case of a photographic lens 225 lines per mm. were found to be the result. If, however, the resolving power of a sensitive film be desired a negative is made and examination of the negative follows. Obviously, it will be less than with the optical image and will depend upon the contrast in the subject and other things. The use of a filter, for example, will make a difference. Sandvik has shown (see page 406) that there are many factors even in the photographic manipulation which affect resolving

power, so that all the conditions should be carefully defined.

It is the custom with a leading maker of sensitive surfaces to give the resolving power from which it is seen that it varies for the emulsion from 30–40 lines per mm. for an extremely fast panchromatic emulsion to 100–120 lines per mm. for a very slow non-colour-sensitive high contrast surface.

Visual acuity varies with the hue of the light in which the object is observed. Roaf has stated that the definition with light of short wave-lengths is less accurate than with medium or long wave-lengths (Roaf, H. E., "Visual Acuity in Light of Different Colours," *Proc. Royal Soc.*, Series B, Vol. 106, No. 13744, p. 270). This appears to be in harmony with the observations of other workers which have led to the adoption of mercury vapour lamps—where the most luminous portion of the light emitted is green—for the illumination of the dials upon instruments in central electric generating stations, to mention only one instance where the figuring is fine and not easily read.

Measurements have shown that with the normal eye the minimum visibility is obtained with an element (a dot, say) of about 0·266 mm. at a distance of 100 centimetres (or 0·0105 in. at 39·37 in.), or an area the major dimension of which subtends an angle of one minute of arc or $\frac{1}{60}$ of a degree. This is for the *fovea*, which is the most sensitive spot in the retina, but for other parts of the retina the visibility is lessened. If we have this power to a high degree it is said that the resolving power is good or very good, and so forth. But for all individuals eventually a limit is reached.

The same effect is produced if a given series of lines and spaces be moved farther and farther away, so that it will be seen that it is a matter of angular magnitude, the angle subtended by the element with the pupil of the

eye. Any small element may be used to produce the same effect; for example, black dots may be employed. If a series of black dots of uniform size be placed upon white paper, the effect to the eye when the assemblage is examined at a sufficiently great distance will be that of a shade of grey, the depth or intensity of which will depend upon the proportion of black to white. This principle has been employed for many years by the illustrative artist when preparing matrices for printing, for example, by the lithographic draughtsman when making drawings upon stone or metal to simulate the effect of shading or continuous tone. It has been adopted by the photo-engraver, the novelty in the application being the method by which the continuous shading of an original is automatically translated into dot or broken tone, by means of a mechanical device termed the "ruled screen," which, when used, as it is used, produces its effect by optical causes. It should, however, be remembered that the principle of the translation is quite independent of its application—it existed before the half-tone process.

It is convenient at this stage to explain why it is in certain processes that we are not able to produce the effect of shading without this translation. Consider the conditions which obtain. Printing means the transfer of ink received by the matrix from the roller to paper or other suitable material, and the process can only transfer the ink as it rests on the matrix. The reception of this ink, the inking of the matrix, is produced by contact—in the letterpress process by the charged roller passing over the surface of the matrix. It is a surface effect. The amount of ink received by the same kind of letter in different parts of a forme of type will be the same, provided that the inking has been properly done, and any other letter, larger or smaller, will receive a supply proportionate to its area,

so that if black ink be used in the printed sheet all letters will be equally black. If the subject be a line block, then all lines, large and small, narrow and wide, will also be equally black—there is no selectivity. It is quite true that the printer, by reason of his "make-ready," by lightening the pressure, may produce some effect, but this effect really resolves itself into preventing the finer lines becoming too broad owing to the pressure he requires for other parts of the block. He cannot make a fine line a grey line—the block is not in any part selective, nor is the paper during printing. Consequently, if there is to be a grey line it must be produced *as a grey line* in the matrix.

So much for the printing. We may now approach the subject from the aspect of the block-maker. In the process of making the line block, the negative of the drawing is the first stage. Consider two lines side by side, the one black, the other grey, such effect being necessary to secure the effect to the eye desired by the artist. The negative, if true to tone, would show the black line with no deposit, but for the grey there would be a deposit, and the ground corresponding to the white would be opaque. Equally, the negative maker could probably render, were the differences not too great, both lines as clear in the negative as if they were both black in the original drawing. Assume the former case. A print upon metal is now made by exposing under the negative a piece of metal bearing on its surface a film of albumen and an alkali bichromate. In order to produce a suitable print, the coating under the line must become quite insoluble right through its thickness down to the supporting metal, otherwise it will not remain upon the surface but will wash away during the development in water. Now the minimum effective exposure to light is the exposure which just produces this effect—the firm insoluble line. But in the grey line there

is a deposit, and in consequence the exposure will not be sufficient; hence this line will vanish in the subsequent development. If the exposure be increased to compensate for the fact that the line is not clear but has a deposit, eventually the coating would be rendered insoluble and would remain. But now both lines are alike, and when the plate is etched and mounted into the form of a block, both lines will be type-high and will, in consequence, receive ink in the same way from the roller, and they will print black. So for two lines in the drawing, one black and the other grey, we have two lines in the reproduction, but they are both black and in consequence false to the original. So whichever way we approach the matter, whether from the aspect of the printer or the block-maker, the effect is the same. It is this that is the cause of much of the dissatisfaction with the line block process as a reproductive process, and if artists and printers' publishers could be brought to an appreciation of the reason, much heartburning would be avoided.

It may be said that there are technical ways of overcoming the defect whilst still employing the line block process, but they all require skill, and in consequence are expensive. The most satisfactory way is to render all the lines as if they were black and then to pass the etched plate to the engraver, who will with his graver now reduce the ink-bearing area of the light lines, so that when the block is printed an *illusion* of the effect of the original is produced; and if the work be done skilfully, the means for ensuring the end need not be noticeable to the ordinary observer. Many of the most beautiful line works which have been produced—the transcripts of celebrated artists' pen drawings printed in *Harper's* and *Scribner's* magazines—were treated in this way, and the effect was very charming. Owing to the passing away of so many of the old artistic wood engravers, who turned their attention to finishing

photo-engraved plates, this retouching, if it be of high quality, is now difficult to secure.

Matters of reproduction raise the whole question of the relation between the originator and the reproducer, between, say, the artist and the photo-engraver. Where a drawing exists and a transcript is desired, then that process should be employed which will secure the best effect in the most economical manner. But if a drawing is to be made with the ultimate object of its being reproduced, or rather rendered, by a photo-mechanical process, then the kind of drawing and the process of making the transcript should be considered as a whole—it is not the production of one man, but of several. Hence has arisen the practice of "drawing for process." Not always, however, it may be observed, is the work done with the most satisfactory results, but still with a greater approach to success than was the case when the old haphazard methods prevailed. It is not only a recognition of the most obvious things, such as the use of a white drawing material and a black ink, and the use of lines of uniform intensity, for these are the merely elementary mechanical aspects. By far the greater difficulty lies on the aesthetic side, the taste and ability to recognize that certain types of drawing "come well" in certain processes and others do not, and if general satisfaction be sought the "others which do not" should be left alone or some other medium be chosen for their presentation.

Although the rendering of an artist's drawing in line satisfactorily is an important task very little attention is given in our technical literature to the subject. We have discussions never ending on features of the rendering of tone subjects, but line renderings so far as the printed explanatory word goes are the Cinderella of the literature. But recently a thoughtful article has broken the spell of silence—"Optical Factors Involved in Facsimile

Copying," *Photo-Engraver's Monthly*, June, 1948, p. 155—and we have so far as it goes and on one aspect of the subject "the pure milk of the word." The matter, however, as the Author feels sure Mr. Smethurst would agree, does not end there by any means. The word *facsimile*, by the way, should never be used to describe the work of the photo process worker save in a very limited sense for, to be plain, such things do not occur.

The artist's line drawing contains always lines of different intensity. This is partially the way in which he gains his effects and is inherent in the method and the tools he employs. For he, like the formal "draughtsman," does not work with a ruling pen and could not do so, and to attempt it, did the pen permit, would be to rob him of some of the means for producing his effects.

But let it be granted that the lens can and will give a critically sharp image of the drawing and is used to give that advantage; we have, say, a negative that gives all the lines and white spaces in the darks correctly. What then? The negative is only a means to an end. Consider the process of making the print on metal for the resist and the etching thereof. Will the advantage persist? No. Whatever process be used there will be a falling off.

Mr. Smethurst pays attention to the means of production of a sharp image and notes now in practice how difficult it is to obtain a really sharp image and wisely advises focussing in the dark slide. Many years ago Piazzi Smyth, wishing to make sharp negatives of fine line spectra, found he could only do so by having recourse to several trials of positives about the focal point and then picking the best result. But granted that Mr. Smethurst be satisfied, he is only part of the way through. Some lines are wider than others, and this width means that many of the very fine white spaces in the darks are filled in. Now we start with a line negative in which

something is lost and letting correction be made as far as possible by this ingenious masking method proposed we seek to produce a print on metal. Here there is no half-way house. If we print sufficiently we print all the lines, if not we miss some of them altogether. If the former, then all the lines in the final type-high block will print of equal intensity; if not, some are lost and we are back at the old falsity. The Author thinks the only way to produce *truth* would be to print on a *fine* grain collotype plate and to ask a very skilful hand press printer to proof it.

In this Author's opinion, to expect a perfect translation of the artist's work, say that of the great pen artists' work, their fine detail in nervous line, is to expect more than is really practicable. But, to be fair, some artists are really fortunate and the rendering of Mr. Hauslip Fletcher's drawings in the *Sunday Times*, in a newspaper mark you, are very good. With careful negative making and printing on metal etching and, if necessary, some hand engraving the renderings can be made to be good.

A difficulty when we seek appreciation is that judgment does not rest upon the final product from the press, upon the engraver's and the printer's work. Is it good absolutely, is it tasteful and beautiful? Then let us be satisfied and not try "to snatch a grace beyond the reach of art." But many artists want facsimiles of line and tone with no other man's handiwork, and in the Author's opinion this is to expect more than is really practicable. He feels that if a series of fine pen drawings and their renderings by the process engraver and printer were side by side and subjected to critical comparison, many judges would agree. But nothing that has here been said detracts in any way from the value of Mr. Smethurst's paper. He deserves all praise, and it is to be hoped that he will continue to interest himself in this important subject.

Reverting to the fact that it is not practicable to render directly gradations of tone as they exist in the original by means of the line type-high printing process, we may say that the same arguments apply to the ordinary lithographic process. The stone is not selective with respect to the ink taken from the roller, and with regard to the negative and the process of printing on the stone or metal, or by transfer, the conditions hold as held for the type-high process. It is only by means of a translation of the continuous tones into broken tones, which will simulate the appearance of the continuous tone, that it is possible to produce copies of drawings in shading by means of the type-high block or the surface process of lithography. This translation is effected by placing in front of the sensitive plate in the camera during the making of the negative, at a distance determined by the circumstances, what is known as a "regular cross-line screen," or a similar "screen" with "irregular grain." To the rendering so produced the name of "half-tone" is given.

The first person to employ this term was F. E. Ives, and it was given to the work produced by the use of a mechanical method worked out by Ives himself, so that the word "half-tone" was used before the introduction of the optical screen process.[1] The credit for the origination of the idea of using any form of screen for the purpose of breaking up the continuous tones of a photograph is sometimes assigned to Fox Talbot, but while this is true in a certain sense, it is somewhat misleading if used in any

[1] This translation by means of the screen is also employed for drawings in line where the lines are not of equal intensity, and for pencil drawings. Such line transcripts are not by any means wholly satisfactory by reason that the whites are rendered not as white, but with a tint, owing to the fact that there is a dot all over the area. This can, however, be removed by a process of stopping out the lines and continuing the etching until the ground dot is removed. For ordinary work, when well done, it suffices, but it must be recognized that to maintain truth to the original is a very difficult matter, and so perfect fidelity to the original must not always be expected.

account of what is known as the "half-tone principle" or "half-tone process." Fox Talbot sought to produce the grain or cellular structure in a photogravure plate—the necessity for which is fully explained in Chapter VIII—and for this purpose suggested in his patent of 29th October, 1852, the use of crape or gauze, which he placed between the positive and the bichromated gelatine during exposure, but when speaking of this crape or gauze, he says: "It would be proper to fabricate a much finer material and to employ five or six thicknesses of it *or else to cover a sheet of glass in any convenient manner with an innumerable quantity of fine lines or else with dots and specks, which must be opaque and distinct from each other.*" But while we have the screen suggested, its use was not proposed for the *translation* of continuous tone into broken tone, nor was it then used in any way comparable with modern practice in the "half-tone" process. It is, however, interesting to note as an example of Fox Talbot's prescience that the modern practice for producing the cellular structure in photogravure matrices is in accord with his suggestions made in 1852.[1]

Fox Talbot's idea to use a ruled screen was followed by suggestions made in a paper by C. J. Burnett in March, 1858, and read to the Edinburgh Optical Society (see Abstract, *Photographic Journal*, 11th December, 1858), but the first practical proposal for the use of a ruled screen in the camera was made by E. J. Bullock, who took out a patent in 1865. The idea was to use the negatives obtained for the purpose of making photo-lithographic transfers, and he and his brother appear to have sold photo-lithographic transfer paper for use by others. Messrs. Bullock used a single-line screen, and are

[1] See A. J. Bull, "The Beginnings of Photogravure" (*Penrose Annual*, Vol. XL, 1938, pp. 102–104).

supposed—but without any evidence in the patent specification—to have turned the screen through an angle of 45° once during the exposure of the sensitive plate to secure the cross-line effect.

A further development was made by J. W. Swan (afterwards Sir J. W. Swan), a name rightly esteemed in photographic circles, who, in 1879, patented a method for the use of a single-line screen placed in front of the sensitive plate in the camera during exposure. Equally, the screen could be used in contact with a transparency during its copying or during the process of printing, by putting the screen—produced on a film—between the negative and the sensitive printing surface. When in the camera, the screen could be moved (rotated) periodically during the exposure. As well as suggesting the methods for a particular process of his own, Swan proposed the use of a single-line screen and turning it during the exposure for making negatives for printing on zinc or copper coated with bichromated gelatine.

In 1882, Meisenbach proposed the use of a single-line screen, adopting Swan's principle that the screen be turned during the exposure to secure the cross-line effect. One of the earliest workers in the Meisenbach Co.s Works, at West Norwood, writing to the Author in 1926, said, "Our own made single-line screens were used inside the carrier and changed after half exposure. These carriers were made by my brothers before we left Germany, and also all the printing frames—with wedges. For each size of plate a separate carrier was necessary. Of course the dark slide had four points so that it could drop in the same position every time. Like this we worked only eighteen months, when we introduced the better method, viz. two wings inside the camera, one left, one right, holding single-line screens, each screen having lines in the reverse direction to the other. From that time no more trouble

occurred as far as 'doubling' was concerned. In 1888, I made the first double screen in *one* operation, *not* two single lines put together; photographed in a double exposure from a single engraved screen which we brought with us from Munich. The result was that each line was partially transparent and on the crossing the two partially transparent lines formed a black square dot, so this screen consisted of white squares, black crossings, and grey lines. Very first-class work resulted, and shortly after I cemented two single lines perfectly opaque. I sent the new method to my old Master, G. Meisenbach, and this caused him to install engraved single-line screens cemented together. Unfortunately, for a long time we worked with the wrong proportions." In a later letter (7th March, 1930) the foregoing information was supplemented. "For nearly two years half-tone negatives could only be made from transparencies; any original had to be taken and photographed by wet plate; transparencies made by wet plate, matt varnished and thoroughly touched up; then this transparency had to be fixed on to another glass and the single-line screen in front—(between the lines and transparency)—half the exposure—cap the lens—reverse the screen and expose again. Of course the positive had to be fixed on to another plate with gum strips and held in position in grooves, the screen was held left and right by clips. Half the exposure done, cap, release the clips, turn screen and fix screen again with clip. The changing of the screen could not interfere with the positive. Like this we worked from 1879 till 1881; from then we improved and used two screens at the back of the camera, as I told you."

In England, the Meisenbach Co. soon gained support, and the process of half-tone block-making was taken up by other engraving houses. Meanwhile, progress was being made in the United States, largely by F. E. Ives.

Disregarding his earlier processes, which were mechanical (see *Process Photogram*, 1898, pp. 56–57, and *The London Technical Education Gazette*, 1899, p. 2 *et seq.*), Ives turned his attention to the optical method with the experiences he had gained and with certain well-defined principles in his mind. In 1886 he introduced sealed cross-line screens and recommended the use of a diaphragm with a square opening in the lens. In 1888 Ives described his method of work (*Journal of the Franklin Institute*, May, 1888), and explained the optical principles involved, but the exposition was somewhat brief, and the full details of his procedure did not become known until some years later. Mr. Ives eventually came to England, and was engaged in installing his process in the studio of a new company (with Sir Joseph Swan at the head), which was called the "Swan Engraving Co." There can be little doubt that the correct method of work was first laid down by Mr. Ives, and his coming to this country marked an epoch in the technical history of half-tone photo-engraving. The interest aroused by the new productions and the rapid commercial demands caused attention to be devoted in many quarters to the production of suitable cross-line screens. The first serious attempt on a commercial scale was made by Wolfe, of Dayton, Ohio, U.S.A. Wolfe took an original plate ruled upon glass, and made contact copies upon dry collodion plates, first introducing unsealed single-line copies but later sealed copies in cross line. These screens were remarkably good compared with any previously made. But the great step forward was made by Max Levy, of Philadelphia, who, having devoted an immense amount of thought and work to the subject, issued in 1896 engraved line screens. These screens differed from any previously issued in that the lines were etched into the glass, and the etched lines were then filled with an opaque pigment. Since that time there has been

no change in the type of screen, and the Levy ruled and engraved cross-line screen has become the standard, although not by any means the only one made.

Since the introduction of the screen much has been written upon the principles of its action and the method of its use. Much that is not serious can be disregarded, however, and the classical papers are given below. To these the student who desires to be fully informed upon the theoretical aspects is referred—

"Screens for Half-tone Work," Dr. J. M. Eder (*Photographisches Correspondenz*, Vol. XXXII, p. 165; *Photographic Journal*, Vol. XIX, 1895, p. 295; *Photogram*, Vol. II, 1896, p. 53).

"The Science of Tone Rendering in Opaque Ink," A. A. K. Tallent and A. W. Dollond (*Photographic Journal*, Vol. XIX, 1895, pp. 272–284).

"The Theory of the Screen in the Photo-mechanical Process," E. Deville (*Process Photogram*, Vol. III, 1896, p. 36, *et seq.*).

"Experiments on the Half-tone Process," A. J. Bull, W. J. Smith, and E. L. Turner (*Photographic Journal*, 1917, Vol. XLI, pp. 7–14).

"Tone Rendering by Half-tone Processes" (Review), A. J. Bull (*Proceedings, Seventh Int. Cong. Photography*, 1928, pp. 374–384).

See also the Report of the important lectures delivered by F. E. Ives at the Bolt Court Technical School, London (*London Technical Education Gazette* (*L.C.C.*), Vol. V, 1899, p. 2, *et seq.*).

References to the literature on the aspects of practical work in half-tone processes are given in Chapter X.

For an understanding of the optical effect of the screen the regular cross-line screen is the simpler to follow in any explanation of the action. The cross-line screen (Fig. 24) consists of two sheets of glass cemented together by means of a transparent medium, viz. Canada balsam. Essentially, when cemented, the pair may be regarded as forming a single slab of glass. On the inner surface of each one of the pair a series of lines of uniform width have been ruled

with a diamond point on a special type of ruling machine, and between each line and the one next to it there is a clear space equal to the width of the line.[1] The lines, which at a certain stage in the process of manufacture are in intaglio, are filled in with an opaque black medium, so that there results a series of opaque lines and clear lines or spaces. The lines are ruled at an angle of 45° to the sides of the sheets of glass. On cementing together, these lines

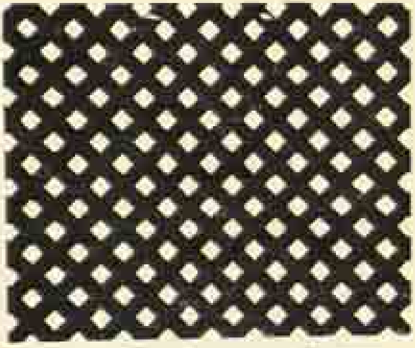


FIG. 24. THE CROSS-LINE SCREEN

cross at right angles, and when this is done the result is a regular "mesh," a series of rectangular openings perfectly transparent. It is this mesh which is supported in front of the sensitive plate in the camera during exposure. The number of lines is the "ruling" of the screen. Rulings are in general use from 60 lines to 175 lines to the linear inch, and since the 1 : 1 ratio is in use the width of line and opening can be seen. The term "pitch" is sometimes used, which means the distance between the centres of two contiguous opaque lines, opaque to opaque. Low rulings are sometimes called

[1] For an understanding of the action of the screen it is not necessary to consider the method of its manufacture. In passing, it may be said that the ratio of the width of line and clear space was not always that given, but this ratio of 1 : 1 has been found to give the best translation and is now the one generally adopted.

"coarse," high rulings "fine." Screens could be obtained in which the lines were formed by coating the glass with a "ground" and removing the "ground" by "ruling" in the machine, and the lines so ruled constituted the clear lines of the screen, whilst the ground remaining formed the opaque lines. Such screens—known as "Economic"—were much cheaper than the standard ruled and engraved screens, and are, in use, satisfactory. In the ordinary wear and tear of shop use, however, screens sometimes require separation of the components for repair purposes, and this is not practicable with the "Economic" screens, so that their purchase in some cases may result in a false economy. They are now no longer manufactured.

The finer the ruling, the better the rendering of small differences in gradation in the original—commonly called "detail"—but the surfaces (printing matrices) are not so easy to print, and better ink and, generally, smoother paper are required.

The distance of viewing at which the broken-tone image ceases to appear as broken tone but appears as continuous tone is important. The consideration of the problem does not arise in connection with prints from blocks of ordinary size as used in books and periodicals which are examined at distances comparable with the normal distance of vision. Under such conditions the dot formation is not obtrusive and is not noticed particularly, except by those having very keen eyesight. It is, however, important in connection with the production of large picture posters where the half-tone process in some form is used, especially when the picture is in one printing. The mechanical conditions of printing and the quality of paper make it easier and therefore more economical to use a large dot formation such as would be given by very coarse screens, and the pictures with these formations have greater contrast, and are therefore better for large posters

viewed at a distance, than would be the case were fine screens used. The use of screens for the direct making of negatives of huge size is not practicable, for the cost of ruling would be high, and the limited use would not make it worth while to rule them even were it a practicable task.

The problem is, that given a certain size of poster which is to be exhibited in a certain position and consequently viewed from a certain average distance by passers-by, what is the largest dot formation—to what ruling of screen does it correspond—that can be employed without the dots being obtrusive to the ordinary observer? Fishenden has considered this subject for the observer with average eyesight from the standpoint mainly of "visual acuity" (Fishenden, R. B., *Process Year Book*, 17, pp. 185–189), and gives the following table—

Screen lines per inch .	50,	40,	30,	20,	10,	5,	2.
Mean invisibility distance in inches .	40,	50,	67,	100,	200,	400,	500.

It is usual, under the circumstances, to make a small negative, from this a positive, and from the positive to make an enlarged negative on sensitive coated film or paper.[1] Under this condition an original negative for a quad-crown poster 40 in. × 30 in. (the image to fill the sheet) could be made 8 in. long with a 50-line screen and enlarged five diameters. The poster picture, if viewed at not less than 200 in. distance, would not show the dot formation but would appear as continuous tone.

Modifications of the cross-line screen have been introduced from time to time, one of the most striking of these being the "wavy-line" screen of Dargavel (1907), the object of its use being to obtain effects as near as practicable to those obtained by the wood engraver. This "wavy-line" screen was not entirely new, for a similar kind of

[1] The problems involved in enlarged "screen" negative making have been considered by F. J. Tritton (see "Photo-lithography for Posters," *Penrose Annual*, Vol. XXXIX, 1937, pp. 125–128).

mesh was used by von Egloffstein in some experiments made in the United States as early as 1865.

Other forms of screen have been proposed with a view to producing better rendering, as, for example, a square ruling with *thick* lines together with a network of finer lines which were placed along the meshes of the square ruling (Levy) or parallel to the square ruling so as to divide it into a number of smaller squares (Jacobson). In 1902 a screen with rhomboidal openings was patented in England by Schultz for which was claimed more accuracy in rendering. There is also in use at the present time, for half-tone type-high blocks for advertising purposes, a screen with vertical ruling which has attained a certain degree of popularity, and blocks are also being produced from negatives made by means of silk gauze screens.

IRREGULAR GRAIN SCREENS

An *irregular* grain screen differs only in the fact that the openings are irregular in shape and not uniform in size, though it may be said that when comparing small areas in different parts of the screen the irregularity is practically similar, that is to say, the screen when examined as a whole presents a uniform appearance. The idea underlying the irregular grain screen is that it would eliminate the geometrical form of the elements themselves and their arrangement, and that in consequence the renderings would be more pleasing; they would, in fact, be more like a rendering or translation produced by the hand of an intelligent craftsman. Actually, the renderings are equally monotonous with those produced by the regular geometrical screens. There are two types of this form of screen—very many individual screens have been introduced—the one where the openings are clear and the covered spaces are opaque, as in the regular cross-line screen, and the other where, instead of this form of

assemblage, there is a series of small lenticular transparent cavities, as in the Metzograph screen of Wheeler, which was never largely employed and has now practically gone out of use. The main objection—for there is an objection—to the use of all kinds of irregular grain screens lies in the loss of outline and gradation in transcripts made with their aid, and furthermore, the negatives are more difficult to make. An improved irregular grain screen by Erwen has been introduced, from the use of which good results have followed, particularly in photo-lithography.

The subject of the use of irregular grain screens has been very fully considered by Newton (*Process Year Book*, 14, p. 145), and by Fishenden (*Process Year Book*, 22, p. 85), and to these papers the student is referred.

Since the effect produced by any screen is due to the mesh—the glass being only a support—and the distance of the mesh from the sensitive plate, the student will find that it is simpler—the glass being liable in different screens to differ in thickness—to consider the glass as not being there. Let him think only of a very thin metal plate having the same openings as in the screen, which can be brought so close as to be in contact with the sensitive surface. Let him further regard the screen as being held in a frame which can be moved to and fro, so that the mesh may be at different distances at will, but its plane always strictly parallel to the plane of the sensitive plate, there being no lateral or vertical shift.

ACTION OF THE RULED SCREEN

There are few things in photo-mechanical work that the beginner finds so difficult to understand as the action of the ruled screen in negative making, and any real understanding will only come after careful study and experiment. It is desirable that the student should consider at first the simplest part of this work, and understand

what the screen actually *does* in the process of negative making. It has been explained that the function of the screen is to translate or convert the "continuous" or closed tones of a drawing or photograph into "broken" or "open" tones, and the "regular" cross-line screen performs this function by producing a series of circular dots of different sizes, the dots being the smallest in size in the darkest tones of the subject and becoming larger as the tones increase in brightness, until in the highest light —which may, for the sake of explanation, be white—the dots overlap, leaving cushion-shaped clear openings. The range or contrast *in the negative* is determined by difference in dot size, but finally the range in the positive or print is governed, so far as the half-tone relief process is concerned, by the subsequent process, and within considerable limits may be varied. The fact that it can be varied is an important item of value in relief block methods. But whilst the dots vary in size they must not vary unduly in opacity. This is a theoretical condition. The purpose of the negative is to produce a print on metal, and the sensitive coating, where protected during exposure to light by a dot, must be protected to that extent which will enable the uncovered part to be exposed sufficiently to become insoluble. Now the dots in the darker tones are always less opaque than those in the lighter tones, but in practice the negative maker arranges that they are sufficiently opaque — the extra opacity in the lighter tones does not matter. So, from the practical aspect, bearing in mind the reservation, we say that the dots vary in size but are equal in opacity, and they must be sufficiently opaque to enable an image to be printed in the metal.

If the mesh were placed in contact with the sensitive plate during exposure—it has been assumed that the supporting glass is not present—then the dots would be rectangular, would be equal in size, and unequal in

opacity. In practice, if the glass were not disregarded, and the screen, as it is made for use, were placed as close as possible to the plate, a similar result would follow, especially if the aperture in the lens were small. A negative of this character would be useless. This would be strictly true were the plate in contact with a grainless sensitive film. But such a film does not exist in practice, and both the sensitive surfaces used, wet collodion and dry plate films, are turbid and therefore scatter light—irradiate. In consequence, by irradiation there would be a variation in dot size, for in the lighter tones the dots would be larger than the screen openings. This fact has been known in the early days of the process to lead people astray, for they imagined that translation of tone could be effected by placing the screen in contact, whereas any variation in size produced in that way is purely adventitious and has nothing to do with translation. There would be no variation in dot size and therefore no translation or variation in tone rendering, and a print produced from such a negative would show only two tones, black and white. The appearance would be as in Fig. 25. Practically, this is a replica of the screen, while here and there are small patches, apparently running into the screen, which are the darks in the original. All the lighter tones are rendered as if they were white. Let us now consider the other extreme and place the screen at a considerable distance. The negative will show no trace—the screen might not be there, but actually by cutting down the light we have reduced the effect for a given exposure. Inasmuch as the area for the transmission of light is in the usual cross-line screen with the standard ratio 1 : 1, only one-fourth of the light is transmitted. The screen would act as a piece of neutral tinted grey glass transmitting only one-fourth of the light, and if we increased the exposure in this ratio, no difference—the one with, the other

without, the screen—in two successive negatives would be seen. Both negatives would be the same—they would be in "continuous" tone. In contrast with the example in Fig. 25, there is shown a rendering with the screen at the correct distance (Fig. 25A), and two renderings of the same subject with a finer screen, in one of which (Fig. 26) the

FIG. 25. EXAMPLE OF THE EFFECT PRODUCED WHEN THE SCREEN IS IN ACTUAL CONTACT WITH THE SENSITIVE PLATE DURING EXPOSURE

FIG. 25A. THE SAME SUBJECT AS IN FIG. 25 WITH THE RULED SCREEN AT THE CORRECT DISTANCE FROM THE SENSITIVE PLATE DURING EXPOSURE

screen has been removed to a slight distance, when a rendering of the gradation is given, and in the other (Fig. 26A) to a greater and the correct distance, where the rendering of the tones of the subject was found to be good.

In order to produce the necessary translation the screen must be placed at a particular distance, and that distance can be calculated. A full consideration of the whole of the theoretical aspects (for a résumé of the subject see Clerc, L. P., *Ilford Manual of Process Work*, pp. 102–112)

of the problem is somewhat complicated, and even the best practice based upon theoretical considerations accepts a simplification for the sake of convenience. The conditions which govern the distance are the size of the screen opening—this depends upon the ruling—the distance from the sensitive plate to a certain position in the lens, which, for practical purposes, may be taken as the distance of the diaphragm from the sensitive plate, frequently termed the "extension," and the relation borne by the diameter of the "effective aperture" in the lens to the extension, called the "F value" or the "conjugate angular aperture." Given these three values, the fourth or the "screen distance," the distance of the screen to the sensitive plate, can be calculated.

The simplified calculation does not take into consideration certain things that the more complete calculation would consider. For example, no notice is taken of refraction in the glass of the screen, and the nodal point of emergence would be a more correct distance than the position of the lens aperture. In practice, round stops or apertures are generally employed, and the calculation for such is complicated, so that the figure of value taken is the side of the square aperture.

The rule for the distance of the screen simply expressed is that the ratio of the screen opening to screen distance must be the same ratio as the diameter of the aperture to the distance of the sensitive plate from the aperture. In practice, what is known as the "$\frac{1}{64}$th rule" is frequently adopted, so that taking, for the sake of simplicity, a 100-line screen the opening in which would be $\frac{1}{200}$ in. (0·005 in.) with a lens aperture of $\frac{1}{64}$ of the distance of plate to aperture, the screen distance would be $\frac{1}{200} \times 64 = \frac{64}{200}$ (0·32), practically $\frac{1}{3}$ in. measured from the mesh. In actual practice, the real distance from the surface of the glass would be 0·32 in. minus the thickness of the cover glass.

Provided that it be desired to make a negative in which the translation of tone closely follows that of the original, the exposure of the sensitive plate may be made with one

FIG. 26. RULED SCREEN TOO NEAR

aperture, and that aperture may be round. But in "day-to-day" negative making, certain departures are made from this simple procedure. In the highest lights of the negative—the part rendering a "white"—the completed

negative ready for the engraver's printing room (the place where the resist on metal is prepared) should show isolated dots, or, to use negative makers' parlance, "the

FIG. 26A. RULED SCREEN AT CORRECT DISTANCE

high light must be well joined," so that there are isolated dots of resist on the metal, for, if not, the etcher will have difficulty in producing a plate where the high light tone is "smooth." If the negative is not joined in the high

lights, then the tones will print in "cross line," and that is a real drawback in the etching operation. Further to this, the dot must be of a sufficiently large size to remain a dot, type-high, whilst the plate is being etched to printing depth. If the dot be too small it will etch away by "undercutting" (see page 297) before the necessary depth is obtained. It is found that if a square stop be employed of suitable size, instead of a round stop, the slight extension at the corners allows of a join whilst maintaining a larger clear space and consequently a larger resist dot on the metal. "Much, frequently, would have more," and, since to some, negative making is to "join the lights and leave a pin-point in the shadows," the introduction of squared stops with extended corners came into use. The abuse of this type of stop causes—with the excessive "flashing" exposure for the shadows—a lack of gradation in the middle tones, the restoration of which throws a totally unnecessary burden on the "fine etcher."

With difficult copies, very dark shadows, or originals of a non-actinic colour—in reltaion to the spectral sensitiveness of the surface used in the camera—there is a difficulty in obtaining a shadow dot sufficiently well exposed to yield the necessary printing density. To remedy this a "flashing" exposure is given. The original is covered with a sheet of white paper and a brief exposure is given in the first instance, a stop smaller than the main exposure stop being used, though this is not necessary. If the image on the focussing screen of the camera be examined with a magnifying eyepiece when the screen is set at the correct position, the part of the plate opposite the centre of a screen opening will be found to be bright and the luminosity will fade away towards the margin, so that a series of dots of different sizes would be produced by a series of different exposures. By giving a brief exposure, only the light opposite the centre of the opening is registered and

hence a small dot. If the "flashing exposure" be made with the main exposure stop, and does not exceed 3 per cent of the main exposure, the best result follows. It is sometimes stated that the flashing exposure should be such that were there *only* the flashing exposure no effect would be seen on development of the plate, and the unguided student, who may have no knowledge of the real sequence of what happens when a sensitive surface is exposed in the camera, is considerably puzzled. Every sensitive substance has *inertia*, which means that it is unable by itself to change its condition whatever that condition may be. A sensitive substance remains unchanged so long as it is not subjected to a disturbing influence, and of possible disturbing influences we need only consider light. When energy, in the form of light, falls upon the sensitive body, it produces a changed condition, and that changed condition, in the case of the substance in a sensitive plate in the camera, shows itself upon the application of the developer, that is, if the amount of exposure, actually the quantity of light energy, has been sufficient. But if the amount of exposure has not been sufficient to bring the sensitive substance into the developable condition, then for practical purposes the exposure need not have been made. What the flashing exposure does, when properly made, is to overcome the inertia of the sensitive plate—it may, of course, do more—so as to create the most favourable condition for the main exposure to act in producing the effect desired. Therefore a great effect is produced by this main exposure because of the flashing exposure, even though the plate would have shown no effect, or practically none, had it been developed before the main exposure was given. Workers to-day deal with materials in the camera so very sensitive that questions of prior exposure of a plate to weak light for the purpose of overcoming inertia before

exposing to make the negative, and so producing a better result with the exposure possible to be given, do not arise, but the practice of this "pre-exposing" was common enough in ordinary photography in the days when wet collodion was the only negative-making process in use.

Some negative makers employ a "flashing exposure" with one stop, a "main exposure" with another, and a "join-up exposure" with a third, and this procedure is quite unnecessarily complicated. The student, reading the literature of the subject, may be rather astonished to see the diversity of shapes in stops recommended for screen negative making. Most of these are of no advantage, and many harsh things have been said as to the results of their use, but, fortunately, as Bull has pointed out, "No difference in the rendering of tone values due to the employment of stops of different shapes has yet been detected with certainty. Far more evil results from the attempts to make screen negatives with ill-chosen apertures and screen distances, when tones are falsified and distorted, than by the use of quaintly-shaped stops." ("Tone Rendering by Half-tone Processes," *loc. cit.*)

DIFFICULTIES IN SCREEN NEGATIVE MAKING

Without desiring to represent the craft of screen negative making as difficult, the Author would wish to warn the student against forming the idea that its operations can be determined by a few elementary mathematical calculations, for this is not the case. Screen distance calculations and exposure calculations are made to fit normal cases, and a normal case is one that has been defined as that which fits the calculation. Amongst the things that cause variation are the nature of the original and the spectral sensitiveness of the plate that is being used (see Chapter XI), and considerations of this kind lead the student into

what, for him, may be deep water. Every sensitive surface suffers from the defect, to a greater or less degree, of not being sufficiently sensitive to some colours in relation to others, and may have, in fact in some cases has, no sensitiveness to some colours. Consequently, in a monochrome rendering the effect will not be proportional to colour brightness. Expressed in another way, if we take the spectrum of white light and plot the relative luminosities of the different regions, then photograph the spectrum, and plot the luminosities of the different regions, the two curves will not be the same, whereas they should be. Now these differences will be greater or less according to the sensitive surface. With a wet plate and an ordinary dry plate of any degree of sensitiveness there will be a remarkable difference, but with a modern panchromatic dry plate or panchromatic collodion emulsion, the approximation will be very good. Expressed more popularly, and taking an actual case, upon a wet plate or an ordinary dry plate, blues are registered and only blues; all other colours are without effect. The question then arises, how is it that the screen negative does show some dot effect even from a brown print, to which question the reply is "that every surface reflects unchanged white light, and it is the blue in the unchanged white light that does the work." The operator faced with such a copy, and knowing the result will be poor middle tones and worse shadows, tends to force the effect by closer screen distance and longer flashing, but even this course does not exhaust all the difficulty. Every sensitive surface has inertia, and slow plates are plates with high inertia value. If the copy—even a monochrome copy—be very dark, and more especially if the illumination be not good, the light reflected from the darker tones of the copy will not produce an effect on the plate in proportion to its brightness, but low tones will be

rendered as if they were still lower in brightness. Now, this defect will be increased if the print be of a non-actinic colour, for it means that the effective light value—measured in terms of the chemical effect of the plate—is very small. It is to meet difficulties of this character that departures from calculated distances are made. Moreover, it may be taken as a truism that the best results are always produced when the illumination of the surface to be copied is high, and this, in daily practice, means large amperage arc lamps. There is, further, the fact that frequently true copies of the original are not wanted, but something that is different.

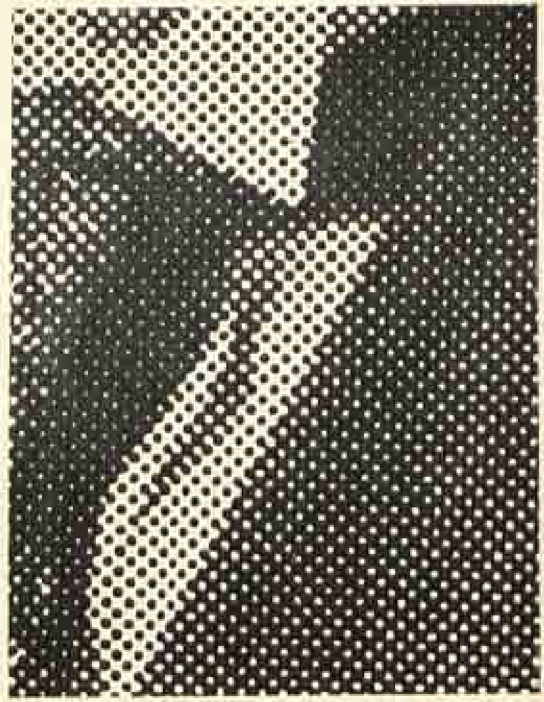
The student must, in addition, understand that the process of screen negative making is only applicable to originals with a certain range of contrast, actually to those which are represented upon flat surfaces. Screen negatives cannot in practice be made from objects in relief, because the range is too great, save in the case of a few subjects—*low* bas-relief, for example. In consequence, where relief subjects are to be rendered, an ordinary pure photograph is made, and the print from the negative becomes the original for the half-tone negative maker. This applies to *all* relief objects save those mentioned above.

The student should understand that after the plate is developed there will result in the negative a series of dots of different sizes. For reasons connected with the mechanical structure of the image, what is now to be explained will be more easily followed if we take as an example a negative made upon a wet collodion plate as it comes from the operator's hand, washed after the potassium cyanide, that is, after "fixation." In a wet plate the image is on the surface of the plate and is of a compact nature. In a dry plate the image is in the film and the particles tend to be more dispersed. The film of collodion is open and readily permeated by solutions, but in gelatine the reverse

is the case. Actually, also, the image material is in a different physical condition. The modern very thin film dry plate with reduced gelatine content approaches the wet plate in the physical character so far as it behaves towards solutions.

When the conditions of screen distance and aperture in lens have been correctly satisfied, the dots will vary in size—but will be of suitable size—and will be cone-shaped. If the screen has been too close the dots will be too small in the lights, and the section of the dot will be that of a truncated cone, a cone with the apex cut away. When the screen has been too far away the dots will be far more truncated, will be too large, will be fuzzy, and in the shadows will generally be very weak. In the lighter tones the dots may even join (see Fig. 27). When a negative receives the first examination it should be studied against a white or evenly illuminated surface for general rendering, and compared with the original, because in a screen negative where the gradations are correct, the gradations will show properly, as they do in an ordinary continuous-tone negative. Too often operators are content to examine the structure of the image—the dot formation—with a magnifying glass, and do not pay attention to the tone rendering. The negative must now be intensified and "cut," the intensification being necessary to increase the dot opacity sufficiently to enable it to be usable for printing, and "cutting" to alter the dot formation. Since the process of intensification adds to the quantity of image substance, the dot cone will be higher and the cone base will be larger. Now the cutting process is a reducing—a dissolving—process, and the effect of the solution employed is to take away the thin edges at the base so that the dot becomes smaller. At the same time it loses in height. In practice, there is generally greater opacity—which corresponds to greater height—than is required,

Negative



Print from the etched plate

FIG. 27. EXAMPLES SHOWING THE FORMATION OF THE IMAGE IN THE HALF-TONE PROCESS

Portion taken from a portrait showing part of the throat, collar, tie, and coat

so that whilst, to commence with, the dots are generally more or less too large and, in consequence, the edges of the bases of the cones approach too near each other, after reduction the fringes have gone, but there has not been a harmful loss to the opacity of that which remains. The process is essential, but its abuse is serious and leads to the practice so scornfully described as "making negatives at the sink," which means trying to retrieve a negative, bad from the first owing to faulty adjustments and exposure in the camera, by chemical operations. It is always uneconomical.

After the chemical operations are completed the negative goes forward to the resist printing room.

For the rendering of tone, for the production of the picture, the negative may be used for either the type-high block process (see Chapter X) or the surface process of photo-lithography (see Chapter IX), observing that in the latter case the negatives must be made of a different type, principally with respect to range of contrast, as compared with the former. This is due to the fact that at present the block-maker has greater power of control or correction in the block process. The student should understand that there have been several proposals for the translation of continuous tone into broken tone for the particular purpose of producing type-high printing matrices—to which only titular textual references have so far been made—by mechanical means, the earliest of which appears to be that of D. Winstanley (1866), London (see *Process Photogram*, 1895, pp. 26–27), who was followed by Charles Petit (1878), Paris (see *Bull. Soc. Fr. Photo.*, 1880, pp. 136–140, and also Ives, *London Technical Education Gazette* (*L.C.C.*), 1899, p. 2, *et seq.*) and Ives (1878), Philadelphia (*ibid.* and *Process Photogram*, 1898, pp. 56–57). Later still came N. S. Amstutz (*Process Photogram*, 1900, pp. 54–56).

For a general history of the optical processes the reader is referred to W. Gamble (*Photographic Journal*, 1878, pp. 126–134), and to the Report of the lectures delivered by Mr. F. E. Ives at the Bolt Court Technical School, in 1898, given in the *London Technical Education Gazette* (*L.C.C.*), cited above.

In the cases to which attention has now been given the translation is effected *in the negative*.

ALTERNATIVE METHODS OF TONE RENDERING

There are, however, other processes in which the translation is effected by what may be termed natural as against optical means, and by natural is meant changes which occur in the sensitive surface. In order to be able to *express* a variety of tone—a variation in the light and shade as expressed in the subject and in the ordinary or continuous-tone negative of that subject—there must be a variation in the ink-bearing area. Of two tones, for example, one brighter than the other, the part representing the brighter tone in the printing matrix must deliver less ink to the paper than the part representing the other tone. Consequently, if we can imagine a sensitive surface on the way to becoming a matrix and having at the time the two tones taken as example, which would both become type-high, for instance, if a type-high process is being considered, then something must happen to reduce the ink-bearing area before the surface *does* become the printing matrix. This is actually what does happen in one important class where the natural or automatic rendering of tone depends upon what is known as the "reticulation" of gelatine. Under certain conditions an exposed bichromated gelatine film will take on a crinkled surface (see "Surface Processes," Chapter IX), and the crinkle will vary with the intensity of the tone. Certain parts will rise and others fall in value, so that whether we

finally convert the surface to one that is type-high (Pretsch), or use the surface itself (Collotype), or pull a transfer from the surface after inking and lay this down upon stone (Papyrotint), the ink-bearing area will vary throughout the tones, and thus the necessary condition will be fulfilled.

Again, we may utilize a negative carbon (gelatine insolubilized) image to regulate the degree of depth to which a surface is etched (see "Photogravure," Chapter VIII), and in this way represent variation in tone by a variation in the *quantity* of ink delivered to paper.

The principles of the rendering of tone having been described, the student is referred to Chapters VIII, IX, and X for information as to the actual way in which the principles are applied. Since this book is not a practical manual in the sense that it gives directions as to how printing matrices should be made, but rather the principles underlying their production, should information of a workshop character be desired the reader is referred to the standard books on the different branches of the subject.

The need for some process of producing an illusion of shading by means of type-high blocks was in itself a stimulus to try any method that appeared likely to lead to success. It has already been stated in connection with lithography (see also Chapter IX) that a line drawn upon a grained surface of the stone is not continuous, for the tops of the pyramids, the upstanding "grains," alone take the lithographers' chalk; but by varying the pressure the amount deposited varies, for with a light pressure only the tip is touched, whilst if the pressure be increased the crayon coats more or less of the sides, with the result that there is produced to the eye a lighter or a darker line which appears—with a "fine" grained stone—continuous, but is really not so. This is one of the lithographic

draughtsman's methods of producing the *appearance* of shading.

Drawings such as these were frequently transferred to zinc by the process of pulling prints in transfer ink and laying them down on the metal, the image being eventually etched type-high. Such work requires very great skill in transferring and in etching, and generally it may be said that in tonal qualities the prints from these were much below those printed direct from the stone. The principle having been seen, other applications were naturally sought. Drawings could be made, and were made, upon rough papers such as "Ingres" and "Michellet," and if the crayon were properly used, the image would be broken up into irregular dots, so that, while appearing as more or less continuous tone, it was really broken tone. The drawing was then photographed, printed on metal, and etched type-high after the then manner of the line zinc engraver.

The demand for illustrations caused the introduction of a special type of board for the production of these drawings which was known as "scraper board." A scraper board was a thin board coated with a white composition which was afterwards impressed with a grain of either regular or irregular dot or line, and in some cases grain or line was printed in black ink on the coating. The term "scraper" arose from the fact that particular kinds of lancet knives are used for scraping away parts of the surface to produce effects when the drawings are made. Thus, one knife may have a series of fine regularly-disposed teeth like a saw, and by drawing this across a board impressed with a line tint, the lines become dots, whilst with a smooth-edge knife portions of the remaining dot tint can be wholly removed, so that in a drawing made on the material there may be by this simple device two textures and white; and by the addition of black pigment

we may have a fourth effect. Still further effects may be produced by drawing upon the grain of the surface. In the hands of a skilful worker who is an artist as well as being acquainted with the technique, very excellent effects may be produced. The finished drawing, which is now entirely in broken tone, though looking like shading, goes to the photo-engraver, and from it a type-high block is produced. To-day, considerable quantities of these boards are used. Many advertisement blocks are produced in this way, though they are credited with being ordinary half-tone. If a drawing is to be made for the purpose *de novo*, it is often cheaper to proceed by scraper board, from which the negative is made without the intervention of the screen, afterwards printing on metal and etching for type-high printing, than to make a half-tone block in the usual manner.

Given *transfer* scraper boards where the coating is of a special character, the drawings may equally be *transferred* to stone or metal and printed lithographically on the similar "grain" paper.[1] Those who are desirous of learning more of the technique of scraper board work are referred to the manuals cited at the end of this book.

MODIFICATIONS IN SCREEN NEGATIVE MAKING METHODS

For the making of screen negatives other than by the normal static screen system there have been many proposals, of which the following are amongst the more important. Dr. E. Albert, placing the screen and the negative together above the sensitive surface in the printing frame, fixed before these an arc lamp with a

[1] "Grain" paper is paper coated with a composition of a soluble character and then impressed with a grain so that it presents a similar surface to that of a grained stone. It formed a convenient substitute for the latter and was very largely used by lithographic draughtsmen. It was first introduced by Messrs. Maclure, Macdonald & Co., about the year 1868.

square diaphragm in front of the light. Bassani makes the cross-line screen move in its own plane with a slight circular movement. If we consider only a single aperture, we may regard this aperture as being rotated in a circle of minute radius. This system (Patent No. 222,872) is largely used in the U.S.A.

Ronald Trist produced a graduated dot screen by rotating a sector in the plane of the aperture of the lens whilst copying an ordinary cross-line screen in the camera. The *graduated* dot image screen thus obtained was placed in vacuum contact with a sensitive film in the dark slide, and for this purpose a special slide was required. By varying the conditions it was possible to vary the type of dot—its curve of gradation (if the density from centre to margin were expressed statistically)—and this being so, it was possible to make negatives having different degrees of contrast, and to extend or flatten the scale of the darker or the lighter parts of the subject. These screens were not by any means easy to make, but, when once made, negative making was not difficult (Patent No. 286,340 of 1928).

A process was invented by J. A. Branfill, who placed a continuous-tone positive—or negative—in front of a projecting lantern, inserting a square stop in the lens. In front of the lens in a suitable position were erected the ruled screen, the positive (or negative), and the sensitive plate, with the necessary separations (*Process Year Book*, 1901, p. 15).

Similar to this is the proposal of A. A. K. Tallent, who does away with the lens. In this scheme a very simple piece of apparatus is used, which consists of a box bearing at one end an arrangement for holding a ruled screen, a transparency, and a sensitive plate, in this order and at certain distances. At the other end of the apparatus is a source of light, actually a glow lamp, and

above a diffusing screen in contact with a diaphragm which can be varied in size and shape. With this simple arrangement there are all the requirements for making screen negatives. The disadvantage is that it is necessary to make, if no negative of the size exists, a continuous-tone negative, and from this the transparency. Screen *positives* may be made by using a negative in the apparatus in place of a positive. There are advantages in making screen positives where much modification is required, for screen positives lend themselves to local reduction, and from the reduced dot positive a negative may be made by contact. We have, therefore, the power of first, modifying the negative, second, modifying the dot positive, and third, modifying, by the same process of local reduction, the dot negative. In connection with this work, the student is referred to page 267 for an account of the first proposal for a systematic method of reducing screen negatives (Peridak process).

The method of Tallent is a simple and a good method, and has the advantage of requiring inexpensive apparatus (See *Process Year Book*, Vol. XXXI, 1929, p. 69.)

The Kodak Co. has introduced (1941) two contact dot screens to be used in lieu of the normal cross-line screens when making dot (half-tone) negatives or positives. One of these screens is the "Magenta Contact" for making direct half-tone negatives for the albumen surface process of photo-lithography, and the other the "Orange Contact" for making half-tone positives from continuous-tone negatives for the "deep-etched" litho process. For reasons given in the text the dot formation in the negatives and positives for the correct results is not the same, and consequently the forms of the dots in the screens must differ. The one will not answer for the other and to attempt to make them do so is to court failure.

On both screens the dots are graduated (vignetted), but the gradient of density in the dots of one screen is not the same as in dots of the other.

It is necessary to see that perfect contact exists during exposure between the surface of the screen and the sensitive surface, and for this purpose vacuum contact is used in the camera back and in the printing frame.

CHAPTER VIII

TYPICAL PROCESSES: INTAGLIO

THE student will have read in Chapter I that an artist's picture is produced by the regulated application of pigment to paper. The *quantity* of pigment—say, indian ink—applied is varied, and by this variation in the pigment the different tones of the picture are made. The fact that the total quantity of pigment is very small must not blind us to the fact that there *is* a different quantity in the various tones. If the varying thickness could be enormously magnified, then we should see the paper covered with hills and dales of colour, the hills representing the darks and the dales the lighter tones. It is well that the student should keep carefully in view this image of the thing—the picture surface. It is now desired to make copies of this picture, and the process selected is an intaglio process (see page 7, Chapter II). To photographic intaglio processes the name *photogravure* (heliogravure) is given. Sometimes the matrix is—and generally so to-day—cylindrical, and then the expression *rotary photogravure* is used. A later form, where the plate is made flat and afterwards curved, is known as *plategravure*.

The first step is the making of the negative, and this negative would be known as a *continuous-tone* negative. Let us take this negative and from it make a positive or print upon a piece of sensitive paper. We employ "bromide" paper, that is, paper coated with a sensitive film of bromide of silver. We expose this paper under the negative and then submit it to the action of a developing solution, and there results a series of tones, some light, some dark—the reverse of the negative—and corresponding to the original picture. These tones are

formed by varying quantities of silver particles. We have again the hill and dale, but this time, instead of particles of indian ink, we have particles of silver.

But suppose that we took a piece of paper coated with a mixture of gelatine and potassium bichromate, and exposed that under the negative. A reference to page 142, Chapter VI, will show that under this condition the effect of the light action is to change the gelatine so that it will no longer dissolve in warm water, and, further, that the amount of this potentially insoluble gelatine so produced depends upon the amount of light action involved. Now this amount will be controlled by the tones in the negative, so that after the correct exposure has been given we shall have upon our piece of paper coated with bichromated gelatine, various quantities which have been changed, corresponding to the tones of the negative, and which will not dissolve in warm water, mixed with some bichromated gelatine unchanged, which will dissolve. By suitable procedure we can remove this unchanged gelatine, and we have, as the result, a picture the tones of which are formed by different thicknesses of insoluble gelatine, thicknesses which can be seen by the naked eye, so that we have made our hills and dales a reality. Incidentally we may regard this as a *mould*. If we took paper coated with a very thick film of gelatine, the various picture tones, *as different thicknesses*, would be readily recognizable. If we introduced some indian ink into the mixture of gelatine and potassium bichromate with which the sensitive paper we use was coated, then the final print would show two things, different thicknesses of gelatine and also different quantities of indian ink, because the different thicknesses of the gelatine would contain different quantities of indian ink. This is not an imaginary process, but a real one in everyday use. It represents the "carbon" or "autotype" process.

Now when considering a process it is oftentimes desirable to proceed by easy stages and in a roundabout manner in order to understand it. We will do this with the photogravure process. It has been stated that, by means of our exposed gelatine paper, we have produced a *mould*—a *matrix*, in fact. Now from a mould we should be able to produce a "cast," a "replica," but the replica will always have the opposite character. Our mould has "hills and dales," and the cast from this will have "dales and hills" (see Fig. 28), so that as the mould

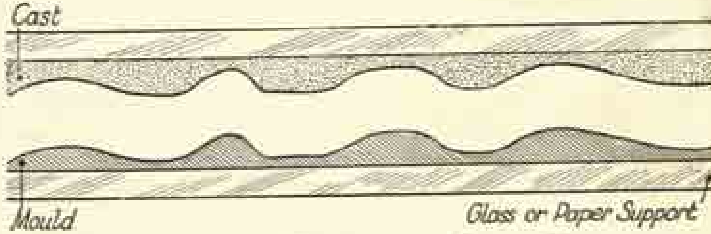


FIG. 28. "MOULD" PRODUCED BY CARBON PROCESS, AND CAST FROM THIS MOULD

has hills for the dark tones and dales for the light tones, our cast will have the reverse, dales for the dark tones and hills for the light tones. Thus, while from the negative the print mould made would be a positive—as it should be—the copy or cast would be a negative, i.e. would always be the opposite. We could, however, avoid this difficulty if we wanted in the end to produce the mould as a positive, by using, in the first instance, a positive, and by exposing our sensitive paper under that positive. This fact the student should bear in mind. How can this mould be made? The paper print is laid upon a sheet of glass and lightly rubbed over with french chalk. A small quantity of bees-wax is melted, and while in a liquid condition is poured over the surface of the print and allowed to cool; when hard the paper print is stripped

off, and there results our mould. We could repeat this so long as the print lasted. Now many years ago the investigator, W. B. Woodbury, sought to make copies of photographs in a mechanical manner, using for the purpose a mixture of warm gelatine solution and colouring matter. He got so far as to produce the gelatine print, a negative print from a positive. Had this print been of metal his next step would have been easy. He would have levelled his print and poured his warm gelatine over it, laid on this a sheet of paper, put the whole under a press, applied uniform pressure (when the excess ink would have been squeezed out, leaving the ink in the matrix sticking to the paper), and when the ink was set, upon pulling away the paper, the ink would have come with it, and there would be the print. But the print mould was not metal; it was gelatine, and it was quite impracticable to pour a watery gelatine ink on to a gelatine mould. Mr. Woodbury, always very ingenious, got over the difficulty in a particularly neat manner. He laid a sheet of good-surfaced thin tinfoil on the top of the gelatine mould print, and pulled the two through a rubber roller mangle, when there resulted to all intents and purposes a metal matrix. This was the "Stannotype" process. Not satisfied, Mr. Woodbury developed the idea into what became the process of "Woodburytype," which was patented on 24th July, 1866. This process, now no longer used, is probably the most perfect, so far as results were concerned, of all the processes of photo-mechanical photography which have been invented. In the "Woodburytype" process, a negative of the object of which a picture is desired is first made, and from that negative a positive is produced upon carbon tissue, i.e. paper coated with bichromated gelatine and pigment. This positive is developed upon a piece of glass previously coated with collodion, which produces a very thin structureless film.

When finished and dried, the image resting upon this film is stripped from the glass, the film acting as a support. Woodbury found that this insoluble gelatine image when dry was extremely hard and tough, so much so that if a piece of smooth pure lead was placed on its surface and the two squeezed together under a press, a perfect mould of the carbon image could be produced in the lead. He developed this method, producing in time a perfect mould. Prints were produced by placing the leaden mould on the body of a press—a simple press like those sometimes employed in offices with letter copying books—pouring over the surface a solution of gelatine containing pigment—the ink—placing paper on the top, and applying pressure. The excess ink was in this way squeezed out, and on lifting off the paper there was found a perfect cast of the matrix in chilled gelatinous ink, which was then allowed to dry.

It has now been shown step by step how from a drawing it is possible to produce a transcript by utilizing the properties of a mixture of gelatine with potassium bichromate, and how the transcript is like the original in this respect, that the tones are produced by varying quantities of pigment throughout the scale. This process is an intaglio process, and it must here be made plain to the student that only by an intaglio process, a process where there are *cavities of different depths*, is it possible to produce different tones with *different quantities of pigment*. All other forms of printing matrix give only *an illusion of different quantities*, with the possible exception of the surface process of collotype, where the effect is produced partially by *some* differences in the quantity of ink.

THE ORDINARY INTAGLIO PROCESS

Let us now consider the intaglio process in its extreme simplicity, disregarding any connection with photography.

On page 7 the Author has taken as his illustration a simple plain visiting card. This is produced from an incised (intaglio) copper plate. Now the engraver, when he engraves such a plate, must consider the printing process. When a plate of this character is to be printed, the process is to cover the plate after it has been warmed with a stiff ink, the ink filling the interstices or cavities made by the engraver. The excess is now cleaned off with a particular kind of muslin, leaving the *surface* of the copper quite clean and the ink remaining in the cavities, after which the print is made by putting a card on the top and pulling the two through the press. Now it was found very quickly that if the ink was to remain in the cavities, the width of these interstices was of greater importance than their depth—that if the width were too great the ink would wipe out, and wipe out irregularly. Consequently, the engraver had to devise a method of overcoming this difficulty, and the method he adopted, when he wished to produce an incised patch of more than a certain width, was to divide it into a number of small patches, as, for example, by engraving a number of very fine lines close together. Under these conditions the ink remained in the cavities during the wiping process, and the print did not show the divisions—a uniform patch resulted. The student is asked to remember this and its necessity as a constant fact to be appreciated and provided for in any intaglio process where the excess ink is to be removed by a wiping system, which, incidentally, is the only method used.

The production of pictures by the medium of an intaglio process upon copper is an old craft which has yielded in the past, and yields also to-day, very beautiful results. Probably few processes give such fine and such *individual* results as the copper-plate engraving in the hands of a capable artist-etcher.

There are several ways of engraving a copper plate to which a brief reference may be made. The clean copper plate may be incised directly by the tool, the V-shaped tool, the "burin," being employed, or the etching needle, which produces a different form of incision; or the plate may be coated with a mordant or etching fluid-*resisting* medium, the etching "ground," and the design produced by removing the ground with the needle down to the metal, which is then etched by the application of the mordant, that is, the plate is subjected to the action of some liquid which attacks copper, such as nitric acid, and thus it is removed. The two methods, needle and mordant, may also be combined.

THE MEZZOTINT AND AQUATINT PROCESSES

Further to this, there is the mezzotint process and the aquatint process. In the "mezzotint" we have a reversal, for whilst in the ordinary copper-plate process the artist starts with a smooth copper plate and produces different shadings from light to dark by making cavities, the plate of the mezzotint is artificially roughened at the first into cavities, and the artist works from dark to light by removing the roughness—the cavities—to different degrees, until in those parts meant to represent high lights or white we come back to copper, where all the roughness has been removed by means of a burnisher. In the aquatint process the metal plate is coated with a solution of resins, generally colophony and Burgundy pitch, in dry, water-free alcohol. If the plate be coated in a warm room the resins do not form a continuous film, but break up into a series of grains, and the "grain" can be controlled. This forms the resist. The artist's design is transferred to the surface of the resist and the plate is now submitted to the action of the etching mordant, which attacks between the interstices around the resin grains.

Now a brief action will mean that only small area, small depth, cavities are produced, and, translated into terms of printed picture, this would mean a light tone. *But* if the action be prolonged two things take place: the mordant bites deeper and *at the same time* bites laterally, undercutting the resin grain, and so a smaller grain results, which means a darker tone on printing. By this method of proceeding the artist has the depth of tone exactly under his control. When, therefore, the artist sees that any particular patch of tone in his drawing has gone far enough he withdraws the plate, paints out that part with a resisting varnish, and returns the plate to the mordant bath. Incidentally, as will be seen later, the same method with different procedure—actually the reverse—has been employed in the making of relief blocks, with excellent results.

The mezzotint process is particularly interesting to the photo-mechanical worker because it is the nearest of any of the artist's processes to photogravure.

It will be seen, it is hoped, by the student, how well the artist-etcher is equipped with methods, each of which produces results of different character, and how monotonous must be a series of transcripts by photogravure when compared with what the artist could do by means of his various methods. Nevertheless, the photogravure process does yield the best result with respect to quality.

THE TALBOT-KLIC GRAVURE PROCESS

It is hoped that the student is now prepared for an understanding of the process employed for producing a modern photogravure plate, that is, a plate which is etched to different depths, and therefore produces its effect when printed by different quantities of ink upon the paper. The process was first worked out by Fox Talbot, who employed an exposed gelatine film of which the

unchanged parts were not washed away, but was later developed by Karl Klic, who applied Swan's "carbon print" in lieu, and it has, therefore, come to be known as the "Talbot-Klic" process. The process is further divided into the resin grain—the original Klic process—and the ruled screen grain, also Klic, and is now again divided into the "flat-bed" and "rotary" processes. In the flat-bed, fairly thick copper plates are employed and printed flat, frequently for bank-note production, but in the rotary process the image is upon a copper cylinder, the ordinary and now well-known term "rotary photogravure" being employed. A later and very promising development has been to produce the image upon a thin copper plate (about 20 gauge), and to bend it into cylindrical form upon the printing machine. This method is of considerable economic importance, because it places photogravure printing within the power of a good printer who could not hope to meet the expense which would be incurred by the employment of heavy copper rollers which would have to pass between himself and the producing engraver, and who, moreover, does not desire to become a matrix producer. So far as the process is employed to-day, it may be said that ordinary flat-bed resin grain gravure is very little worked. By far the greater bulk of the enormous amount of gravure work done at present is by means of ruled-screen rotary gravure. With respect to the quality of result it is agreed that no process equals gravure. At the same time, for ordinary commercial work it competes economically with any other process, especially for long runs.

In rotary gravure the cylinder, after the run, must be ground off for removal of the image and then repolished ready for the next picture. The constant regrinding means reduction of the cylinder diameter and has many other drawbacks. As an alternative, the original and highly polished cylinder receives a *very thin* coating of

nickel, and on this there is electrolytically deposited a skin of copper about 0·006 in. in thickness which is hard and coherent and suitable for etching. The skin, after slight polishing, receives the resist and is etched. After the edition has been printed the skin is easily peeled off, when the cylinder is ready for another deposition. Many advantages follow this procedure, which is now largely employed.

The etched cylinders are frequently chromium plated to enable the image to withstand long runs, although long runs are obtained without this addition.

ETCHING PHOTOGRAVURE—PRINCIPLES

The mordant employed is iron perchloride (ferric chloride).

The different depths required to produce the different tones are produced by the solution acting in different places for different times. If we can produce an ink-bearing matrix with cavities of different depths, we have produced one essential for the rendering of gradations of light and shade. Let us consider now the picture. Each tone requires a corresponding cavity, and this cavity must have a certain depth in relation to other cavities. Moreover, these cavities must not be of too great order in depth, for, if they were, too much ink would be delivered to paper and the picture would be too dark. Therefore, in the tone representing black the cavity must be sufficiently deep for the pigment it will hold when delivered to paper to give black, whilst in the part representing pure white there must be no depth at all. This is the "range" or "contrast" expressed in terms of depths of cavities in the metal, and between the two extremes, depth and no depth, there may be a large or small number of cavities of different depths representing the intermediate tones in the picture. This condition will vary with different subjects.

How are we to produce these different depths? By the process of etching for different times. How may this be accomplished? The student will remember that it was stated that water and certain aqueous solutions were absorbed by ordinary gelatine, and that gelatine which has been insolubilized by light action has not wholly lost this property, but the absorption or penetration of the liquid takes a longer time. Ferric chloride will penetrate gelatine even when the gelatine has been insolubilized.[1] To give a preliminary understanding, a non-photographic illustration of the action of the mordant will be taken. If we take a very thin film of gelatine and lay it upon a piece of white paper, and on this put a few drops of ferric chloride, we shall find, if we raise the film of gelatine after a little time, that the ferric chloride has penetrated the film and stained the paper. Now if we put two films together, one on the top of the other, place these by the side of a fresh single film, both on white paper, and touch both with a few drops of ferric chloride and observe the time of penetration, we shall see that the penetration is much quicker through the one film than through the two; in other words, the different thicknesses have regulated the time of passage, so that the white paper is stained much more quickly in the case of the thin film than in the case of the thick. The period when the film is penetrated so that the paper is stained represents the commencement of the action, and the time that the first stain is in advance gives the amount of the start the first had compared with the second. Let us now imagine a piece of copper, one half covered with one film of gelatine and the other with two films, and then placed in a solution of ferric chloride. Directly the ferric chloride has passed through the thin film it will attack and etch

[1] The student may note for information that ferric chloride will directly insolubilize gelatine without light action.

the copper, to be followed after a certain interval by the ferric chloride passing through the second film, when the copper underneath will be attacked. But No. 1 film has had the start, and in consequence, after an interval of time, the copper under No. 1 film will be more deeply etched than the copper under No. 2 film. This is the principle of photogravure etching; this is the basis of the production of cavities of different depths. Because the mordant penetrates a film it is termed "through" etching, and the means by which the picture is produced in the copper is an insoluble gelatine image which regulates the etching. We make from the subject to be rendered, say, a picture, a photographic negative and from that negative a positive. From the positive we make a picture or print on a suitable carbon tissue and this is developed upon a sheet of copper. This will be a negative picture. When dry, the sheet is placed in a bath of ferric chloride, and the penetration commences. As it is a negative, the darkest tones will be represented by the thinnest part of the film and the lightest by the thickest part of the film, and between the extremes there will be different thicknesses representing the different tones. The ferric chloride will penetrate through the different tones in proportion to their thickness, and when it does penetrate will commence to attack the copper. The attack on the copper can easily be seen, for the metal at once darkens and the darkening proceeds in sequence tone by tone. As the dark tones must be etched to the greatest depth it will be seen why a negative image is taken, for there the layer of insoluble gelatine is the thinnest. When the etching has been judged to have proceeded far enough, the etcher at once removes the plate and plunges it into an alkaline solution, which arrests the process. The plate is now cleaned free from the resist. Examination will show a picture, the tones being

represented by cavities of different depths in the copper. The process of etching is not by any means easy until considerable experience has been gained. The etcher employs solutions of ferric chloride of different concentration, by which the penetration of the film is regulated, and in this way has a considerable measure of control over the contrast and gradation of the picture. For preparation of the tissue or pigment paper see Appendix.

WIPING THE GRAVURE PLATE—THE STEEL DOCTOR

We have anticipated for reasons of simplicity, for no provision so far has been made for the "grain," that device by means of which the ink is retained in the cavities when

FIG. 29. THE "DOCTOR" IN ITS MOUNTING

the plate is subjected to the process of "wiping" for the removal of the superfluous ink. It has been explained that only when the cavities are very narrow will the ink remain when the plate is "wiped" with the wiping muslin, and the artist-etcher or engraver prepares his plates knowing this and making provision for the requirement. Now a plate may be wiped by hand or mechanically by cloth or by paper, or by means of a thin flexible steel blade called a "doctor," which, pressing against the surface of the plate, removes all the superfluous ink, leaving the picture-making ink where it should be, viz. in the cavities. *But* this is so only if the cavities are themselves narrow, for if they are beyond a certain width the steel "doctor" will dip and remove some of the ink, and the picture tones

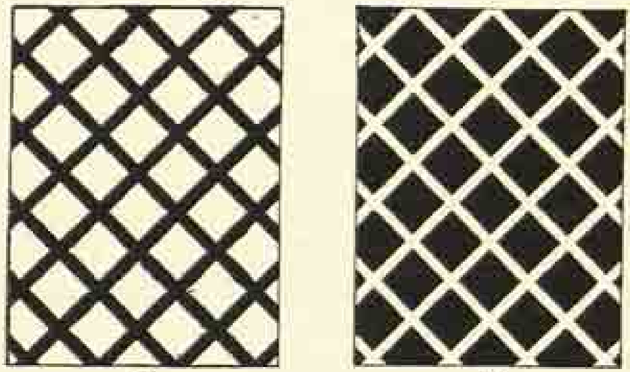
will be spoilt. The doctor and its holder are shown in Fig. 29.

The use of the "doctor" is not peculiar to the photogravure process. It was introduced as early as 1785 for the process of calico printing from intaglio rollers, and later was employed for the process of intaglio wall-paper printing, and has been employed for these purposes ever since.

THE MODERN METHOD FOR THE PRODUCTION OF THE "GRAIN"

We have now to consider the means for the production of the "grain." Although the resin grain is little used to-day, because the rotary process has almost entirely replaced the hand-wiped flat plate, it is an important method, and the student, because he is a student, should know something about the way it is obtained. Moreover, methods do not necessarily die because they may not be used, and a method that has lapsed may at any time, because of some particular virtue it possesses, be revived. Briefly, the copper plate, before receiving the carbon print image, is exposed in an atmosphere of finely divided resin (colophony) or bitumen dust. The minute grains settle upon the plate and are afterwards slightly melted by being heated, in consequence of which the grains stick. On the grained plate the carbon image is developed. Now the effect is to prevent the metal being etched where it is protected by the "grain," as this is not penetrated by the mordant. Thus, all through the tones there are left little spikelets of copper, so that a cavity is not a continuous area but one broken up into little compartments by these spikelets of copper. In this way the necessary condition is secured and the method of wiping does not remove the ink from the spaces where it should remain. In the rotary photogravure process the effect is obtained in a

different way. The carbon print after exposure under the positive is again exposed under a "ruled cross-line" screen. This screen ("master") as originally supplied (of which examples are in use) was a series of opaque lines on glass, crossing at right angles and leaving clear spaces. The ruling was 175 lines to the inch—ratio of opaque to clear spaces 4:1 or 3:1. The "working"



(a) (b)

FIG. 30. THE CROSS-LINE GRAVURE SCREEN

(a) The original "master"; (b) the reverse copy as made for "screening." The latter also represents the appearance of the present etched glass "working" screen for "screening"

screen was a reverse of this produced photographically by contact copying on a suitable dry plate or film. In Fig. 30 are shown (a) the original "master" as ruled, and (b) the reverse. The "master" is no longer offered by the makers, having been replaced by an etched glass "working" screen which is a reverse of the former "master."

Under these reverses the carbon tissue which has been exposed under the picture positive is again exposed to light or "screened," or is "screened" beforehand.[1]

The effect of this exposure is to "lace" the picture with a series of lines of insoluble gelatine, for the exposure is

[1] The photographic reverse is inferior to the etched "working" screen, and so the effect of the "screening" with the latter is better.

such that the lines are thicker than any part of the picture tones, and in consequence when the copper is etched no etching takes place where the metal is protected by the lines. The final result is that each tone cavity is broken up into a series of rectangular cavities all the same size.

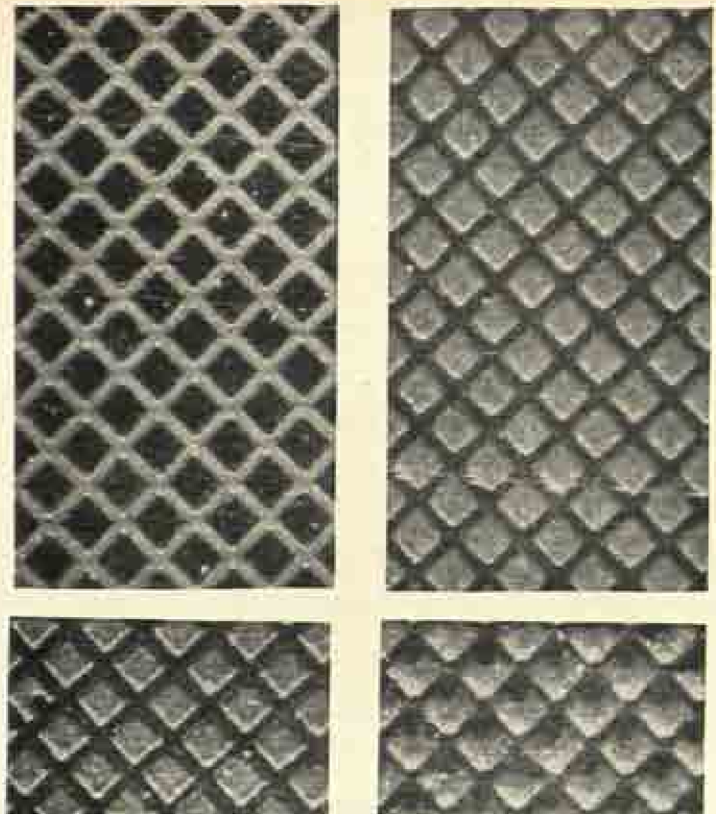
L No. 1 R

FIG. 31. TALBOT-KLIC DUST GRAIN

NOTE.—It is important that this example be viewed with the side L on the left hand of the observer.

But they will be of different depth, for that is not affected by the use of the screen. The lines or walls of the copper prevent the dipping of the doctor blade wiper.

The thickness of the blade, which is of the finest steel, varies from $\frac{3}{100}$ in. to $\frac{1}{100}$ in., and the working edge is ground to a slight camber. Often the blade is backed up by a slightly thicker blade, the unsupported edge of the actual wiper being slightly in advance.



2 3 4 5

FIG. 31 (*contd.*). EXAMPLES, MAGNIFIED (× 35), SHOWING A TINY PATCH OF TONE IN A GRAVURE PLATE

2. Resist lines only on plate before etching. 3. Slight etching. 4. Etching more prolonged. 5. Etching prolonged until cell walls have broken down

The examples in Fig. 31, Nos. 1–5, show magnified pictures ($\times$ 35) of etched gravure plates. No. 1 is a Talbot-Klic, resin grain plate, and Nos. 2, 3, 4 and 5 show "screen" gravure plates having different depths of etching. The screen "walls" of Nos. 2, 3, and 4 are intact, whilst in No. 5 the etching has been too prolonged, the mordant has penetrated through the screen line resist, and the "walls" have in consequence suffered.

No process is capable of yielding such beautiful results as photogravure when properly carried out. Much of the quality depends—as with all intaglio processes—upon the fact that the tones in the pictures are rendered by different quantities of ink, this being due to the variation in the depth of the cavities so that they correspond in method to the way that the artist produces the tones in his original.

Compared with the half-tone relief process or the application of the "half-tone principle" to photo-litho, where the tones are produced by variation in dot area by, to be plain, an illusion, there is a very great difference. The student who has read what the Author has written in the previous chapter, may quite possibly be tempted to think that, as the tonal gradation is produced in the applications of the so-called "half-tone" principle by the action of a cross-line screen, the ruled screen when used in photogravure has some influence upon the gradation, but to think so would be an error. The only purpose of the ruled screen in photogravure is to provide a simple means of producing a cellular structure to the cavities, which structure is necessary because of the "wiping" process, the means by which the superfluous ink is removed from the plate during the process of printing. Its use replaces the resin grain. In some instances instead of "screening" the exposed carbon tissue when it comes from the

transparency under a *regular* ruled screen, an *irregular* grain screen is employed for the purpose.

THE COMBINATION OF TYPE WITH PICTORIAL MATTER IN GRAVURE

For detailed information upon this important application of the process, see Appendix.

THE "INVERT" HALF-TONE INTAGLIO PROCESS

There is another process of preparing photographically intaglio plates, which, though very little known, should be understood by the student of reproduction methods. This process is termed "invert half-tone." It is of slight importance although it has been used commercially even to the extent of being employed for newspaper printing.

In the preceding chapter the method of rendering tone in the so-called "half-tone" process is explained, and the application of the principle is given in Chapter X. By far the greater amount of tone work is to-day done upon this principle, and will probably always be so because of the way that the publisher of illustrated books, magazines, and other kinds of printed matter works. Nevertheless, where the work can be well planned beforehand, where there is time for arrangement, and where the matter has unity—as in a well-planned illustrated catalogue—and the make-up is not likely to be disturbed at the last moment because of illustrations which "must go in," there is no doubt as to the increasing use of photogravure, and not alone in the most expensive work. But any application of the half-tone principle is of importance, and for this reason "invert half-tone" is here briefly discussed, so that the student, having read the description of the ordinary photogravure process, may see the difference.

A continuous-tone original is translated into broken tone by means of the ruled screen, and the gradations of

the negative are then expressed in dots of different sizes. From this negative a positive is made. A sheet of copper is then coated with bichromated fish glue in the usual way, is exposed under the positive, developed in water, and, if seen to be properly printed, is dried and burnt into the enamel stage. The plate is then etched in ferric chloride, and when sufficient depth is obtained the etching is stopped. The gradations are represented by cavities of different sizes, *but all of the same depth*. Here is the fundamental difference as compared with photogravure, where the cavities are of *different depths*.

The plate is now printed as an intaglio plate. In place of the enamel resist the ordinary carbon resist may be employed, and the effect is to give a greater softness in the gradation. Apart from the fact that the "grain," the "half-tone" dot in this case, shows much more distinctly than the grain in photogravure, the general effect is not comparable, and the process has little value relatively.

PHOTOGRAVURE AND THE OFFSET PROCESS

At the first sight it may seem somewhat strange to the student that a process, the particular virtue of which lies in the fact that the gradations are rendered by different quantities of ink, should be, so to speak, translated or "rendered" by a method where this particular character is sacrificed, for the offset (as any surface process) cannot give tone gradation by variation in quantity or thickness of the elements, but only by variation in their area. Nevertheless, in practice, advantages are found in the conjunction of the two methods. One interesting example is in the application of the photographic process to the decoration of wood. Many panels of wood, apparently with beautiful figure or "grain," are produced by photographing a genuine panel, translating into "half-tone,"

and printing an image upon plain "white wood," generally "ply" wood by the photo-litho-offset process, two or three printings being used to obtain the effect; sometimes hand-worked plates are used in conjunction with the photographic plates. After the ink is dry the panels are polished and then only an expert would be able to detect the imitation. It has been found that the photogravure plate can be used instead of the half-tone photo-litho (zinc) plate. The ink in the deep cavities "squashes" and spreads, but this has been found to be an advantage as tending to obliterate even the mild "screen effect" in photogravure, and, apart from other advantages, detection of the mode of production is rendered more difficult. Offset photogravure is also applied to the printing of images on enamel tablets for the "burning-in" process.

ALTERNATIVE SYSTEMS OF GRAIN PRODUCTION

It is sometimes thought that the use of a ruled screen for the purpose of producing the cellular structure necessary in intaglio plates arose with Karl Klic, but this is not the case. The use of a single-line screen for the same purpose was suggested and patented in connection with Niepcé's intaglio process with bitumen (the earliest intaglio process) by Berchtold in 1857, who says, in describing the use of the screen, "when the metal plate coated with its bitumen varnish has been exposed to light under the negative, before it is washed [viz. developed], the ruled glass plate is substituted for the negative and the light allowed to act . . . . . after sufficient exposure to light the ruled glass is lifted and turned in an opposite direction —that is, placed at right angles to the first lines, and again exposed to light, but for a shorter period than before. The ruled glass is next placed diagonally to the squares obtained and repeated in the opposite direction, the time of exposure decreasing with each change of position. In

this manner a multitude of fine points are obtained over the plate, but only in those parts where they are required."

It was the absence of grain or cellular structure in Niepcé's original intaglio plates that prevented the rendering of half-tone, thus confining the method to line subjects, so that the introduction of Berchtold marked a step in advance. At a later date the same idea was used by Baron F. W. von Eggloffstein, who made experiments in the United States (in Philadelphia), in 1861, in the use of a screen as part of the procedure in making steel plates for intaglio printing, but he did not divulge his method or take out a patent until 1865. Eggloffstein's screen was a plate of glass coated with bitumen and smoked by being exposed over a lighted wax taper. The plate was ruled in straight lines—very fine rulings, 200–500 to the inch, were made—by means of a diamond point in a ruling machine. To use, the sensitive bitumen-coated plate was exposed to light under this screen and then exposed under the photographic image. The effect would be to produce the necessary cellular structure in the printing plate. In view of Berchtold's patent, in the specification for which the whole method is described, it does not appear that there was any originality in Eggloffstein's idea.

In addition, the same principle was used by Charles Eckstein, of the Royal Topographical Bureau, at the Hague, prior to 1890, in his process of litho-heliogravure. In Eckstein's process he produced a ruled tint in intaglio on stone, and from this stone he pulled transfers, which were laid down on stone prior to the development of the carbon print which he used as his etching-resist. In this case the ruled tint was on the stone.

CYLINDER OR "ROTARY" GRAVURE

Because it is the easier to explain, in view of the simpler mechanical conditions, attention has in the main been

paid to outlining the operations for plate gravure, but whether the matrix be plate or cylinder, the essential principles of the operations are the same, and, similarly, the routine of making the negative and positive (though more difficult where the subject consists of a number of images, especially when associated with type matter) and exposing and "screening" the tissue is carried out in the same manner. But with copper cylinders (particularly with those of large size) the practical work is more difficult and greater skill is required. The difficulty increases still further with colour work.

The student is referred to *Photogravure*, by H. Mills Cartwright, for details of cylinder production, and for much valuable information upon this gravure process in every aspect.

CHAPTER IX

TYPICAL PROCESSES: SURFACE

IN Chapter II a "surface" process has been described briefly, and in its essentials, as one by means of which there may be produced from a plane surface a picture, the tones of which are determined by the arrangement upon that surface of an "accepter" and a "rejecter" of printers' ink. In a process of this character the selectivity is produced by physical causes. The latter part of this definition is open to objection, because the mechanical causes which operate with both the relief block and the intaglio plate are physical, but the term is used with reference to properties exerted by the substances forming the image, the selective and rejective materials themselves, independent of their shape. Thus, a wet surface will always reject varnish ink, whatever be its form, and, similarly, a design in printers' ink will attract printers' ink, however it be arranged. Surface processes to-day include printing from the *surface* of stone or metal (zinc or aluminium). The former is referred to strictly as "lithography," and the two latter as "zincography" and "alagraphy," or taken together as "metallography." These surface processes are sometimes referred to as based on chemical principles; indeed, Senefelder himself used the term "chemical ink" for the "fatty" material he used for the purpose of making his drawings. The term is now seldom used, and advisedly so. It is not a suitable term, if only for the reason that it implies to most people a change in the composition of the materials employed or changes during the operations, and in this case no such changes take place, or at least, no change has been proved.

Frequently, however, the term "lithography" is applied indifferently to all three processes, which, incidentally, are essentially the same. These processes are frequently either hand processes entirely, or photographic processes entirely, in which latter case the prefix "photo" is employed, but in many instances, particularly in the best modern work, both methods are used in the same job. In addition there is the purely photographic process of Collotype. Some years ago a method was introduced (although the principle is not by any means new) of printing from an iron plate chromium faced (Pantone), where the image—the accepter—is chromium and the rejecter is a silver amalgam. To this the old term "*Mercuriographic*" printing is sometimes given. Methods using the same principle continue to be introduced, such as the Lenzart and the Renck processes.

BIMETALLIC PLATES

The success of the Pantone process (which was dropped for quite other reasons than that of being a failure) led to further experiments upon the same principle, and as a result we have the introduction of the bimetallic plate. On several pages it is stated clearly that some surfaces accept lithographic ink whilst others reject it. This is, in fact, the basis of all lithographic processes. The suggestion to use metallic plates is not new. There are differences in the behaviour of metals, for example, in their acceptance or the reverse of oil[1] and water, it being largely a matter of surface tension—or perhaps

[1] The Author feels that the student may get somewhat wrong ideas by the way in which the term "oil" is used when actually varnish is employed in the process. In the polymerization of linseed oil by which linseed varnish is produced many of the properties of the original oil disappear. It may well be that a surface might accept oil and reject varnish, so that it is not wise to use one or the other as if they were so far as concerns physical properties interchangeable. In lithographic printing many inks will tend to "tint" the plate because of some residual oil in the varnish.

the term "wettability" may be preferred. (See Tritton, F. J., *Penrose Annual*, Vol. XLI, 1939, p. 41.) Some, such as copper, accept oil in preference to water, and others, such as lead and chromium, are the reverse. In bimettalic lithography advantage is taken of this principle. For example, we may take copper and lead. An image resist is produced upon a copper plate, and after upon the bare portion there is electrically deposited lead and when the resist image is removed we have the ink accepting copper and the water accepting lead and therefore ink rejecting. Or a plate of stainless steel such as steel chromium coated is taken and on it the resist image is produced and the bare portions are given a coating of copper by electric deposition, and we have ink accepting copper and the chromium accepting water. In either of these instances it is the copper which accepts the ink.

There are apparently four bimetallic processes—

(1) Selective chemical deposition where no image exists.

(2) Selective electro-deposition of metals on image or where there is no image.

(3) Image production by selective etching through a layer of metal, usually electro-deposited to another metal underneath.

(4) Other processes.

The subject has now assumed important dimensions. A very comprehensive account is given by G. A. H. Elton in *Patra Journal*, X 5, November, 1947, pp. 118–127, from which with due acknowledgment the foregoing particulars are abstracted. Many articles on bimetallic plates appeared in the pages of the "Modern Lithographer" during the years 1947–1948.

THE PRINCIPLE OF LITHOGRAPHY

Senefelder had shown in 1796 that the hard coherent limestone of the Solenhofen quarries could, by a new and fairly simple procedure, be converted into a printing surface and although since the day of the discovery there have been many changes and modifications in the way in which the process has been worked, no new principle with respect to the formation of the image has been introduced since Senefelder's time, from whose discovery a very important branch of the printing industry sprang. Solenhofen stone is a calcium-magnesium limestone of close uniform texture which is capable of taking a very smooth and, if necessary, polished surface. The stone is yellow, grey or grey-blue—the colour is due largely to the presence of iron in different states of oxidation—of different degrees of hardness, and, approximately, in this order. Although the stone is coherent, it is not by any means non-porous, and the ability to absorb water is one of the properties which make it of value and better for the purpose of printing than either zinc or aluminium, which are both devoid of porosity to anything like the same degree as the stone.

If the stone be wetted, some water penetrates the surface and will there remain for a brief time. If, whilst in a wet or damp state, a roller charged with stiff varnish ink be passed over the surface, ink will be rejected—it will not "take"—the water being a "rejecter," and consequently conferring the property upon the surface. If the stone be allowed to dry and when in a dry condition it be rubbed with some substance that will reject water, as, for example, a fragment of paraffin wax, a piece of bees-wax, a tallow candle, a piece of hard soap (all of which bodies are capable of rejecting water, and are, therefore, not wetted by that agent), we have a potential printing process due merely to something which will take ink and something

which will not. If we wet the surface with water as before, the bare stone will take the water, but the portions where the foreign bodies mentioned have been deposited will not, and so we have some parts of the surface dry and others not. It does not follow that because a substance is dry it will now take ink, for a metallic amalgam—as in the Pantone process—is a rejecter. Nor, since it is desirable in all these matters to be exact, does the wetted stone, as stone, refuse ink of itself; it is the film of water that refuses the ink, the stone is merely the support for the rejecting water. But the substances mentioned—the paraffin wax, the bees-wax, the tallow candle, the hard soap—with their natural surfaces, will take varnish ink, and so, if now we pass over the surface the charged roller, ink will be deposited upon the dry parts and rejected by the wet. We have thus on the surface of the stone produced an accepter and a rejecter of varnish ink. Senefelder himself says: "I drew some lines with soap on a newly polished stone, moistened the surface with gum-water, and then touched it with oil colour which adhered only to the places covered with soap. In trying to write music on the stone, with a view to printing it in this way, I found that the ink ran on the polished surface; this I obviated by washing the stone with soap-water or linseed oil before I began to write; but in order to remove again this cover of grease which extended over the whole surface (so that the whole stone would have been black on the application of the colour) after I had written or drawn on the stone, it was necessary to apply *aqua-fortis* which took it entirely away, and left the characters or drawings untouched. My whole process was therefore as follows: to wash the polished stone with soap-water, to dry it well, to write or draw upon it with a composition ink of soap and wax, then to etch it with *aqua-fortis* and, lastly, to prepare it for printing with an infusion of gum-water. I had hoped to have been

able to dispense with the gum-water, but was soon convinced that it really enters into chemical affinity with the stone and stops its pores still more effectually against the fat, and opens them to the water . . .

"The use of dry soap naturally led to the chalk manner." (Senefelder's *Complete Course of Lithography*, 1819.) Here we have in Senefelder's own words the basis of Lithography. It is interesting to note, for it fixes priority, that later in his treatise he says: "The chemical process of printing is not only applicable to stone but likewise to metals, etc., and Lithography, therefore, is only to be considered as a branch of the more general chemical process of printing. Amongst the different materials applicable to this new method of printing, the calcareous stone occupies the first place. It possesses not only a strong tendency to combine with unctuous substances, and retain them obstinately, but it likewise possesses the power of absorbing bodies of a different nature such as aqueous fluids; so that the stone, thus impregnated with them, will repel oleaginous and unctuous bodies," and he goes on to say, "This excellent quality, the cheapness and facility with which these stones could be procured in Bavaria [where Senefelder resided] determined me to overcome the few defects or inconveniences they presented." The material with which Senefelder made his drawings upon the stone he calls "chemical ink," which term he considers to be "an appropriate denomination from its constituent parts, viz. unctuous and bituminous substances, and an alkali would be fat or alcalic ink . . ." It is used for writing or "drawing immediately on the stone, or for covering the surface of its etching like ground, or for transferring drawings executed on the paper, to the stone," and he proceeds to give formulae for inks for different purposes, one of these for writing on stone being as follows—

Wax, by weight	12 parts
Common Tallow	4 "
Soap	4 "
Lamp Black	1 "

but if the ink is to be employed for writing on paper prior to transfer to stone then he would use—

Shellac	3 parts
Wax	1 "
Tallow	6 "
Mastic	5 "
Soap	4 "
Lamp Black	1 "

To use, the ink is rubbed up with water. "For dissolving the ink, distilled water is best; pure rain water, or if this cannot be had, pure soft river water, will do in case of need," and he appears to have had the same desire for the freshly-prepared liquid as the lithographic draughtsman of to-day. It has been thought that it would be of interest to give the principle of the production of the lithographic image in the words of its inventor, including the formulae of the "inks" employed. Many have been the modes of application of this principle, complicated the processes, but, for all that, the essential principle has been in every case the same.

THE CAUSES OF THE FORMATION OF THE LITHOGRAPHIC IMAGE

Many explanations have been offered since Senefelder's time as to the reasons why an image is formed. It was suggested in the early days of lithography that the compounds in the ink formed fatty salts of calcium and that the gum or some of its constituents behaved in a similar manner, that is, the gum formed compounds with some constituent of the stone, and that the existence of these compounds accounted for the well-known stability of the image. These views are still held in some quarters and

are, unfortunately, taught. If the chemical nature of these substances and that of the stone be reviewed, these hypotheses are far-fetched, are entirely without experimental proof, and, as explanations, are unnecessary. The lithographic stone is porous. An ordinary polished stone freed from moisture by heat will absorb, when placed in pure water, a considerable amount of that liquid. Similarly, it will absorb gum[1] water and the constituents of the "chemical ink" when in a liquid state, though more slowly when in a solid state, as in the case of the lithographic chalk. An image on stone will penetrate to a considerable depth, so much so that when one job, after the work has been printed, has been ground off and the stone re-prepared for a fresh job, the old work will sometimes "come back" during the printing of its successor; to guard against this the lithographic artist frequently makes a deep scratch in the stone to which the stone preparer has to grind down and so ensure that all the old image has gone. If a thin vertical section slip be taken from a stone where an image has rested for some considerable time, and from this slip a micro-section be prepared, the infiltration of some of the constituents of the ink into the stone can be easily seen when the section is examined under the microscope. There is produced a zone *slightly* darker than the surrounding stone.

It suffices, therefore, for an understanding of these processes, to recognize that some materials will accept printers' ink—in this case a pigment suspended in a linseed varnish, which latter constituent is the essential

[1] P.A.T.R.A. (Printing and Allied Trades Research Association) has proposed in lieu of gum arabic a solution of low viscosity "Cellopas" W.F.Z (I.C.I. Explosives Section). The real function of the gum (in lithography) which is absorbed by the lithographic stone or *ad*sorbed by the zinc on aluminium plate, is to provide a slightly soluble layer so that a "tint" due to a slight deposition of the printing ink during machining can be readily removed by the machine man with a wet cloth. "Cellopas" is said to be superior to gum for this purpose. (See *Patra Journal*, X 3, 1947, pp. 115–117.)

thing—and others will reject that material, and, therefore, if a design be made on the surface of stone or metal (zinc or aluminium) with the one, and the other be applied to the spaces where the design has not been made, we have all that is necessary for a printing process, provided that these two conditions of "accepter" and "rejecter" can be maintained in their original forms. If we draw upon a lithographic stone with lithographic ink—made, for example, as in the formula already given—and when that ink is dry apply a solution of gum arabic (gum acacia) to the stone and allow that gum arabic to dry, on wetting the stone the parts covered by the gum will, for a brief time, hold water. If now a roller charged with varnish ink be passed over the stone, the ink will "take" upon the ink design. It is usual—though not essential for the purpose of demonstrating the principle—to rub over the surface, after the stone has been allowed to dry, french chalk. This adheres to the image and makes it more resistant, largely because of its repellent character for any aqueous solution. A dilute solution of nitric acid is now applied—the so-called "etch." This, by dissolving away the *immediate* surface of the stone, takes away dirt or "scum" which may have accumulated. The surface is washed and again gummed and dried, and then wetted. A remarkable action is now taken by the printer. Whilst the stone is wet a little turpentine is sprinkled on the surface, and the stone rubbed over with a rag and then wiped with a moist cloth again. There will be seen the design in a *very pale grey tone*, this being due to the infiltrated constituents of the ink. Still maintaining dampness, if the stone be re-rolled with the inking roller the design comes back, and this design can be transferred by pressure to paper, the stone redamped, and again rolled up for the next impression.

What has taken place is that the essential constituents

of the ink have penetrated the stone and have formed the water-rejecting area—the pigment particles not essential for *image* formation are too large to enter the pores of the stone and, therefore, remain behind. It is interesting to notice that without the gum there would be a tendency towards a lateral spread of the image. This lateral spread is sometimes seen if a stone be left not "under gum" for any length of time. The image extends, and so a fine stipple or fine line job will after a time become coarsened. It will be seen that neither the presence of the pigment, nor of the surface varnish together constituting the ink applied, nor of the pigment in the original litho drawing ink, is essential to the return of the image on re-rolling up. The rejecting material has penetrated the stone and, consequently, water will not take or hold on those parts, so the image "rolls up" and becomes full and strong on the second application of the inking roller.

Water is essential, and there is, more or less, always difficulty in the stone holding the water during printing, especially in warm weather, in badly-designed and ventilated printing offices. In printing, some stones are smooth but others are rough "grained," the surface being by means of a grinding process covered with a series of small pits.

LITHOGRAPHY IN GRADATED TONES

Grained stones are used as a basis for making "chalk" drawings, that is, drawings with a "fatty" crayon, called a "lithographic chalk," such drawings being made to give the semblance of "continuous tone" (Fig. 32), whilst being really "broken tone," for a line drawn on a grained surface will not be a continuous line as it would were it drawn upon a smooth surface, and with greater or less pressure the imitation of a dark or a grey line can be produced.[1]

[1] The principle involved in the production of gradated tones is precisely the same as in the half-tone process (see p. 171). Instead of the fatty crayon, gradation can be produced by "stippling" dots with brush or pen, using "fatty" ink. See also shading media and the like, p. 290.

These pits produced by the graining operation hold water in addition to that held by the pores, whilst the smooth stone depends on the pores. In consequence, the grained stone gives less trouble during printing so far as the maintenance of a moist surface is concerned. Now metal plates are not porous, and present considerable difficulty in printing, which is lessened by giving a "grain" to the surface. But a grain is inimical, from the artist's point of view, to the formation of very fine images, and so the grain is kept as fine and as shallow as practicable, which

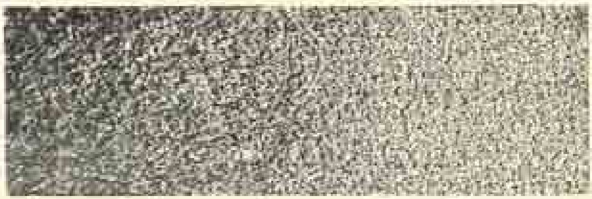


FIG. 32. A PATCH OF GRADATED TONE (MAGNIFIED) PRODUCED BY DRAWING WITH A FATTY CRAYON UPON A GRAINED OR ROUGHENED SURFACE

mars its value from the printer's aspect. In the early days of zinc printing, when only fine line work, as in early photo-lithography, was done, the so-called "anastatic" grain was employed, which was a film on the metal produced by the action of a solution of nitric acid and alum. This was excellent from the point of view of allowing a fine image to be produced, but it soon wore away during the printing operation, and such plates were unpractical as printing surfaces (see page 276).

The present-day grain upon the metal is produced mechanically by placing the metal plates in a box and covering the surface with fine sand or glass powder, which is then wetted. Over this surface there is placed, so as to cover the whole area, marbles of glass or porcelain about 2 in. in diameter. The box is now caused to move fairly rapidly with an eccentric horizontal motion, and

eventually, on cleaning the plate, the surface is found to be pitted. The fineness of the grain is determined largely by the fineness of the glass powder or sand grains, and the time of graining. Other factors influencing the grain are the amount of water, the speed of graining, and the size and number of the marbles. The number (and nature) of the marbles used is important, for as this number increases so does the number of grinding points, a grinding point being where the marble touches. It is not easy to standardize the process of graining, and so produce results having *constant* character, save by considerable experience. One of the principal causes is that the gritty material used, the sand or glass, changes as the graining proceeds, becoming "pasty" with the water and losing its "cutting" character, and this change is progressive. So, as stated above, considerable experience is needed, and the procedure dictated by this experience should be maintained in the graining operation. In the Litho Preparation Room of the College of Technology, Manchester, carborundum powder was early introduced in lieu of sand and glass powder with success. The powder used is 40's, 100's, and 220's. The character of the grain produced is good, and although carborundum is higher in price than the powders previously employed the process is strictly economical.

Considerable attention has during recent years been given to the subject of the best methods of producing "grain" upon metal plates—the grain which is the necessity for holding water during the operation of rolling up the image with varnish ink. The polished metal itself, unlike stone, does not absorb water or at least does not absorb it to an appreciable and sufficient extent, and therefore does not offer—the necessity for which has been explained—a rejecting surface in the non-image parts. As explained on page 276 the difficulty was sought to be

overcome by the "anastatic grain," but the surface so produced soon wore off and was a quite impracticable device in routine printing. It suggested that the thing to do was to produce a series of cavities—a substitute for the natural minute cavities of a porous surface—to hold water, but the production of the surface required has proved to be by no means easy. Recently, however, good work has been done on this subject. C. C. Redman has considered the whole matter and in a thoughtful paper ("The Photo-litho Plate Surface," *Photo-Engraver's Monthly*, May–June, 1948, pp. 139 and 177) gives considerable detail on the principal methods for producing a suitable grain by sand blast and ball abrasive methods. The paper gives considerable detail and is well illustrated. As might be imagined, it is possible to produce a variety of grains with different degrees of "fineness" by varying the abrasive material, glass, quartz, flint, carborundum, aloxite or garnet, and the conditions of their use. It is interesting to note that certain sea sands with their rounded grains—owing to weathering—are of no value for graining. The marbles employed may be of steel, porcelain, glass in sizes between $\frac{3}{8}$ in. and $1\frac{1}{4}$ in. diameter. Increases in the weight of the marble produce increases in the depth of the grain, while the material of the plate, presenting as it does differences in hardness, controls the depth and sharpness of the grain. Stress is laid on the influence of the practical experience of the grainer in producing particular grains and their uniformity one day with another when it is sought—as is quite necessary—to standardize the effects, for the process is never automatic when a given grain is sought. The kind of grain is important because it controls the water-holding capacity of the surface of the plate and is a further important factor in determining the rendering of gradation as compared with the original subject being portrayed. In

this essential see Bruno M. H. and C. W. Jorgensen in The Control of Tone Reproduction in Lithography (Lithographical Technical Foundation, U.S.A., April, 1948).

As might be expected the size and type of grain affect the detail of the printed image and influence the thickness of the sensitive film used.

The student should consult these valuable papers,

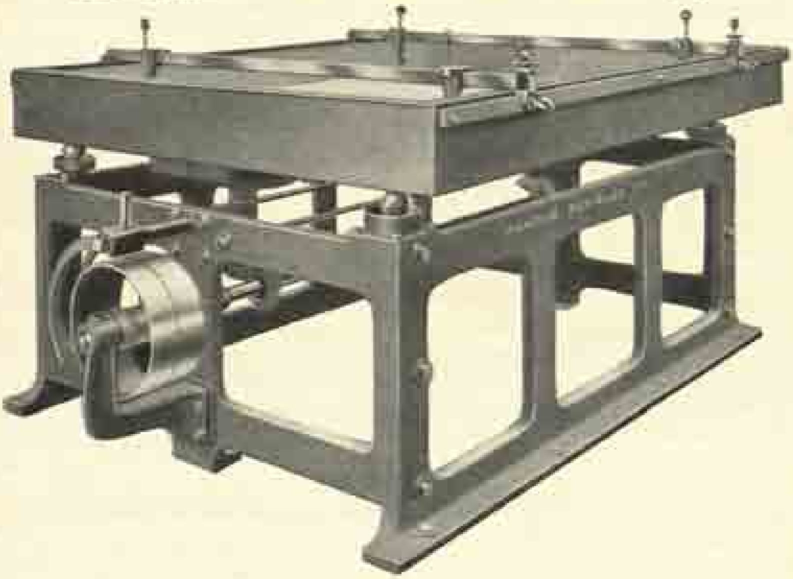


FIG. 33. MACHINE FOR "GRAINING" METAL PLATES FOR LITHOGRAPHY
(HUNTER-PENROSE)

more especially if he be engaged in any branch of photolithography since the type of grain produced on the plate will considerably affect the "printing down" procedure and a full knowledge is desirable.

P.A.T.R.A. has also conducted a series of experiments which may be regarded as a continuation in detail of those described by Redman. In these it is sought to provide a reliable knowledge of the printing properties of the particular types of grain.

The matter of plate grain was methodically and quantitatively investigated by G. A. H. Elton and G. Macdougall (*J. Soc. Chem. Ind.*, Vol. LXV, 1946, pp. 212–215), and to this important paper the reader is referred. The work was undertaken by P.A.T.R.A.

RECENT RESEARCHES INTO METALLOGRAPHY

The principles underlying lithographic printing have been carefully studied experimentally by Tritton, whose conclusions were communicated to the Society of Chemical Industry in 1932, and the paper should certainly be studied by those who desire a full knowledge of the process. (See *A Study of the Theory of Lithographic Printing*, Tritton, F. J., *J. Soc. Chem. Ind.*, LI, No. 36, Sept. 2, pp. 299T–306T, and No. 37, Sept. 9, pp. 307T–313T, 1932.)

Briefly, Tritton concludes, "that in the case of metal plates lithography is based essentially on the *ad*sorption[1] of fatty acid by the metal, while the non-image areas are kept free from ink by gum arabic, which is apparently also *ad*sorbed on to the metal. The chemical action of sensitizers has been examined, and they have been shown to produce basic substances on the face of the plate, which substances are therefore capable of *ad*sorbing fatty acids. Lithographic etches produce non-polar deposits not capable of *ad*sorbing an acid, while both contact angle and lithographic experiments have been used to demonstrate that, in the absence of *ad*sorption, water is capable of displacing *greases* from the surface of litho plates; thus for the first time it is possible to explain the real difference between grease receptive and water receptive lithographic surfaces. The majority of etches form films of aluminium

[1] The student must try to understand the meaning of *ad*sorption, which is not the same as "absorption." *Ad*sorption means the *adhesion* of the substance to the *surface* of the body, whilst the word "absorption" is intended to convey that one body fills up the interstices of another body as water fills up a sponge.

phosphate or zinc ammonium phosphate on these two metals."

The Author is concerned in this book with lithography and its principles as they are utilized in the photo-mechanical processes, that is, in *photo*-lithography, *photo*-zincography, and *photo*-algraphy, and sufficient has now been said by way of introduction to the subject. There are now to be considered the ways and means by which the necessary images are produced upon the surface of stone or metal without the hand of the artist, that is, by a photographic process, observing that when once the image has been so produced its after-treatment and procedure for the making of prints does not differ—save perhaps that in some cases greater care is required—from that which obtains in ordinary hand-drawn lithography.

THE PROCESS OF PHOTO-LITHOGRAPHY

The methods which are adopted are those in which there is employed the main underlying principle in the production of images for photo-mechanical purposes, viz. the production of insolubility, and the separate adaptations of this principle can be stated quite briefly.

(*a*) A sheet of paper coated with bichromated gelatine is exposed to light under a "direct" (unreversed) line negative. After sufficient light action, the paper is withdrawn, and is then coated on the exposed gelatine surface with a thin film of photo-litho transfer ink, afterwards allowing the sheet to stand for a brief period to enable any diluent used with the ink to evaporate. The transfer is wetted; the exposed portions do not absorb water, the unexposed portions do. If the surface is gently rubbed with cotton wool or sponge, the whole of the ink comes away from the unexposed parts, leaving the ink on the exposed lines. Finally, there remains a print in which the lines of the original are represented by lines of insolubilized

gelatine which hold tenaciously upon their surfaces a thin film of litho "transfer" ink. The "transfer" is now dried. Within any reasonable period of time the transfer may be damped in the usual way which obtains in the practice of lithography, and the ink image can then be transferred to stone or metal.

This is photo-lithography by gelatine photo-transfer, first introduced in 1859 by J. W. Osborne, in the Survey Office of Victoria, at Melbourne. Originally, the soluble gelatine in the transfers was washed away in hot water, leaving the insoluble ink-bearing portions behind. It was A. Wood, in 1863 (*Photographic News*, 1863, p. 154), who first pointed out that hot water was not necessary, and who gave the present method of development of the transfer, viz. by rubbing the wet transfer with a sponge to remove the ink from the soluble parts—the whites.

This method is one capable of yielding excellent results, and was in general vogue until it was very largely replaced some few years ago by direct photo-lithography, which, incidentally, can be used equally well for the preparation of transfers when transmission of the finished metal plate from maker to user may not be convenient.

(*b*) A piece of zinc (or aluminium) slightly larger than the image is taken, and is grained with a fine mechanical grain and afterwards made clean. It is then coated with a solution of albumen (or fish glue) and ammonium bichromate, rotated upon a whirling device for the purpose of producing a thin—and uniformly thin—film, and is dried by gentle heat over an electric heater, or a gas flame face up to avoid products of combustion reaching the coating. It is now exposed under a negative, the exposure to light being sufficient to render the whole thickness of the film under the clear portions of the negative quite insoluble. The plate is removed and coated—preferably, though not essentially, by means of a roller—with litho

transfer ink, which should be "short," and after a very brief time, sufficient to evaporate the diluent of the ink, the plate is placed in water. After a minute or two the image can be developed in the same manner as the paper transfer. The plate is now rinsed and is given an ammonium phosphate-nitrate[1] "etch," rinsed, dried, and then wiped over with an even film of *thin* gum arabic solution.

Trouble frequently occurs owing to the surface of the metal of zinc litho plates being affected by corrosion, especially if they be kept in a warm and moist atmosphere so that the plate may be made useless. To remedy this the *Cronak* process has been perfected. This consists in treating the metal surface to begin with by a solution of soluble chromate and bichromate with the addition of sulphuric acid, when there is formed on the metal a firmly adherent film of chromium chromate. This enables the plate to resist oxidation, the printed images develop more easily in the first place, and possibly it prints better. (See *Patra Journal*, X, 5th December, 1947.)

There are now proceeding experiments to see if a treatment cannot be evolved for aluminium plates for a similar purpose. At present the method adopted is as that for zinc, using a solution of ammonium bichromate and hydrofluoric acid in water. This is the basis of the *Brunak* method.

It may be mentioned that most photo-litho transfer ink commercially supplied is greatly improved by the addition of *real* bees-wax. To six parts of transfer ink one part of bees-wax is added, and the whole melted and thoroughly mixed together. This makes the ink "short." As a diluent for the ink, there is no better solvent than turpentine, but as good turpentine is expensive, a suitable

[1] This is only one form of "etch." Many other solutions are used in its place.

substitute is "coal-tar naphtha," which is volatile, leaving no greasy residue.

It is advisable to allow the plate to stand for a short time before use. It can be now used as a printing plate or a plate for the purpose of providing transfers in the usual lithographic manner.

In lieu of albumen, fish glue may be used. It is, however, more expensive and does not give so sensitive a film, but it is far more convenient. Fishenden showed that when fish glue is used it is an advantage to place the plate for a brief time in a solution of chrome alum immediately after development.

This is the "direct" process of photo-lithography. The direct processes antedated the processes for producing transfers. The first process for direct printing was introduced in 1853 by Lemercier and by Lerebour, both of whom employed bitumen (see page 240) as the sensitive agent. This process was used by Macpherson in Rome in 1855, and in the Imperial State Printing Office, Vienna, 1859. In 1855, Poitevin, the French chemist, introduced for the first time the process of printing direct upon stone, using a film of bichromated gelatine for photo-lithography. In 1859, Asser, of Amsterdam, used bichromated gum coated upon blotting paper, and in 1860, Sir Henry James employed bichromated gelatine paper at the Ordnance Survey Office at Southampton.

The student may note that in the early days of these processes of surface printing they were all classed under the term "Photo Lithography," but at the International Congress of Photography held in Paris in 1889, the subject of nomenclature was considered, and the word "Photo-Collographic" was adopted for Poitevin's process, because it was recognized that there was no lithography about the method, the lithographic stone being merely a support for the gelatine film. Eventually, glass was adopted. For

"Photo-Collographic," we in English-speaking countries employ the word "Collotype," and in German-speaking countries the word "Lichtdruck" is used.

Where a good tracing of the line subject exists and copies are desired, a useful method is that due to Vandyke (who was originally a Sapper in the Royal Engineers), which was perfected in the India Survey Office. A sheet of metal is grained and made clean in the usual manner, coated with bichromated fish glue, and dried. It is then exposed under the tracing, with the image next to the film, for a sufficient time to make the film under the clear parts quite insoluble. After this exposure the plate is developed in warm water. In order to see the image, which is practically invisible, the plate is drained and then flowed over with an aqueous solution of a coal-tar colour—*methyl violet* is a suitable substance—when the dyed image can be seen. If correct and free from flaws the plate is well rinsed and dried. In order to free all the bare parts of the metal—the lines—from any trace of the fish glue, the plate is immersed in a very weak solution of ferric chloride, which, when diluted has only a slight etching action, and this cleans the surface. The plate is now rinsed and dried. Any uncovered places which have been left are now covered over by means of a brush dipped in gum arabic solution. There is then rubbed over the dry plate a fatty ink, composed of lithographic printing and lithographic writing inks, copper-plate transfer ink, asphalt, and resin.[1] A mixture of this ink in turpentine to a liquid condition is now made, and is applied to the plate by means of a piece of soft flannel wherever there is image, avoiding unnecessary places, viz. where there is not uncovered metal—the non-image parts. The plate is now well warmed and then is allowed to cool, and is afterwards

[1] An unnecessary complication. Far simpler "inks" are now employed in this kind of process.

placed in a very dilute solution of hydrochloric acid, 2 per cent. After a few minutes, on being gently rubbed with a tuft of cotton wool, the fish-glue film will be detached, leaving a firm and strong ink image upon the metal. The plate is now etched, washed, coated evenly with thin gum, and dried, when it is ready for proofing. Modifications of this process, following the same principle, have been introduced by Douglas, of the Photo Process Department of the Egyptian Survey Office, Cairo, and by Roussel, Telkampf, and others.

PHOTO-LITHO PLATES FOR OFFSET PRINTING—SURFACE AND "DEEP ETCH"

Photo-litho plates are of two kinds: surface "negative," or "positive reversal," and positive reversal "recessed," "deep etch" or "offset deep." In the second kind the recess is *very slight*. In both kinds the zinc plates are grained to meet the necessities of printing (see page 229) but the grain—especially when pronounced, or coarse—is inimical to perfect plate production so far as the regularity of a fine line or dot image is concerned. In the surface plate the grain is the main contributory to irregularity in shape of the dot and to the more or less rough edge or fringe, both of which increase with increase in grain coarseness. This effect is reduced in the recessed plate. Even the very slight recession which obtains in good "deep etch" plates gives cavities with less fringe, especially on fine grain plates when the initial stage has been a well-printed resist image preparatory to the etching for recession. The recessed plate carries more ink—without spread—than the surface plate and enables a richer impression to be obtained on the blanket and thence to the sheet. In the true surface plate, by positive reversal, and in the recessed plate, the image after development is clean metal. In that state it receives a

coating of litho transfer ink, when there is formed a real union as in ordinary lithographic practice. In the ordinary negative process, when an exposed and therefore an insoluble colloid image is inked and then developed, the insolubilized image remains on the plate, insulating the metal from the ink. Such images cannot be so durable as when the ink comes directly in contact with the metal.

The method of production for the ordinary negative process is given on p. 222. In the positive reversal process, a negative stencil is produced by printing under the positive after the routine given for the Vandyke process (p. 235) but with improved technique. The stencil reveals an image of bare metal. The surface is now coated with transfer ink, when adhesion with the metal is established. The stencil is eventually removed, leaving the ink image.

There is little doubt that the photo-litho deep etch plate is better than the surface, and the principal reasons have been given. At present the main work that is being done in photo-lithography is for the improvement of the "deep etch" process, or "intaglio" etching as it is sometimes called. This term was, however, first applied to the invert half-tone process (see page 211).

The procedure briefly for the production of a "deep etch" plate is as follows. The carefully cleaned grained plate is treated with a dilute solution of acetic acid, washed, brushed and washed again. It is then coated with a solution of best quality gum acacia and ammonium bichromate, whirled and dried and exposed under a good positive—one in which the image is sharp and opaque. The exposed image is developed with a solution of calcium chloride and lactic acid, the image being *gently* rubbed for development. Etching is now done with a solution of calcium chloride, ferric chloride and hydrochloric acid, the etching process being very deep. Industrial spirit is now applied, after which the plate is dried

off. The image is next coated with reversing ink, which is well rubbed in. Afterwards the stencil—the exposed gum film—is removed by rubbing with a soft pad and slightly acidulated water, and the image is treated with "litho etch" and then gummed in.[1]

The purpose of the final "etch" is to remove from the bare portion of the metal plate any matter which might attract ink when the plate is printed and so cause scumming. The basis of the "etch" is phosphoric acid, or a phosphate and ammonium nitrate and sodium nitrate are used. There are several proprietary "etches" used by experienced printers and supplied by process material houses.

This process is due to Mason Willy, and is fully described in *Practical Photo-Lithography*.

Amongst the "deep etch" methods there is the proprietary process Howter offset deep etch method.

The metals used are zinc and aluminium, and the procedure is almost identical with either. The fact that zinc is far the more used would seem to indicate that in practical experience it is the better, although aluminium is not without its strong advocates.

For details of the methods of producing photo-litho plates, see Mason Willy, C., *Practical Photo-Lithography* (Pitman).

For a critical review of processes and detail directions for special methods of procedure, see Cartwright, H. Mills, and others, "Improvements in Photo-Lithography," *Photographic Journal*, Vol. LXXI, 1931, pp. 226–273.

DIRECT PRINTING UPON STONE

To revert to the production of images in which a photographic negative is used, it may be said that prints can be produced direct upon stone—the method of the early investigators—although the use of stones beyond a

[1] The depth of etching varies between 0·0003 and 0·0005 in. (P.A.T.R.A.)

certain size is obviously inconvenient. The method had the advantage that for fine line work the results are probably as sharp and well-defined as it is practicable to obtain. The well-polished stone is warmed and coated in the ordinary way, and dried by being placed near a source of heat so that the surface becomes slightly warmed; or the slightly warmed stone may be gently rubbed over with a pad dipped in a solution about twice the normal concentration and then dried. As regards securing contact, the Author has found that the best type of negative to employ is a wet collodion film thickened by rubber and flexible enamel collodion stripped from its glass support. The stone, sensitive coated, is now placed level, and over it is poured a mixture of equal parts of mineral oil (the so-called "medicinal" paraffin is excellent for the purpose) and mineral naphtha. The film negative is lowered on to this mixture and then squeezed to the stone with a rubber squeegee. This method answers admirably, excellent contact being possible. After exposure, the negative is lifted off and stored between sheets of paper for future use. The surface of the stone is now freed from oil by means of clean naphtha, being finished off with turpentine, and afterwards transfer ink is applied in the usual manner. The stone is then developed, washed, and gummed up. This method is a good one for small work, because small stones are not inconvenient. It is less important now, and far less convenient, because metal plates are more easily obtainable, but it is desirable that the student of reproduction methods should know at least the outline of the mode of use.

THE USE OF ASPHALT OR BITUMEN IN RESIST MAKING

Prior to the use of bichromated albumen, gum, and fish glue, another substance was employed, viz. asphalt or

bitumen of Judea—the employment of which is of considerable historic interest—where the principle of change in solubility was also utilized. Although, to-day, asphalt is in practice probably never used, it was of great importance in the past, and some knowledge of the substance and its method of use is desirable as part of the student's education.

Asphalt, or bitumen of Judea, sometimes called "Syrian Asphalt," is a naturally-occurring substance which is regarded as a fossilized resin, but is sometimes considered as a solidified petroleum which has undergone a change. This body should not be confused with the viscous, practically solid body, which forms the material of the so-called Pitch Lakes in Trinidad, and which is useless for photographic purposes. Syrian Asphalt is a black body, brittle, breaking with a glassy fracture, and may be resolved, by pulverizing, into a brown powder. It is wholly soluble in benzene, chloroform, and turpentine, partially soluble in ethyl ether, and a small portion dissolves in alcohol. Actually, it may be resolved by means of differential solution into three substances of interest to the experimental photographer. If powdered asphalt be treated with ether a large portion dissolves. When the mass is free from the ether soluble constituent, the residue will yield to alcohol a few per cent of a brownish constituent, leaving finally a black amorphous body. This is technically known as "washed bitumen," which is soluble in benzene, and is also soluble in turpentine. It is this portion alone which is sensitive to light. If a solution be made in benzene and a thin film be produced upon metal and exposed to light, a change takes place by which the body is no longer soluble in turpentine, and it is this change of light which was utilized for practical picture-making in the earliest days of photography. It was Joseph Nicéphore de Niepcé, in 1813–27, who, studying

the action of light upon resins, perfected process for a utilizing the light-sensitive properties of asphalt, producing by his method. which he called "Heliography," an intaglio metal plate; and for this discovery, which may be regarded as the forerunner of the modern process of photogravure, Niepcé may be regarded as the Father of photo-mechanical photography.

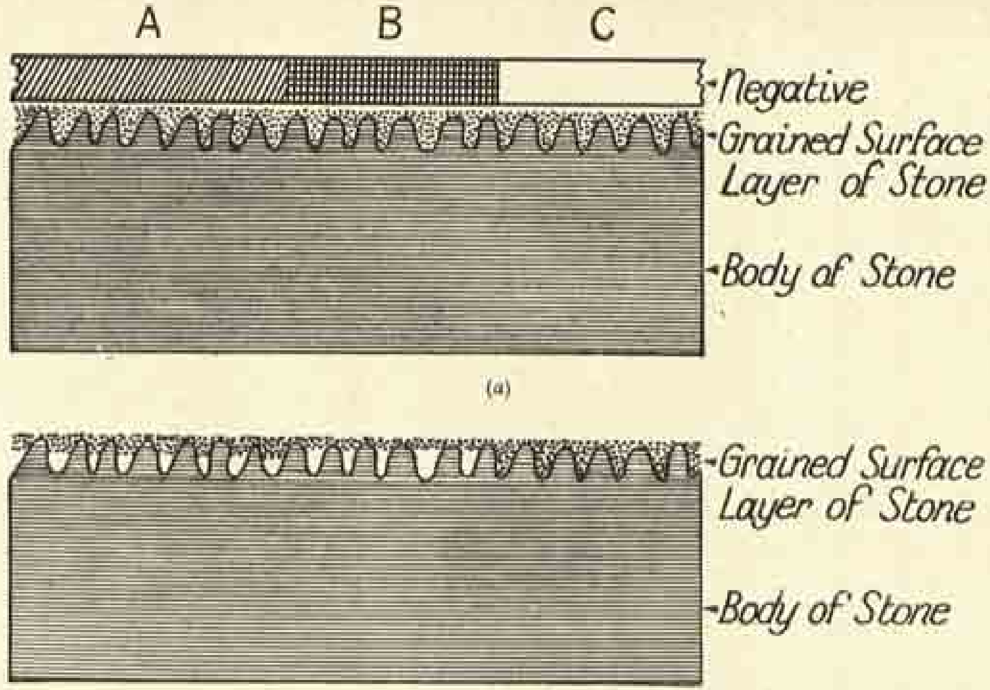
Since Niepcé's time asphalt has been largely used for the purpose of resist making. If the most sensitive film be required—and this is desirable since under the most favourable circumstances bitumen is exceedingly insensitive compared with bichromated albumen—ether-washed bitumen is employed in solution in benzene to which some chloroform and a very small quantity of oil of lavender are added. Development after exposure is effected by means of turpentine. Valenta has shown that by heating bitumen and sulphur together for a considerable time a body is formed which is more sensitive than ordinary bitumen, but the Author can state from practical experience that the gain is not commensurate with the trouble involved in the method.

Bitumen has two great advantages. It gives a very sharp line which is better than that given in the albumen ink process, for in the latter there is a tendency for the edges to "drag" and become ragged during development, more especially when the print has been too fully inked before development. Further to this, there is a tendency to "raggedness" at the edges of the line during development if the exposure has not been sufficient to give a firm print. This latter shows in *any* process, but in the ink development process, where the image is touched, the defect is exaggerated. Bitumen is also capable of withstanding, for some little time without any reinforcement, the action of dilute acid used in the first stage of etching, a property not possessed by the initial inked albumen

line. But the cost and the insensitiveness of the film compared with the substances now used—which are especially important, since, under the stress of modern life in a reproduction studio, artificial light must be used—are serious drawbacks, and so asphalt remains now but an interesting milestone along the road of technical progress.

DIRECT PRODUCTION OF GRADATED PICTURES BY MEANS OF BITUMEN ON STONE

The student who may have grasped the principle will be constantly puzzled when reading the history of the early processes and some later developments to find surface processes described for producing pictures in gradated tones by exposing a film of bitumen upon a lithographic stone under an ordinary, that is a continuous-tone, negative, and may find difficulty in understanding how such a procedure can give any useful result. But the method does work and has given useful results, and it is desirable that he should understand the reasons for its working. It should be remembered that when the bichromated albumen or fish glue, or the bitumen processes, are used with broken-tone negatives, there is employed what is essentially a smooth plate (for the grain is very fine) which receives a uniform coating of the sensitive material. In the process where a continuous-tone negative is employed, the surface receiving the sensitive coating is not smooth but is "grained"—and the grain is deep—with the consequence that the film is not uniform in thickness but varies from one grain to another, and from one part of the same grain to another part. Consider now what would be the effect of exposing such a sensitive surface under a continuous-tone negative, a negative the tones of which have different degrees of opacity and, therefore, transmit different amounts of light. We have a film upon a deeply-grained stone, a condition suggested



(b)

FIG. 34. (a) BEFORE EXPOSURE. SECTION OF GRAINED STONE BEARING FILM OF SENSITIVE BITUMEN (DOTTED PORTION) WITH A THREE-TONE NEGATIVE (b) THE STONE AFTER EXPOSURE AND DEVELOPMENT. THE DIFFERENCE IN THE DOTTED PORTION REPRESENTS THE DIFFERENCE IN THE AMOUNT OF BITUMEN MADE INSOLUBLE

in Fig. 34. The dotted shading represents the film of bitumen, and the horizontal lines of shading the stone. It will be seen that the bitumen covers the top of the grains all over the surface to a slight extent. Above is the negative, where *A* is a medium tone, *B* more opaque, and *C* quite transparent, so that in a given time of exposure a certain amount of light has passed through *A*, not quite so much through *B*, but more through *C*, because it is transparent. Now let us assume that the time of exposure has been such that the coating under *C* has become wholly changed, so that down to the bottom of the cavities the whole of the bitumen has been altered. Then, because there has not been so much light passed through *A* there will not be so much bitumen changed, and there will be still less under *B*. Say, that under *A* it has changed through one-half of the thickness, and under *B* to one-quarter of the thickness. Now let us consider the next stage, when the film has been subjected to the action of the dissolving turpentine. The unchanged parts dissolve away, leaving the insoluble, that is, the changed, bitumen behind.

THE EFFECT OF EXPOSURE

Now, apparently, the whole surface of the stone is covered, and it ought to take one uniform film of ink and give no sign of difference to show difference of tone. But as a matter of fact it does show a difference, and that difference is probably due to the fact that there is a rubbing process during development, and the less exposed parts come away, leaving the more exposed parts sticking to the stone to different degrees. It might be expected that such a process would not give very perfect rendering of the gradations in the negative, and such, as a matter of fact, is the case. Widely differentiated tones are shown, fine differences are not shown. Such a process cannot be

used with any great satisfaction for "one-printing" work. Where it has been used, as some years ago in colour work, many printings were employed, almost always in connection with hand-work, and the different printings were made to correct individual deficiencies. Nevertheless, fair work has been done even in one printing. The earliest published print appears to have been produced from a negative of the Angel Dial on the Exterior of Chartres Cathedral. This was published in 1852. A reproduction of the original is to be seen in Eder's *Handbuch der Photographie*, Vol. I., Part 1, and even in the reproduction the rendering of gradation is reasonably good.

GRADATED TONES IN LITHOGRAPHY BY MEANS OF BICHROMATED GELATINE

There are, however, other methods which are used in surface printing for the production of tonal gradation which may be termed "natural" methods, processes where changes in the physical condition of the sensitive surface produce the selective effect, as distinct from optical and mechanical methods. Processes of this character were in use, in fact, long before the introduction of the optical method, and were employed long after the introduction of the latter mode. It is convenient at this stage to discuss their nature, observing that there was only one principle of moment in use, namely, the rendering of gradation by the differential grain produced by the reticulation of a layer of bichromated gelatine, which reticulation was primarily governed by the degree of exposure to light. The first process of this character was that of Paul Pretsch (1854), termed by him "photo-galvanographic." First introduced for the purpose of producing intaglio matrices, it was afterwards employed in making type-high blocks for the letterpress machine. There has been considerable controversy as to the claims to priority between

the two contemporary workers, Pretsch and Poitevin, and the decision as to who was actually the first when there was so little difference in point of time between the two is not very easy, and discussion is somewhat profitless. The De Luynes prize of 8,000 fr. was awarded to Poitevin, as against Pretsch and other competitors, by the French Photographic Society in 1867 for the best work, without deciding questions of priority. To give each one his precise measure of due at this juncture, so long afterwards, when the literature published at the time is far from precise, is not easy. What, however, may be said with respect to parentage is that Poitevin must be regarded as the parent of Collotype, whilst to Pretsch we must assign typographic block-making, which originally was due, as explained, to the swelling and reticulation of gelatine.

THE "RETICULATION" EFFECT

If a film of gelatine be taken and impregnated with potassium bichromate by immersion, be then allowed to dry spontaneously at ordinary temperatures, and afterwards be exposed to light, for a period less than that required to produce complete insolubility, finally being placed in water, it will absorb a certain quantity of the water and will swell to a slight extent, both the absorption and the swelling being governed by the degree of insolubility produced by light action, but the swollen film will be quite smooth. The gelatine is said to have been "hardened" by exposure to light. With different kinds of gelatine, absorptions of water differ, and the term "hardness" is used roughly to express this fact, a "hard" gelatine meaning that it will absorb less water than a "soft" gelatine. The expression fairly accurately describes one effect of the exposure. If, however, the bichromated gelatine be produced in liquid form, and a

film coated on ground-surfaced glass at a fairly high temperature, say, at 60° C., or an impregnated coating on paper, as in the first instance, be dried in warm air, the gelatine appears to dry in a state of strain. If exposed to light and immersed in water the partial swelling takes place, but the surface no longer remains smooth; it "crinkles," the swollen portion becomes "reticulated," and the amount of reticulation (and to some extent its precise nature) varies with different amounts of exposure. A similar effect takes place with the gelatine on the paper, and the effect is increased if the soaking water be warmed, an untoward effect sometimes observed when this condition—fairly high temperature in the drying room, and, water above normal temperature for development—has, through oversight, been allowed to occur when making ordinary photo-lithographic transfers. This reticulation can be varied by the addition of certain substances to the sensitizing solution for photo-litho paper, and, based on observations of this nature, a process for producing transfers, giving rendering in half-tone, was worked out by Sergeant-Major Husband, who was probably the first lithographer enlisted in the Corps of Royal Engineers, in the Photo. School of the School of Military Engineering at Chatham, and published in 1887 ("Practical Lithography in Half-tone," *Photographic Journal*, April 29, 1887). Husband's process, "Papyrotint," which was a modification of Abney's process, "Papyrograph," employed a sensitizing bath of potassium bichromate, sodium chloride, and potassium ferricyanide. After exposure under a continuous-tone negative, the paper was placed in water, and when fully swollen was surface-dried and inked up with a composition roller charged with lithographic transfer ink until a clean well-defined image was obtained. The transfer was then placed in a solution of potassium bichromate and tannin, removed, dried, and

exposed to light. After exposure the transfer was damped and the image transferred to stone. In this process the "grain," or reticulation, develops on wetting in accord with the exposure, so that there is a different amount of grain in parts that have received different amounts of light during the exposure when printing, viz. in the different tones of the subject. The general size of the grain is governed by the amount of potassium ferricyanide and the temperature of drying of the paper after sensitizing, and also by the use of water at different temperatures—not cold—in the first soaking after exposure. For the character of this reticulation, see Fig. 35, page 256.

Processes of this character have been worked successfully on a commercial scale. It may, however, be observed that the results depend, as may be seen by this description, upon the nice observance of many conditions, involving considerable skill, and few business houses essayed the work. But they are practicable for those who will give the necessary attention to detail. Transfers may be pulled from the stone, laid down on metal, and then etched for type-high printing, and this was one method employed for the production of type-high blocks before the screen half-tone processes had obtained a fair degree of success.

HISTORICAL METHODS—THE PRETSCH PROCESS

The reticulation of gelatine has other interesting features. It was utilized by Paul Pretsch, in 1854, in his process of "photo-galvanography," which was an intaglio process in the first instance, and one of the earliest practical methods of photogravure, being, in point of time, the immediate successor to the process of Fox Talbot. Pretsch produced his plate by exposing a sheet of glass coated with glue, potassium bichromate, silver iodide, and

silver chromate[1] under a positive. This plate, after development in water, showed reticulation. From this a mould was made in gutta-percha, or in a spermaceti-asphaltum-plumbago mixture, which mould was afterwards electrotyped, and from this another was made, which, backed up by type metal, constituted the *intaglio* printing plate. It is interesting to note that the cellular structure necessary in all intaglio plate processes where a wiping method is employed (barring the "doctor" wipe) —the practice in all cases—is furnished by the reticulation.

An admirable example of Pretsch's intaglio process is to be seen in the *Photographic Journal*, Vol. VI, 1859, facing page 28. This picture is doubly interesting by reason of the fact that the plate from which it was printed was one of the earliest to receive, by electro-deposition, a coating of iron as a protection against wear in the printing process, the so-called "steel facing."

As a further application of reticulation, Pretsch, at a later date, developed his method and produced relief blocks for use in the letterpress machine. There are many good examples of Pretsch's relief block-work to be seen in publications of the day, amongst which may be mentioned, as being easy of access to the student, the Porch of Strasburg Cathedral, in the *British Journal of Photography*, Vol. VII, 1860, facing page 340. This was printed on a platen press as a separate supplement, but in the following issue there is another picture, Dover Castle, which was printed in the text of the journal, to which the historically-minded student is referred. Both of these illustrations are remarkably good considering the state of development of Pretsch's process at the time; indeed, it

[1] It is not known whether Pretsch intended there to be silver chromate, but the quantities of potassium iodide and silver nitrate in his formula would leave an excess of silver nitrate, which would yield, on mixing with the bichromated glue of his formula, some silver chromate. Pretsch, himself, later stated that he thought that the granular appearance of his films was due more to the formation of silver chromate than to the iodide.

was only after some years' working that the screen half-tone process produced anything so effective. This reticulated gelatine method for the production of type-high blocks was afterwards developed and improved by the work of Dawson and Dallas in England, and Lemercier in France, and was in regular use for many years.

Examination of the prints from the relief blocks, to which reference is now made, will reveal that although they purpose to show gradation of tone and actually do show such gradation, and are remarkably good as demonstrating what was done in the early days of processes for tonal rendering, the total amount of gradation is small. There is the outline and there are a few tones, and yet the general effect is good. Similar effects are shown in many of these processes for rendering gradation. In Asser's starch process, in the papyrotint process of Husband, in the bitumen process of Albertini (1898), in the process of Ackerman, and, in fact, in any process of this nature, little gradation is shown. Yet they were at the time accepted and even praised by photographers who were acquainted with methods for rendering gradation well, and who were, moreover, keenly critical; from which it appears that for certain types of illustration, so long as the outline of patches of gradation that widely differ is preserved, so long as the picture is rendered in a few dominant tones, the imagination does the rest, and the absence of the more delicate gradations is not perceived by many technical observers, and still less by the layman—which is in harmony with the well-known fact that we recognize familiar objects by their outlines, by their shape, more than by any gradations of light and shade. All interested in pictures know how a clever pen draughtsman will indicate, by means of a few strokes, an individual who is thus easily identified by his acquaintances.

There remains still another process for the rendering of

tone in some respects like the reticulated grain process but not entirely so, the process which is probably the most completely photographic of any method in the whole sphere of photo-mechanical photography, viz. the process of Collotype, due, in its original form, to the experimental ability of Poitevin.

POITEVIN'S PHOTO-COLLOGRAPHIC PROCESS

In August, 1855, Louise Alphonse Poitevin, a French chemist and engineer, announced his process for producing pictures in greasy ink direct from stone. In this method, which was somewhat incorrectly described as "photo-lithography," Poitevin coated a lithographic stone with a mixture of gelatine and potassium bichromate, and exposed the film when dry under a negative. On washing, drying, and again damping and rolling-up with a roller charged with a lithographic (varnish) ink, he obtained an image with gradations of tone, which image was transferred to paper by pressure. The error of calling the process one of photo-lithography was that the particular principle of lithography did not enter into it at all. This fact was afterwards recognized, and the process was eventually termed "Photo-Collographic." In its early days it was improved by the labours of Tessier du Motay, by Lemercier, by Albert, and by Obernetter. Subsequently, greatly developed in Germany, it became one of the most important photo-mechanical processes, and, indeed, has only comparatively recently been replaced by rotary photogravure, which is, by reason of its being of a mechanical nature, more certain as a process of print production. Nevertheless, from the standpoint of the quality it can yield, collotype is an important process.

MODERN COLLOTYPE PRINTING

In modern collotype printing, a sheet of glass, not less than five-eighths of an inch thick and larger than the

picture, is taken, and the surface is finely ground by means of wet emery powder. Usually two plates are placed one above the other with emery and water between, and rotated, until a fine and uniformly-ground surface has been produced, when they are washed clean and dried. The plates are then given a coating of albumen and water-glass (sodium silicate), dried, and made hot. After cooling, the plates are washed and again dried. Ale is very frequently used as part of the composition of the solution for the substratum, probably because of the malt content, which becomes hardened, forming a film which holds the silica in situ on the glass. Ale is mentioned by Vidal as far back as 1893. This somewhat elaborate preparation is made for the purpose of producing a "tooth" or "grain" on the surface of the glass, which in turn is necessary in order to secure that the film of gelatine remains on the plate during the subsequent operations.

Each plate is now coated with a solution of gelatine and potassium bichromate, the glass being placed on the levelling screws of a drying box containing hot water or steam pipes which will permit the plate to be dried by heat. A sufficiently large quantity of solution is put on the plate to yield a thick film. Drying is by evaporation from the liquid gelatine—the film does not "set" in the first instance.

The choice of gelatine is important, and so are the conditions of drying—temperature and rate. Care is taken to allow the plate to cool slowly in the box after heating. It is probable, however, that the film does dry in a state of stress, and the consequently strained condition has considerable influence upon the character of the film and its grain. It is certain that if the film be dried at a relatively low temperature or be allowed to set and then dried slowly, the results are entirely different, mainly in

the absence of grain, which renders plates difficult to print, and there is also a difference in the character of the gradation. After drying, the plate will keep for two to three days if stored in a dry and cool place.

The plate is now exposed to light under a suitable negative, which means a negative having a somewhat short range of contrast, the photographer's "soft" negative.

Collotype plates printed under negatives having strong contrast are seldom satisfactory, and lead to difficulties in the printing. After exposure, the negative is removed and the exposed plate is plunged into cold water and washed until free from the remaining potassium bichromate, when the film will be colourless.

If the surface water be removed by a soft cloth, examination of the plate will reveal a print, the most apt description of this print being that it looks like a design in ground-glass in which the various tones are represented by different degrees of roughness, there being at the same time a certain amount of relief. If the relief be too appreciable it will be a source of difficulty to the printer, and the character of the print will suffer. It may be due either to too thick a coating of the bichromated gelatine or to the use of an unsuitable gelatine (too "soft"). There is always a tendency to produce relief, and this is checked by leaving the back of the frame open during exposure so that a certain amount of light action takes place at the back of the plate and thus the total swelling possibility is reduced. The plate, after development, is dried. When it is to be printed, which may be by hand on the press or by power at the machine, the plate is made level and is covered with a mixture of water, glycerine, and ammonia. This solution is absorbed and the film now swells, and in time becomes "damp" to different degrees according to the exposure received by the different parts. On

removal of the excess solution and making the plate surface dry, it is ready for printing.

THE "GRAIN" IN COLLOTYPE PLATES

Examination of the finished collotype plate when freed from loose water but still in a moist condition, will show that the surface is not smooth but that there is a distinct "grain," and that the grain varies throughout the tones. Further, if a series of plates be examined it will be found that while the general character is the same in the different plates, it is much more pronounced in some plates than others. Actually, a collotype worker does not seek to produce a pronounced or coarse grain, quite the contrary. It was at one time held that a certain amount of grain was necessary, but many modern collotype plates show so little that it may be said to be practically absent, and in this case the differential effect in printing appears to be due to difference in water absorption alone. On the other hand, for certain work—"transfers"—the grain should be of a distinct character. To explain the formation of the grain, one must go back to the preparation of the film on the plate glass. If the film of bichromated gelatine after coating be allowed to set and then be dried at the ordinary temperature of the air, no grain will be seen when the plate is exposed and developed in water. If, however, it be prepared as described and dried at a fairly high temperature, say, 60° C., the film dries under a state of stress. The strained condition is the necessary antecedent to grain formation, and when the film is placed in water, its behaviour will be quite different. The exposed parts of the film will absorb water in proportion to the amount of unchanged gelatine. There will, in consequence, be more swelling in the parts which have been exposed to light under the more dense parts of the negative, because in these portions there will be a greater amount of

unchanged gelatine. In the parts corresponding to the thin parts of the negative—the shadow portions—there will be little swelling; and with some negatives (generally unsuitable ones for the process), where there is a total absence of deposit, the gelatine, if the exposure has been prolonged, will have been rendered quite insoluble. Apparently, also, there should be a sensible amount of relief. There is some relief, but not very much; and being detrimental it is avoided as far as possible by a careful adjustment of the amount of gelatine to a given area.

Accompanying this difference in solubility another phenomenon appears. The surface of the swollen portions takes a *crêpe*-like formation, which is technically known as "reticulation," and its amount varies according to the amount of exposure received by the different portions of the film. In the high-lights the reticulation is considerable, becoming less as the shadows are approached, and in the quite insoluble parts there is none at all. An examination of the illustration, Fig. 35, shows the form of this reticulated gelatine, where gradations of different intensities are represented. At first this reticulation is not easy to explain, but it becomes simple when the conditions are reviewed. The surface of the glass plate used for coating is, to commence with, very finely ground with emery, which gives a matt surface. It is then coated with a soluble silicate solution, dried and heated, and washed afterwards in water. The result of these operations is to give a deposit of silica which adheres most tenaciously to the ground glass. This surface is one which allows of a very close adhesion of the gelatine, and prevents any minute lateral "slip" in the film. It acts in this way, but the real object of the procedure is to prevent the film stripping off in the process of rolling-up the plate with the inked roller in the printing operations.

FIG. 35. EXAMPLE OF RETICULATION OR CRINKLING OF GELATINE (MUCH EXAGGERATED) IN A COLLOTYPE PLATE. ENLARGED (× 2)

CAUSES OF THE PRODUCTION OF THE COLLOTYPE GRAIN

Consider a layer of gelatine which has been exposed to light under a negative. On the under-surface the film is firmly held by the glass. The top surface of the film is a

layer of insoluble gelatine varying in thickness according to the amount of exposure received; between the two is the soluble gelatine. As the film is of uniform thickness, where the amount of insoluble gelatine increases, the soluble gelatine becomes less. We have, therefore, in opposition greatest insolubility to least insolubility. We may further assume that the insoluble layer is capable of exerting a considerable resistance without alteration of the original "figure," which is that of a smooth surface—that it has, in fact, elasticity. If this resistance be overcome the figure will alter. The plate is immersed in water, and absorption commences; and when there is absorption, there will be swelling. Now, the swollen parts, in swelling, exert a considerable stress or disruptive tendency, which is checked by the elastic skin of insoluble gelatine on the top. Eventually a point is reached when the elastic skin gives way, the figure of the surface alters, and the alteration which takes place is that the film takes a crinkle, which is termed "reticulation." There is always a tendency for the film to assume a smooth surface as the final result, and this shows the most in the least exposed parts where the insoluble skin has been slight and the soluble portion considerable. The resistance to swelling has only been trifling and the gelatine has freely expanded, so that in parts not exposed at all, such as in the protected margins of the film, no reticulation is shown. In other places where there has been a slight change in the early stages there is considerable reticulation, but eventually the film swells up considerably, and the reticulation is almost wholly obliterated. This explanation, which was originally given by the Author in 1907 ("Keith Lectures," 1907, *Royal Scottish Society of Arts*, No. 11, Vol. XVII, 1907, pp. 320 *et seq.*), has been considered by Fishenden to be incomplete, and in an article (*The Modern Lithographer*, Vol. 18, No. 7, 1922, p. 123) this investigator

discusses the subject as follows: "This explanation is not completely satisfactory. It would appear that the restricted swelling of the gelatine in the glass confined by the tanned layer cannot in itself produce the reticulation, for the grain is not produced if the gelatine film is dried under conditions unsuitable to its formation; further, a grain may be created under suitable conditions in a film supported on a flexible material, such as paper. If, however, the swelling is considered in conjunction with the state of strain, which in this article has been shown to exist, it will be seen that in the absorption of water the soluble gelatine which is under strain seeks to assume its original configuration during the swelling, a considerable force is exerted, which is thereby distorted and partially cracked into the characteristic *crêpe*-like reticulation of the surface."

Observing that there is nothing in these interesting comments incompatible with the present writer's original suggestion, it may be said in passing that the statement, "further, a grain may be created under suitable conditions in a film supported on a flexible material, such as paper," rather *seems* to suggest that paper would offer no resistance, whereas such would not be the case. There will always be some pull when two such substances having different swelling constants are in contact. The student desiring to understand the subject of collotype in all its bearing is recommended to study Fishenden's comprehensive papers in the series indicated.

Ease in printing demands the formation of a well-defined reticulation, though its absence does not mean that the plate cannot be printed—far from it; nor does this mean that the grain must be coarse. The sentence must be taken to imply no more and no less than it says.

Printing of collotype plates is an art in itself, like the hand-printing of a gravure plate. The ink employed is a

varnish ink "rich" in very finely-ground pigment, "rich" because the intensity of colour must be produced by a very thin film of ink since the plate cannot be "loaded." Some little running is required before the plate takes the ink well and the prints become uniform in character. Further to this, uniformity is very much dependent upon maintaining uniform conditions. The plate is printed in a damp state, so that obviously the hygrometric condition of the atmosphere has a bearing on the work. Slight variations are not so important in monochrome work, but they are important with collotype in colours, and this is one reason why the process has always been difficult for colour work; but where it is utilized for colour there are two or three ways of securing uniformity. One method is to use one impression from the collotype in monochrome, and to print the colours by lithography from hand-drawn plates or stones, or half-tone screen colour stones. A second method is to make collotype plates from the colour-selection negatives, and from these plates to pull transfers and put them down on stone or metal, a procedure which gives an opportunity for correction of colour values. Another plan is to print *direct* from the collotype plates on to thin grained zinc, to send these plates to the artists' room for correction, and to print the corrected plates "offset." All these methods have been employed, and all are capable of giving excellent results, but they are all expensive, largely because of the hand-work and the care required when printing, though, judging from examples of poster work shown, the direct transfers to zinc would appear to be practicable at a reasonable price for such a class of work.

PRINTING COLLOTYPE PLATES

It is now necessary to consider the process of printing. After the plate has remained in running water sufficiently

long for the whole of the soluble bichromate to be removed, it is drained and allowed to dry. It is then placed in water until the film softens, is taken out, and the excess of water is removed by means of a soft cloth. The plate is fixed in the bed of the printing press, and is then ready for inking. The type of press employed is practically the same as a "scraper" litho press, but is generally made with better adjustments, and there is provided an iron bed-plate with sliding plates and screws for clamping the plate. A power machine is similar in character to a litho machine, but the rolling and damping arrangements are somewhat different. Essentially, it may be said that a collotype power machine is practically a high-grade flat-bed litho machine.

Assume, for the purpose of explanation, that the plate is being printed at press, where it is firmly fixed. Whilst the plate is damp, a leather "nap" roller, charged with collotype ink (which is a mixture of finely-divided pigment and linseed varnish) is passed over the surface. The ink will apparently deposit all over, and there will be only a slight appearance of any selective influence being at work. On quickly rolling, the ink will be attracted back to the roller, and eventually the plate will become quite clean. When nearly so, it will be observed that there is, however, some selective action at work, and a faint image of the subject will be seen. If the operation be repeated several times, the plate will begin to pass into the proper condition, and after some little time the picture will be seen. There is always more or less of a deposit of ink on parts where it is not wanted, but the plate can be quickly cleared by a slight increase in the *rate* of rolling. If, when the plate is rolled up, a piece of paper be laid upon its surface and pressure applied, the ink will be transferred to paper, and a print will result. Such a print will usually have a too pronounced degree of contrast. To overcome this, two inkings are given, the one with the leather roller

as described, and the other with a gelatine roller (or sometimes with a perfectly smooth leather roller), charged with a thinner ink, which determines the inking of the lighter tones. As the rolling proceeds the plate dries, and it is necessary to redamp. It will readily be seen that under the conditions described the plate will soon become dry, and, in consequence, the printer has to redamp his plate continually. To overcome this difficulty special types of damping solution are employed. The most obvious thing is to add to the damping water a certain amount of glycerine, which, being a hygroscopic body, retains the water, and this is a quite legitimate procedure. But to ensure long runs without redamping—which means always that the plate has to be worked a little before it is in condition—the plate at the commencement is well damped in glycerine, water, and ammonia. This solution, because it causes considerable swelling and affects the grain, changing the state of the plate and, consequently, the character of the print produced, is called by printers the "etch," which is a misleading term. Other agents are used for making the printing easier, and in the concoction of these the usual superstitions play their part. The fact remains that for making prints no other agent but water is necessary, and the length of time that this must act is governed by the gelatine used, the exposure and the state of the plate, the temperature of the water, and the particular water—for many tap waters are faintly alkaline—the ink, and the printer's idea of what should be the character of the print. The function of the thinner ink is to help the gradation in the lighter parts of the plate. Actually it helps quality for, being deposited all over the plate, it renders the grain less obtrusive, so that in good work the grain can scarcely be seen in the print.

In collotype printing it is not easy to maintain the uniform moisture conditions which control gradation.

Several proposals have been made to overcome the difficulty whilst retaining the advantages of collotype—the ease of plate preparation and the cheapness, especially for small editions. In one successful process a fine grained zinc plate is thinly coated with bichromated gelatine and printed under a screen negative which may have been made with a very fine ruling. After exposure the plate is washed out and printed damp. Here the gradations depend on dot area and the conditions for successful printing are more easily maintained. The results are extremely good (Aquatone). Other uses of the dot negative have been proposed for like purposes.

In one application of the collotype principle a celluloid film base is used with success (Sperati).

THE OFFSET METHOD

One of the most striking things in the history of the evolution of photo-mechanical methods is the way in which the very early process, photo-zincography, was for so many years comparatively neglected, then suddenly sprang into importance and was hailed by many people, who should have known better, as an entirely new thing. Yet there is absolutely nothing in the preparation of the surface zinc plate which was not known and practised with essentially the same material in 1855. It is probable that it came to be accepted, either in the form of the direct process or by means of gelatine transfer, as a routine method for the multiplication of line subjects, and since there was no method commercially available for the rendering of half-tone subjects by surface printing until the process of Sprague, it ceased to attract attention. Moreover, zinc as a printing surface had not come into general use, and did not until its advantages had been seen. But it was an entirely adventitious circumstance that forced the photographic process to the fore, the

observation of Rubel, in 1904, that when printing at the litho machine the feeder had "missed" with a sheet, with the result that the impression was taken by the cylinder and eventually transferred to the back of the next sheet, although it is fair to state that Rowley had printed designs upon card by means of the tin printing machine. It was found that where the image had been taken up by a resilient packing on the cylinder it gave a much better impression upon a rough paper than that which was obtained by direct impression, and this lies at the root of the eventual offset process. The merit of Rubel appears to be that he had the imagination to envisage the possibilities of a new system born of the accidental circumstance although there was nothing new in offset printing, since it had been applied many years before to the decoration of tin for box-making. The principle is that, for the perfect transfer of the ink from the matrix, one surface at least must be elastic, so that if there be a rigid surface of metal from which it is desired to transfer the impression to another rigid surface, it must be done through the intermediary of a resilient surface, and hence the eventual use of the rubber blanket. To all intents and purposes, if we consider areas of the surface of a rough paper in the order of the smaller areas approaching those of a few of the fine elements composing the half-tone picture, the surface of the paper is rigid, and so in order to print fine half-tone images on anything but the smoothest of paper, there must be either an elastic intermediary or enormous pressure. Consequently, the simple way out of the difficulty by the adoption of the offset principle marked a great advance.

THE OFFSET PRINCIPLE APPLIED TO PHOTO-LITHOGRAPHY

The utilization of the offset principle appears to have turned man's attention to the employment of

photography, and since there were no difficulties in the way of line reproduction, thoughts were directed to the rendering of tone. It is probable that had not the half-tone principle in the type-high process been well developed by that time, and become an important economic success satisfying most demands, the application to surface printing would have received more attention, but the early attempts had not been very encouraging. Half-tone images had been printed direct on stone and on metal, and work had been done by transfer, but with little success, although some lithographic houses had employed the method in colour work where the images had been corrected by hand and in conjunction with hand-drawn plates. It is only fair to say that in these trials the type of negative used was that which would have been employed for producing half-tone type-high plates, and this type of negative is entirely unsuitable, for the high-lights are too "open," with the consequence that the contrasts are not sufficient. It does not seem to have been considered that *some* of the difficulty could have been overcome by the use of screen negatives with greater contrast—the practice which was eventually adopted and has now become the rule. Further to this, there was the fact that when gelatine transfers were employed there was always a spread of the dot, first in the transfer, and, secondly, on the surface after the image had been transferred. It was not alone a question of contrast, but of intermediate gradations. The half-tone optical process, excellent as it is, has its limitations, and cannot be worked with success save by preparation of the originals to allow for the flattening of the tones or by such a process as "fine etching," which permits of the correction of the tones. Now, only a certain small proportion of the originals can be corrected, as for example photographs, where, if desired, the "working-up" colour can eventually be removed, and there is

at present no process of treating the plates akin to "fine etching" by means of which the "values" can be changed. Until the technique of the process became developed photo-lithography for tone work, especially for colour, was always illustratively less important than the type-high processes. To-day, offset photo-lithography, even with its technical limitations, has become a very important process, and will probably, for the better class of work, become more so, for this class will "bear" more easily than the cheaper and less important work, the cost of corrections by methods which are relatively expensive.

DIFFICULTIES IN OFFSET PHOTO-LITHOGRAPHY

The difficulty to be overcome is the all-important one, that the tones in the negative are not correct. Neither are they in negatives for the type-high process, but in that process, as stated, there is available the important operation of "fine etching" as a means for correcting the values on the etched metal, which operation is not applicable to surface processes. Further to this, it must be remembered that, even if a process will give tones correct to the original, that value is limited for the reason that the photo-mechanical worker is frequently called upon to produce a picture-printing surface that will "yield" pictures different from the original.

If we consider a dot element image, there are two ways in which the tones may be modified, the one by the principle of using "undercutting," which is the "fine etching" method, and the other if the dots are not of uniform resisting power—are, in fact, conical shaped and, therefore, thinner at their margins than at their centres, as in a collodion plate—by negative "cutting" or in a "high contrast" and process dry plate by "dot etching."

The dot image on a photo-litho plate does not lend itself to correction. Methods involving some form of dot

edge etching for reducing size, or mechanical dodges for a similar purpose, have been tried and have not proved effective. So far as monochrome work is concerned, it might be thought that an examination of the plates printed in the early days when it was sought to produce gradations of tone by the use of the screen negative would have suggested the means for improvement, viz. to make the clear spaces in the high-lights smaller, to make what in the operator's ordinary speech would be an "over-joined" negative with a very small dot in the shadows.

The earliest movement for improvement, however, did come from the use of this different type of negative. In one way or other all the modified half-tone negatives for photo-lithography have been fantasias upon that theme. But there is a drawback. Let it be assumed that there is a black and a white in the original, and that it is proposed to make a screen negative in which the black shall be represented by clear glass and the white by opacity, either by the dot effect having been lost or the clear spaces being so small that the high-light dot will not print. Then, there is no means of preventing tones near to the black and near to the white from being represented in the same way, with the result that there is a loss in gradation. This is the common fault with all the systems which rely purely upon the utilization of the optical principle, and it is only by modification of the negative that the defect can be overcome. To make a contrast negative of the kind indicated is not difficult and requires no special means. Negatives so made—with some masking—may meet the necessities in certain classes of work in monochrome. There are more ambitious methods for making "high-light" negatives but the devices required are costly to install and their efficient use calls for very considerable skill.

It is, of course, quite possible in some cases to adopt the method of "working-up" the original by means of the "air brush," provided the original is a photograph, but this method cannot be applied to existing drawings, and existing drawings have to be used.

It was cheaper, when a half-tone photo-litho plate was required, to make an ordinary half-tone on copper, and take the finished unmounted plate, fill in the hollows with magnesium carbonate (when the copper against the white shows a good positive), and make a negative direct from this plate, afterwards printing down on zinc for the lithographic plate, rather than to employ a negative made directly from the original. It was cheaper because the hand-work necessary to produce an acceptable final result is less. Several methods of this character are used to overcome difficulties in rendering, merely because up to that time what may be described as a suitable straight technique had not been devised for monochrome or colour.

To-day, the most promising "way out" in modification is to begin with the negative—if it be indirect work, say, from relief objects, then first upon the continuous-tone negative, afterwards upon the positive transparency, or print, and then upon the final screen negatives if necessary. In direct work, correction is made both upon screen negatives and positives.

In connection with this work of modification, the most systematic method for modifying or correcting screen negatives and positives either for monochrome or for colour is due to A. Murray, "A New Control Method in Chemical Retouching," a communication from the Engraving Department of the Eastman Kodak Co., Rochester, U.S.A., reported under the title of "A New Way with Farmer's Reducer," in the *British Journal of Photography*, Vol. LXXVII, page 121, 1929. Murray shows that given a certain concentration of potassium

ferricyanide in sodium thiosulphate solution—the mixture forming the well-known Farmer's Reducer—the action, when applied to the negative, proceeds to a limit, and that it is practicable to bring about a certain definite reduction in size of dot. In the completed process, named the "Peridak" process, systematic proposals are made for treating a screen negative by the same kind of system as that employed in the fine etching of half-tone relief plates, viz. by stopping out and then reducing with the standardized solutions of potassium ferricyanide and sodium thiosulphate. Since the introduction of this method, known now as "dot etching," several improvements in detail have been made and it is by many of its users regarded as *the* method for correction, not only for photo-litho, but for other colour processes. See "Half-tone Dot Reduction" (Kodak).

DOT ETCHING OF NEGATIVES AND POSITIVES FOR PHOTO-LITHOGRAPHY

The correction of the tones of a photo-litho plate places a valuable tool in the hands of the photo-litho preparator since the photo-litho image cannot be "fine etched" for correction as the half-tone relief plate. With the "deep etch" process the positive to be used should be made in the camera from the continuous-tone negative, using the ruled cross-line screen. The dots in the image of a positive so made are conical and have a fringe, and it is the removal of this fringe and a portion of the edge of the dots (where necessary) that constitutes the corrective process, and this correction will still leave printing density in the dots. A contact positive from the screen negative of the same subject does not offer this advantage. This process is discussed in an article "Dot Etching Screen Positives" (illustrated) in *Bulletin for the Graphic Arts*, Kodak, No. 5, 1944, p. 9.

The negative preparer, in dealing with continuous-tone negatives and positives, will, for modification, use the ways evolved through long usage in pure photography. A résumé of these is given in the Appendix ("After-treatment of Negatives"). The methods there outlined result in changes in photographic *density* by the application of pigments or other absorbing media in some form, so producing changes in gradation and contrast. Reliance cannot be placed upon estimation of the effect of this treatment by the eye alone, for although the eye—under proper conditions—can decide questions of *equality* it is not able to measure *quantity*. The difficulty is removed by photometric measurement, for which purpose instruments are available, and by their means corrections can be made to a graded scale of tones on the original (which represents its "range"), the values of which are known in figures. A means of correction by *masking* (which means simply *covering-up*), founded on a method proposed by Leitner in 1890 and adapted to "process" requirements by many workers, is now being used. Briefly, by superposing a thin *positive* (in register) made from the negative, the combination gives a lessened *contrast* and the latter is variable according to the positive, whose contrasts depend upon the exposure and development. (See "Modern Masking Method of Correct Colour Reproduction" (Kodak).) Envisaging the advantage of being able to facilitate the "image registration, and to permit half-tone exposures to be made with or without the photographic mask in position on the separation negative during a portion of the exposure," Bassist designed a mechanical device for the purpose. (See J. S. Mertle, "Bassist Masking Process," *Penrose Annual*, Vol. XL, 1938, pp. 118–119.) In four-colour renderings advantage is taken of the "infra-red" plates when making the negative for the

"black" printer (see page 446.) For "Off-set-deep," see Appendix.

Certain departures in practice from the generally accepted theory in tri-colour work are made, and these are referred to in the Appendix (see "Blue Screen and Green Screen Separation Negatives in Colour Work").

THE SILK SCREEN OR PHOTO-STENCIL PROCESS

A process introduced some years ago which was then, and is more so now, capable of producing amazingly good results is that known originally as the "Selectesine" or "Silk Screen" process, though the modern term "photo-stencil" is perhaps the more appropriate. The principle involved is easy of explanation. Consider a fine mesh fabric tightly stretched upon a frame, which mesh is capable of allowing the passage of a fairly liquid pigment colour. Let there be painted upon the mesh a design in monotone in pigment which when dry is impervious. Now if under the mesh is placed a sheet of paper and the liquid pigment is applied the colour will pass through the mesh in all places not covered by the painted image. In this way pictures can be readily produced, and if more than one colour be required, either side by side or superimposed, it is only necessary to prepare the requisite number of stencils and to see that they are in "register."

The effect produced may be admirable. In one class the nature of the ink—its pigment, the medium and the effect when dry—permits a rendering entirely different from ordinary lithographic printing. Given a suitable pigment and medium, an effect can be obtained similar to a drawing in the so-called "pastel" pigments.

Photography takes a part in the preparation of the obstructing design, and the most obvions thing to do is to prepare a carbon or autotype image produced from a positive, that is, to make a negative print in insolubilized

gelatine and to use that as the mask. The exposed carbon tissue is developed upon the well-known "temporary support," and when development is completed it is pressed upon the stretched silk net and the support eventually pulled away, leaving the image upon the silk. We have thus, if the original positive be suitable and the operations are properly carried out, an image in unsoluble gelatine which is quite impervious to the liquid pigment used to produce the picture. Both phosphor bronze and stainless steel gauze can be employed in the place of the silk net if the metal gauze is given, before use, a coating of gelatine and chrome alum, the chrome alum rendering the gelatine insoluble.

The rendering of tone can be effected by using a half-tone positive (made by means of the ruled screen), so that we have a dot image produced in the insoluble gelatine. It is, however, quite problematical whether this form gives the same characteristics as the plain flat tone of the former method, and even at the best there are technical difficulties. In easy work the dot positive should be coarse. Actually there is enough, and more than enough, of the half-tone screen in one process of illustration, and it is a positive relief to come to the smooth flat tones and a non-glossy pigment in place of the "usual thing." The best account of the process of producing the stencil is given by the Autotype Company with that usual careful attention to principle and detail shown by this firm in "The Autotype Stencil Process" (Autotype Works, West Ealing, W. 13).

Silk screen printing can be carried out upon rigid and flexible surfaces, each of which has its own particular advantages—paper, acetate sheets, art silk, cotton, oiled silk, nylon, metal, glass, wood. Where the designs and colour schemes are good some of the effects are beautiful, especially upon fabrics, given a proper choice in the nature of the pigment employed.

CHAPTER X

TYPICAL PROCESSES: RELIEF

THE matrices which are classified under "Relief Processes," as the name implies, are those which are printed in the type-high press or machine. Here, as pointed out previously, we have two conditions, that of taking and that of not taking ink from the supply roller, those parts which take ink being in *relief*. Because they fulfil the same conditions as type they may be associated with type during printing, and this is alone sufficient to give them, from an economic point of view, a position of the greatest importance. This position, for certain classes of work, has been somewhat disturbed since it has been shown that type-matter and illustrations can in many "lay-outs" be readily produced together and at a competitive figure of cost, both in photogravure and in offset photo-lithography. But this is practicable only for work that lends itself to careful planning beforehand, as, for example, in a well-produced catalogue. For the great majority of illustrated printed matter produced under the conditions which obtain, where there are frequently last-minute alterations in both type and illustrations, relief processes are commercially the most convenient.

Relief matrices are in principle of one kind. They are devices for delivering the pigment which they have received from a roller to paper or other suitable material for the purpose of producing a resemblance to some kind of picture, and this resemblance, as already explained, may be an actual duplication, or it may be an illusion. Thus, if the original picture be a black-and-white pen drawing, the resemblance will compare line for line with the original, or it may compare line for line but be larger

or smaller than the original. But if the original be a wash drawing or a photograph, then, so far as concerns tonal resemblance, it will be an illusion, for the simple reason that the original is in closed or continuous tone, and to make the matrix yield a resemblance there has had to be a translation into broken tone, and the effect produced is, therefore, as stated. The principle underlying the production of the "half-tone" effect by means of dots has been very fully described in Chapter VII.

The operations necessary for making the printing matrix are divided, as are all photo-mechanical operations, into the making of the negative and the making of the image on metal—the resist, as it is termed—and, afterwards, etching the image into relief. There is then the final operation of mounting the etched plate ready for the printer's use, although in many instances the trimmed plates unmounted are delivered to the printer, who may find it convenient to mount them himself upon one of the special type of mounting boards made for the purpose.

The principle underlying the making of the negative has been very fully explained in Chapter VII, and there are now to be described the modes of making the initial image, or resist, and the etching of the image into relief, with the reasons for the particular procedure. We may have line relief plates or relief plates in "half-tone," both eventually "blocks," and essentially the same methods—with modifications—are employed for both kinds.

In present-day practice, given the photographic negative, the process of making the initial image is based upon the change which occurs when albumen *or* fish glue and an alkali bichromate are exposed to light, changes which have already been discussed. There are three processes employed, the first, the roller or French method, the second, the dragon's-blood method, and the third, the enamelline method. The first was employed until a few

years ago for all line work, and before the introduction of the enamelline process was used for all half-tone work. It is now seldom used for half-tone work, but the *enamelline* process is very frequently employed for making line blocks, though for this class of work it is not nearly so well suited. Less skill is required, however, or, rather, the quality of the work that passes with the producers and their customers is such that less skill suffices than would have to be employed were the roller method used, or it may be, and is frequently, found that for certain kinds of line drawing the results obtained by the use of the enamelline process are quite satisfactory even when a good standard is adopted. But there are many difficult line drawings to which the enamelline method would certainly not be equal, indeed, for which no line process is adequate, in which case recourse must be had to the ruled screen for rendering—the particular drawing must be regarded as a drawing in continuous tone. If by this method results approaching the effect of the original are desired, then considerable skill and time are demanded, with consequent rise in the cost of production. The introduction of the enamelline process for line work arose largely to meet the rush which obtains in the studios attached to newspaper offices, for the process is quicker than the roller method. The enamelline process is, however, the better for the production of half-tone plates, for the conditions are not the same as those in line work.

For the dragon's-blood method, see page 300.

METALS USED IN RELIEF PROCESSES

The metals employed are zinc and copper. Zinc is employed for the vast majority of line work, but in special cases copper is used, and, indeed, is the better metal for certain classes of work where small, fine, delicate line drawings are to be rendered. Zinc, prior to the introduction

of the enamelline process, was used for half-tone plate making, but the majority of tone blocks are now made upon copper by the enamelline method, although zinc is still sometimes used instead. Zinc tone plates when made by the enamelline process are not so desirable as those which have been made by the roller method, for the reason that the zinc undergoes a physical change when it is heated to the temperature necessary in the enamelline process. When this metal comes to the engraver it has a more or less fibrous character—though this is a somewhat rough mode of describing its nature—but on heating it becomes crystalline in structure and is then brittle. If the heating be not carefully done, then the metal becomes distinctly weaker, and, during the printing of long runs, may fail to stand up to the ordeal. If, however, the plates are reproduced by stereotyping or electrotyping, this weakening is not of serious moment. Electrically-heated "burning-in" stoves are sometimes employed, and with these the temperature can be well controlled, and they are, therefore, safer in use so far as the metal, the zinc, is concerned.

The metals come to the engraver in a planished and polished condition, and of a thickness between 14 and 19 S.W.G. It is usual to employ for good line work on zinc 14 g. metal, though the tendency has been to use a higher gauge, or thinner metal; but thicker than 14 g. is employed when bookbinders' blocking plates are made by the line engraving process instead of being cut in brass. For half-tone work both on zinc and copper 16 g. metal is generally used. The metal is cut slightly larger than the image by means of the guillotine. Cutting with the guillotine avoids the necessity for filing down the edge which is required to remove the "burr" whenever a saw is used—which was the practice before the introduction of the guillotine and still obtains in some quarters. The cut metal is cleaned by means of a moistened pad covered

with fine pumice powder, and is then rinsed free of the detritus. Copper is cleaned, as a rule, by means of a hard charcoal block which leaves a finer surface than the pumice powder. Copper is coated direct with the bichromated glue, and similarly zinc when the enamelline method is used for either line or half-tone plates. If zinc is to be used for the roller method, then it is "grained" before coating. This graining is for the purpose of holding the printed or insolubilized line more firmly during the process of development. The development of a fish-glue inked or albumen-inked print differs from that of a non-inked print, as in the ordinary enamelline method. With the former the surface is rubbed with a tuft of cotton-wool, and however gently this may be done there is a tendency for parts of the image to lift—particularly if the print has not been fully exposed, and full exposure with negatives where the image is rather weak is not always practicable. The graining, by very slightly roughening the surface, helps to retain the image. But with the ordinary enamelline print, development is a pure solution process, and there arises no necessity to touch the print during development.

THE ANASTATIC GRAIN

"Graining" the zinc is effected by placing the freshly-cleaned metal in a solution of common alum slightly acidified with nitric acid. The surface of the zinc quickly becomes matt, and after a minute's interval the metal is removed, wiped over with wool, rinsed, and is then ready for coating. Thus is produced the so-called "anastatic" grain of the early photo-zincographer. The grain and the slight film formed during the graining process hold a little moisture, and when used it serves to prevent the plate "tinting" or "scumming" during the process of rolling-up with the inking roller. It is probable that the film is zinc monoxide ZnO, zinc hydrate $Zn(OH)_2$, or

zinc dioxide ZnO_2. The latter results from the peroxidizing effect of the oxides of nitrogen liberated as the result of the action of nitric acid on the metal, which would probably be assisted by any body present in the zinc that could produce even a slight electrolytic influence, though it is probable that the mere contact between the metal and the liberated gases would be sufficient to produce the necessary cathodic effect. The function of the alum is to coagulate the colloidal oxide produced and to secure its deposition and adhesion to the metal, so preventing its floculation and flotation from the surface of the metal plate.

For the sensitive coating, both for the line and tone resist making on zinc, the standard process employs albumen. Fish glue very much diluted, however, may be used, and the tendency is to employ it in lieu of albumen, but it does not give so sensitive a coating as the latter. It is, however, convenient, and since fish glue is in use for other purposes it avoids the duplication of material in the workshop.

BICHROMATED GELATOSE THE SENSITIVE FILM ON METAL

Fish glue, or "gelatose," which is a hydrolytic cleavage product of fishskin and bone (see Appendix, "Hydrolysis"), is the material used in the enamelline process. The term "enamel" or "enamelline" (sometimes "enameline"), is used to describe a peculiar condition of the fish-glue print produced by strong heat. The image becomes resistant to certain mordants, and the term aptly describes the character of the image, which becomes a chocolate brown, hard, lacquer-like body. The albumen solution employed to give the sensitive coating consists of albumen, ammonium bichromate, and water. This solution is applied to the surface of the metal, which is then heated to expel the water from the film of liquid, and, in consequence, there

remains behind a layer of albumen and ammonium bichromate, which is the "sensitive coating." Incidentally, potassium bichromate is sometimes used, but the coating is not so sensitive as when the ammonium salt is employed. The solution is sometimes called the "sensitive solution," but this is an error. It may be stated once and for all that *solutions* of gum arabic, albumen, fish glue, gelatine, or starch are not sensitive to light. They gradually become insoluble, but this will take place even in the dark. They may be quite freely exposed to the light of an ordinary room. It is only when the moisture has been removed so that the content of water is such as obtains under ordinary atmospheric conditions that the mixtures become sensitive to light. On the other hand, if the mixtures be entirely freed from moisture they become insensitive to light. This state of immunity follows the general rule that chemical action does not take place in the absence of water. A film of bichromated albumen or fish glue on zinc will remain soluble for a reasonable time, but that on copper soon changes owing to the reducing action of the copper. This is sometimes the cause of what is termed a "scummy" print, by which is meant that, independent of the image, there is over the metal a very thin film of insolubilized material, sometimes not uniform but patchy, which is a frequent source of trouble. "Scum," however, may be due to the state of the solution. To avoid the copper action with bichromated gelatine it has been proposed by Cartwright and Tritton, in the case of photogravure (see *Photographic Journal*, "Inherent Fog in Photogravure and a Method for its Elimination," Vol. LXVII, 1927, page 403), to silver the surface of the metal by the application of a solution of potassio-silver cyanide, and there are undoubted practical advantages in this procedure, though it is scarcely worth while in half-tone plate making with gelatose.

If fish glue replaces albumen in the preparation of plates for the roller method, the solution is made very dilute as compared with what would be used for the ordinary enamel coating, but otherwise there is no change in the composition. If the solution be required for enamel plates, the composition is fish glue, ammonium bichromate, and water, and the mixture is one with considerable viscosity.

MODIFICATIONS SUGGESTED IN BICHROMATED GELATOSE SOLUTIONS

It is convenient at this stage to refer to the practical advantages of additions to the otherwise simple composition of the coating solutions. As a rule nothing more is added or proposed to be added to the solutions employed for preparing line prints. It is, however, with the solution for enamel work that superstition has been, and continues to be, the most rife. The additions generally made are ammonia, chromic acid, and albumen. The addition of ammonia is said to produce cleaner prints, chromic acid to make the solution more sensitive and the print to burn-in better and also to be stronger when burnt-in, whilst the albumen appears to have been suggested without, so far as the author knows, any explanation as to its advantages. It merely occurred, and once having found itself in a formula was quite liable to be repeated or omitted, according to the taste of the worker. Let it be at once stated that whilst it is superfluous, and an additional item in the cost, it is entirely harmless. It merely goes to swell the image-forming material.

With ammonia the case is different. When ammonia is added to a bichromate it forms a simple chromate. Now a simple chromate with fish glue will form a sensitive substance, but the degree of sensitiveness is extremely low, and, in practice, the effect is to weaken the solution in active chromium salt, which is the bichromate. As a rule

the amount which occurs in the formula is small, and, therefore, there is no loss of moment. It may, therefore, be described as a superfluous but not harmful addition when present in the usually small amounts, but harmful when used in excessive quantity.

Chromic acid is a little difficult. The effect of chromic acid is directly to insolubilize gelatose, if in a sufficient state of concentration, without the agency of light. The first stage of any photographic change is the overcoming of the inertia of the sensitive body or mixture. A sensitive body or mixture will absorb so much active light, but until there has been sufficient absorption of energy there will be no change that is utilizable. Now, in the case of the bichromated gelatose it is the reduction of the bichromate and the combination of the gelatose material with the chromium chromate produced, that produces insolubility. It is probable that the addition of the chromic acid, tending as it does to produce insolubility by itself without light energy, does reduce the amount of work to be done by light, and in this sense it may be said to increase sensitiveness. In view of the small quantity added the effect is very slight, and it is open to question whether any material improvement in sensitiveness could be produced by this means, for sensible addition would cause the whole solution to thicken and become unworkable. As an addition to the enamelline solution the suggestion may be dismissed. Its only effect would be to produce insolubilized fish glue as done by the light, and where it occurs in formulae, it may be regarded as superfluous.

In no case has there been any experimental evidence that any of these additions is advantageous. The drawback to formulae containing superfluous additions is not that they produce harmful effects, for that result is generally soon found in practice, but that they lead to misconceptions. The unthinking user is apt to conclude they are

necessary, and thus form wrong ideas as to what is taking place. There should not be in a formula a superfluous thing; each thing should have a purpose, and that purpose should be understood. It is important from an economic aspect to increase the sensitiveness of the coating and so be able to reduce the time of exposure. The most promising proposal in that direction has been made by Tritton (*Photographic Journal*, Vol. LIX, 1929, and *British Journal of Photography*, Vol. LXXVI, page 381, 1929. "A Method of Increasing the Printing Speed of Dichromated Gelatine"), who has suggested the addition of cerous chloride to the coating solution, the effect of which is to act as a mild reducing agent, and so bring the substance nearer the insolubilizing point so that less light energy is required to complete the change, and, therefore, since the necessary exposure is thereby reduced, the "speed of the mixture" may be said to have been increased.

The subject of the behaviour of gelatine with a dichromate was originally investigated by Eder in 1878, and since that time there have been many researches. So far as concerns gelatose the most complete recent investigation is that of Smethurst, which was conducted with this worker's care and thoroughness. The student desiring—as he should—a full understanding of the complicated behaviour should consult the original papers (P. C. Smethurst, "Dichromate Colloid Layers" *Photo-Engraver's Monthly*, April, May, June, August, September, 1946). Apart from the practical value the subject is one of intense chemical and photo-mechanical interest. (See also Appendix, "Hydrolysis.")

It is important in practice to produce upon the plate a film of uniform thickness. To secure this, the plate is held in a whirling device and rotated after coating. It is then dried by gentle heat, face upwards, to avoid the

products of combustion, which, if in sufficient quantity, would produce insolubility in the film.

The plate is at once exposed. To secure contact a strong screw-down printing frame with thick plate-glass front is employed, although there is an objection to this on account of the large amount of light absorbed by the thick glass. During recent years pneumatic frames have come largely into use and are very advantageous, especially

FIG. 36. METAL PRINTING UNIT
(HUNTER-PENROSE)

for large plates. One advantage is that the glass base may be much thinner and so the absorption of light is much less. For photo-litho they are almost always used. In most European countries and in the U.S.A., exposing is to the light from arc lamps, but in tropical countries sunlight is employed. It would be impracticable to use daylight in England; even at the best it is far too variable. See Appendix, "Exposure of Sensitive Surfaces."

The printing down of images for resists is now performed in a much more perfect manner than in the early days of the wooden printing frame with heavy plate glass

front and screw down back. Printing cabinets ("metal printing units") are employed having the means for four frames with the exposing arc lamp in the centre of the unit. The frames are pneumatic, hang down to the horizontal position, which permits of easy filling, and are then returned to the vertical for exposing. Each frame is independent of the others. Exhaust is by means of a rotary pump at the base of the box, and the vacuum arc obtained is maintained, permitting of close contact between the negative and the sensitive surface. In another form (see Fig. 36) four independent frames are mounted upon runners so that the distance between arc lamp and negative can be varied.

In these units the arc lamp is enclosed—a manifest advantage.

TREATMENT OF EXPOSED BICHROMATED FILMS

After exposure the treatment depends upon the nature of the exposed plate. We have three separate cases: (*a*) zinc plates for the roller method, albumen, or fish glue; (*b*) zinc plates for the enamelline method, line, or tone; (*c*) copper plates for enamelline method—tone and line.

(*a*) The plate is thinly coated by means of a composition roller charged with transfer ink. The ink for this work should be of "short" character, as described on page 18. If the ink is the reverse of this—if it be like a varnish printing ink—great difficulty will be found when developing to produce a clean print, for the ink line "drags." When coated, the plate is placed in water. After a brief interval the water will be found to have penetrated the ink film and attacked the soluble portions of the coating underneath. On rubbing *gently* with a piece of cotton-wool, the soluble parts will come away, leaving the printed—the insoluble—image bearing upon its surface a thin film of transfer ink. The plate is then dried, and in this state the

ink is "tacky." It is now dusted over with finely-divided bitumen powder, which sticks to the image, and after this the plate is dusted clean. It is then gently warmed when ink and bitumen incorporate, and, on cooling, it is coated with a *thin* film of gum arabic solution.

This is the "print on metal" or the "resist." The same method is adopted for half-tone prints, but greater care is necessary because of the delicate nature of the image and also by reason of the fact that any defect cannot be obviated by retouching, at least only with considerable difficulty.

With respect to defects in line plates, such as broken lines, these may be repaired with a fine brush and a little ink thinned with turpentine. Any faults are made good after the first development and before the application of the bitumen powder, although this is sometimes deferred until after the first acid bath, the so-called "passing bath." It need hardly be said that the retoucher of defects requires some skill in the use of the brush.

(*b*) The plate, after exposure, is at once placed in cold water, when the soluble or unchanged fish glue quickly dissolves, and on rinsing with water all traces of the glue thus dissolved are washed away. But the image is practically invisible, and in order to see if it be free from defects it is dyed by flowing over the surface a solution of coal-tar colour (for which purpose *methyl violet* is generally employed) or by immersing the plate in such a solution. When the image is dyed it is washed clean, examined, and then dried spontaneously or by gentle warmth. The plate is now ready for the conversion process, which is effected by heating. It is held by a pair of tongs, or much better on a gauze tray, over a Bunsen flame, and the first effect is to cause the dye to disappear. The image becomes colourless, appearing to fade away. On prolonging the heating, the image turns brown, and,

finally, if the image material be of sufficiency, it becomes chocolate in colour. If the heating be too prolonged or excessive, the resist will burn and be destroyed. The remarkable result of this change is that the image is now capable of withstanding the action of nitric acid of appreciable strength for a sufficiency of time to enable the plate to be etched to "printing depth." It sometimes happens that the enamel will give way in the etching process. If this be detected immediately it occurs and the depth be sufficient, the plate may often be saved by washing, drying, and rolling-up the image with a glazed roller coated with "finishing" ink. But if the work be properly done it will not occur. The coating of enamel should remain intact, and, indeed, should persist even during a long run at the machine.

The final print, after the "burning-in," is the "resist." It is during the heating of the zinc that difficulty arises from the physical change in the metal, which becomes crystalline and, in consequence, brittle, leading to very poor durability in the machine. The "burning-in" should be done at as low a temperature as possible and in as short a time as it can be effected. If the danger state has been reached the surface of the zinc usually shows a roughness, which, upon examination with a magnifier, is found to be due to the formation of minute fissures. Generally, if this roughness is not produced, the metal has remained in a reasonably good condition. There appears to be a general idea that the enamel image on zinc (but not on copper) contracts as a result of the change in the metal, with the result that the dots in the lights become smaller and the clear spaces in the shadows larger, and as a consequence allowance must be made in the negative. This, though a general experience, has not been proved by direct experiment. It may, however, since it is a reasonable idea, be accepted until it is subjected to test.

(*c*) The treatment here is the same as that previously described under (*b*). No trouble arises owing to the heating of the metal.

In all cases, after the resist has been prepared, and before the etching process, the back and edges of the metal, and in the case of line subjects, all areas within the

FIG. 37. ELECTRICALLY-HEATED BURNING-IN STOVE (HUNTER-PENROSE)

subject of appreciable size, are protected by means of a resisting varnish, which may be shellac in alcohol or bitumen in benzene. The purpose of this is three-fold: it saves consumption of etching mordant, it prevents the back of the plate from being attacked, and in those cases where the roller is used, as in line subjects, the protection of parts of the surface of the plate permits the formation

of "islands," which act as bearers for the roller and ensure uniform rolling-up of the surface. The unwanted metal in this case is removed by the cutter in the routing machine when the plate is finished and mounted, and it is much cheaper and quicker to remove superfluous metal in this way than by an etching mordant.

MODIFICATION OF LINE PLATES

We may now consider cases where the line plate, after printing, is modified before etching. The most simple case is where a "tint" is transferred to some part of the print on metal. The artist, when drawing the sketch, considers, perhaps, that the subject would be improved by the addition of a dot or line tint, or, maybe, some fancy texture. Such practice is common in line fashion-plate drawing. He roughly hatches the selected parts on the drawing with a blue pencil and, if he is doing regular work which is etched by a particular firm, indicates by a number the tint to be used. The blue lines do not show in the negative—they are merely an indication to the resist-maker. When the line print has been dusted with bitumen it is washed so as to remove all traces of powder, and in some cases is passed through the acid alum bath, which renders the surface of the metal quite clean. The dried plate is now painted over with coloured gum on all parts but those indicated by the blue pencil—where the tint is to be placed. There are several methods of laying down tints, but this is the first stage of the process.

The commonest plan of laying a tint was by the "splatter" method. A skilful litho draughtsman could spray, often by means of a toothbrush charged with transfer ink and turpentine against a comb, an irregular mass of dots, and could even vary the intensity in different parts of the area—an often desirable thing. The more general plan, however, was to make a transfer print from

an engraved tint plate, damp the transfer in the "damp book," and transfer the tint to the plate in the usual manner in the litho press. The modern and much better method is to use "shading media." A shading medium is a sheet of gelatine or celluloid, impressed with the pattern *in relief*, which is stretched out on a frame. The surface is inked over with transfer ink by means of a roller and then laid down upon the plate. By slight pressure the transfer ink on the gelatine film is transferred to the bare zinc, and by varying the pressure the intensity of the tint can be varied, which is a very valuable property. After the tint has been produced the plate is washed in water, dried, powdered with bitumen dust, and warmed to incorporate ink and powder. At this stage will be seen the purpose of the gum, for all parts of the tint falling on the gummed parts wash away, leaving it only on those parts where it is desired that it should be. Examples of these shading media are shown in Figs. 38 and 38A (Ben Day). In some cases tints are transferred to a transparent portion of the negative, for which purpose negative tints are provided (see Fig. 38A).

A third method of producing tints is that introduced by Hutchinson, which in some respects presents decided advantages over other processes. In this method there is provided a variety of "tint" or "texture" patterns printed on thin colourless and transparent *cellophane*.[1] The selected tint is placed over the drawing when it comes to the studio, and the shape of the portion to be tinted is traced out. This portion is then cut to the shape and fixed by the edges in one or two places by a simple colourless adhesive over the parts. It may be that on a drawing, two or three different parts will be covered, and with different tints. The drawing is now photographed, and the

[1] Cellophane is a "viscose" product. The new translucent plastic film "Ethulon" is now available for the purpose and is an improvement upon cellophane.

tints in consequence are produced in the negative. Thus the complete picture can be printed at once on the metal. After the drawing is photographed the tint pieces are removed and stored, and may be used to supply smaller shapes upon some future occasion.[1] A tint can be laid by means of a medium on the clear parts of a negative on the film side. It must be remembered that the effect will be reversed, since the work now stands as negative. Thus to make a part very much lighter the negative must have a greater amount of tint laid than the reverse.

From time to time other methods for the production of tints are proposed which are a far cry from the "Norwich" film of Ozias Dodge introduced in 1907. We have, for example, a plan for their optical production carefully described by Frank H. Smith in the *Photo-Engraver's Monthly*, Jan, Feb., Mar, April, 1948. Smith proposes methods for the production of negatives showing pattern by means of the cross-line screen. The methods described are capable of producing with certainty line patterns by following a definite procedure and these so produced are free from the drawback of eccentricity so that in the final printed picture the tint does not of itself attract attention but is merely a tint—as it should be—of a particular intensity.

There is, in addition, the "Para-tone" process. Here transparent sheets bear tint designs. The sheet is laid on the copy (the original), and the design is transferred by rubbing with a burnisher. When the sheet is removed the pattern will be found on the drawing. The tint can be readily removed from the drawing.

"KEYS" ON METAL—LITHOGRAPHIC

If it be desired to produce line[2] colour-work plates,

[1] Tints of different kinds can be—where permissible—transferred direct to line and wash drawings, as with the "Stack" screens.

[2] The word "line" is used in a general sense. It may be a drawing in line, or there may be flat areas of sensible size; or both line and area.

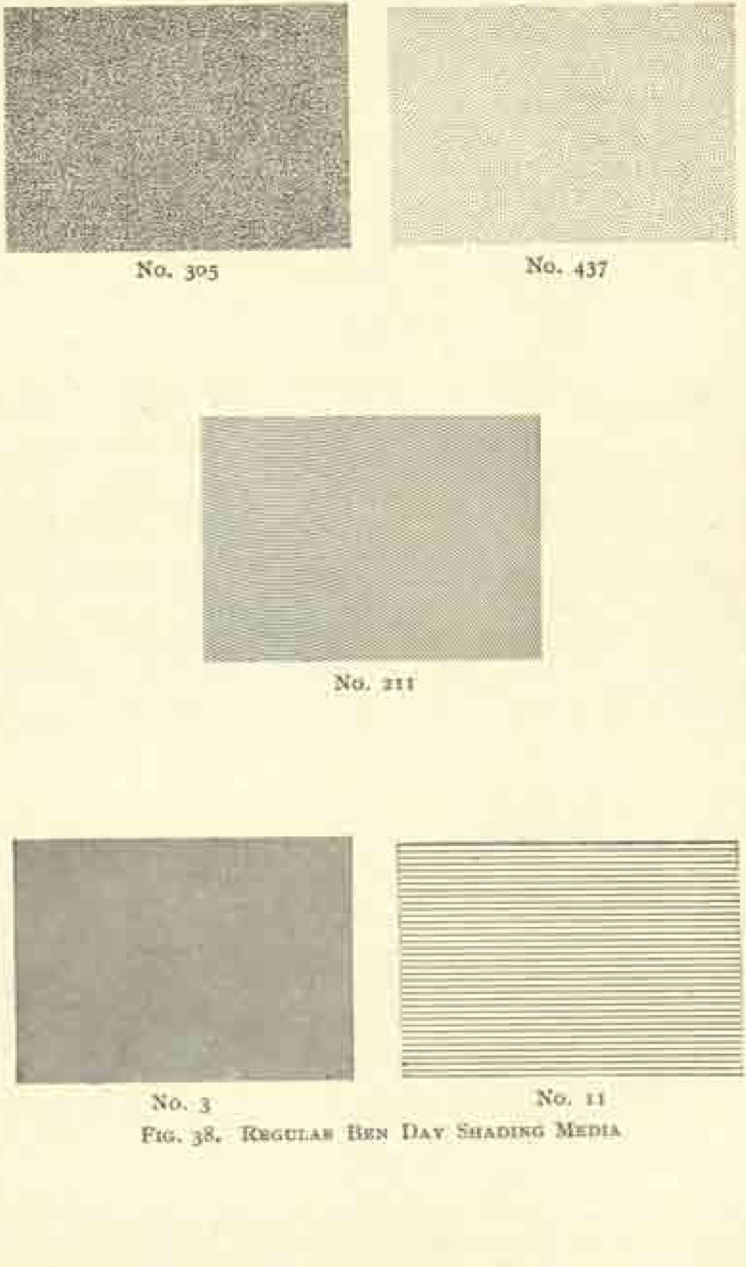
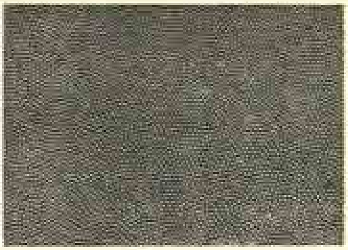
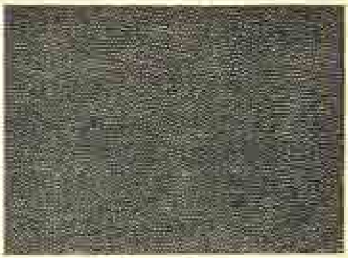


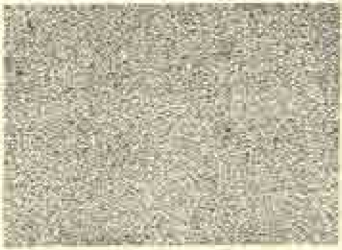
FIG. 38. REGULAR BEN DAY SHADING MEDIA



No. 437



No. 428



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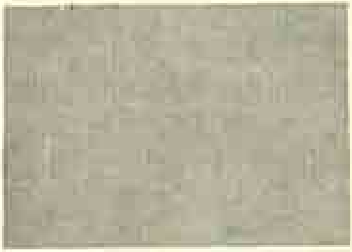


No. 3

No. 11

FIG. 38A. BEN DAY SHADING MEDIA—NEGATIVE TINTS
These illustrate effects obtainable by laying regular Ben Day films of corresponding numbers on the negative—where suitable—instead of on the metal plate or stone

there are several methods of procedure. Where it is sought to produce a picture with a black or coloured outline—which outline furnishes the drawing—it is necessary to ensure that all the colour-plates will, in the end, fit the outline. One method is to produce the outline plate and, when it is finished, to pull from this plate fully-inked prints, which are then covered (*a*) with red chalk "set-off" powder, or (*b*) with a *methyl violet* "set-off" powder, or, still better, (*c*) the plate is inked with a varnish ink containing treacle and *methyl violet* powder. If now pieces of zinc to the required number, cleaned and grained, be taken, the colour can be transferred to the metal in the case of (*a*) dry, and (*b*) if the surface be very *slightly* damped with water, and (*c*) with methylated spirit. These prints are "keys." With the original as guide, the metals are sent to the artist's room, and the colour-plates are now made by any suitable method, generally by the use of shading media. If mechanically-grained metal be used, the colour-plates may be drawn by the lithographic artist and then etched type-high, which is an effective but more expensive plan. It must be understood that this work is not work for the *ordinary* etcher as such, but for the litho draughtsman or the colour etcher, who, in times past, often graduated to photo-engraving through chromo lithography when he learnt the art of producing colour effects by superimposed or side-by-side colours. It may be stated that the two things are not the same, and do not produce the same result, and for the explanation of the difference, see Chapter XI.

"KEYS" ON METAL—CHEMICAL

There is another method for producing keys upon zinc which has the merit of being quick inasmuch as it is not necessary to wait until the outline plate is finished, and this is often an advantage.

If a piece of clean zinc be rubbed over with a watery paste of antimony oxychloride, the salt is reduced and the surface of the plate becomes black owing to the deposition of metallic antimony. Ink prints are now produced from the negative to the requisite number upon those blackened plates by means of bichromated albumen or fish glue, and are treated with bitumen powder. After warming, they are cooled and are treated with *dilute* hydrochloric acid, when the antimony is removed. The plate is rinsed and dried, and the image (or rather the ink bitumen coating on the image) is removed by means of turpentine or benzene. We have now revealed a black image upon the practically colourless zinc, which image forms the key. This key is far more easily seen than any kind of transferred key. If it be desired to produce a key upon copper, the clean metal is treated with a dilute solution of potassio-silver cyanide, as described in the paper of Cartwright and Tritton, for the reference to which paper see page 278. This gives a slight deposit of silver. The prints are now made, as in the case of zinc, and the uncovered silver is removed by very dilute nitric acid or potassium cyanide, or by very dilute ferric chloride, which converts the silver to chloride, which can then be removed by means of *very dilute* potassium cyanide or sodium thiosulphate. When the ink bitumen is removed by benzene there will be revealed a silver image upon a copper ground, which is easily seen.

COMBINATIONS OF LINE AND HALF-TONE

Combinations of line and tone subjects are very frequently made, and for producing these there are several methods which are often determined by the nature of the drawing. In the simple case of a line border surrounding a tone subject, one method is to produce the two independently and then to mount one within the other; or the

line and the tone negatives may be made separately, and the line negative stripped and mounted on to the tone negative, the border having been cleared for the purpose. When the plate is etched, after the tone is completed, it is stopped out, and the etching of the line proceeds. When the work is very complicated, and it is not simple to mount a tone plate within a line plate, this is probably the best method. In some cases the half-tone negative for the whole subject is made, the line border being acceptable when rendered by the screen. There is a variety of work known as "half-line." A simple example by way of "half-line" is where it is employed to lighten a particular part so as to produce a variety of tone. The negative for that particular part is made with a single-line screen close to the plate, so that what would otherwise be a solid is laced with lines. If the part of the original is white, the effect is to darken it. If there be a part that is black that it is desired to lighten, a supplementary exposure is made on a piece of white paper with a line screen in position. Elaborate combinations of tone subjects with fancy borders, such as are often seen in the cheap illustrated press, and which for some mysterious reason are considered by their instigators to be attractive, are produced by making a pattern lay-out in which the border is drawn and the places where the pictures are to come are blackened out with matt black paint. The negative is then made, the black spaces being rendered as clear glass. The tone negatives are made, and then stripped on to paper, cut to the requisite size and shape, and transferred to the line negative in their assigned places. The negative is finally printed on metal for the production of the resist.

The preparation of negative "flats" has already been mentioned in Chapter VI. The printing of a flat is carried out in just the same way as a single negative. A flat is

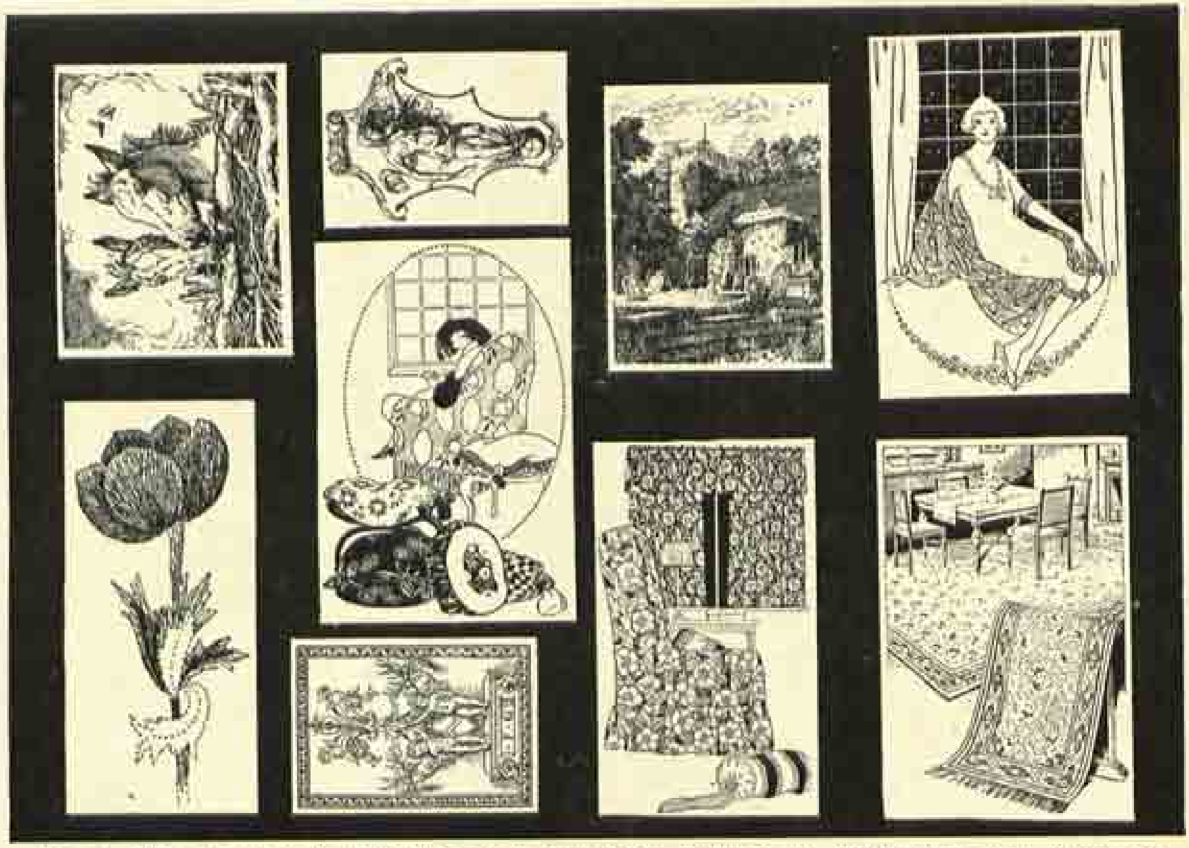


FIG. 39. PROOF FROM AN ETCHER'S "FLAT" OF LINE WORK, SHOWING THE ARRANGEMENT OF A NUMBER OF SUBJECTS UPON ONE PLATE, THE PLATE HAVING BEEN PRINTED FROM A SERIES OF STRIPPED WET COLLODION NEGATIVES MOUNTED ON ONE GLASS PLATE (*Sun Engraving Co.*)

shown in Fig. 39. This represents an assemblage of subjects printed down ready for etching.

THE ETCHING PROCESS

There is now to be considered the etching process. It is shown in Chapter IX, "Surface Processes," that the ink image, to commence with, is identical in both the surface and relief processes, but there is a difference when we come to produce prints from the two plates, for whilst in the surface process the image and non-image parts are in one and the same plane, and the production of the print depends upon there being conferred upon them at the time a different physical state, in the relief process, the image parts stand in relief, as the name implies, and these take ink from the roller by reason of that fact, ink being taken wherever the roller touches. Now there is in the preparation of the two types of plate one condition that must be met if the processes are to be a success, which is that the image must be confined to its bounds—a produced line on metal, for example, must not increase in size, or, to use the common expression of the craftsman, it must not "thicken." Even if a reasonably high standard be exacted, however, it is not easy to prevent a slight spread, for all ink lines tend to do so. The line may spread by excessive exposure when printing the bichromated albumen or fish-glue print, and it may show the same fault if the print receives too thick a coating of transfer ink. It has already been pointed out that the sensitive bitumen of Judea image was freer from the defect of spreading than the inked print image, and it is probable that, given the proper exposure, the fish-glue image for enamelline is sharper. The image may also be quite easily spread by heating too strongly after the initial print has been coated with bitumen powder. The object of warming is merely to melt the bitumen so that it will incorporate. Actually,

the ink image melts at a lower temperature than the bitumen, and what probably occurs is that the bitumen dissolves in the ink and so strong heating is not necessary. The spread is prevented, or at any rate reduced, by careful attention to these details, especially before the first "etch," and by putting the plate "under gum" as quickly as possible. Although the metal is not porous so that the gum penetrates (at any rate into more than the micro-surface), sufficient is *adsorbed*[1] to the surface of the metal to reduce the tendency to spreading of the image.

THE INITIAL DIFFICULTY IN THE PRODUCTION OF LINE RELIEF PLATES

In a line plate there is another tendency, namely, for the image of a line to become *less* owing to what is known as "undercutting," which takes place during etching. This defect is quite easy to understand. The etching process is carried out for the purpose of converting the line, which is on the same plane as the parts that are not to print, into relief. Directly *any* relief is produced the sides of the lines become unprotected and are open to attack by the mordant, and if this is not prevented, "undercutting" occurs and the edges of the lines are etched away. The whole technique of line etching processes, and of half-tone zinc albumen plates, has for its object the preservation of the form of the line and dots true to the original, and the prevention of undercutting. It also aims at the formation of a line of such section as will be mechanically sound and able to withstand successfully the stress of roller and cylinder during printing. The form of the line in relief should be such that the sides are not vertical but slightly concave, as (*b*), Fig. 40. Theoretically, for strength, it can be shown that the best form is in section that of a truncated parabola, but this could not be produced, and, further, were it produced, it would be impossible

[1] See footnote on page 230 for explanation of *adsorbed*.

to preserve the line, for the ink would catch on the sides and cause a thicker line to be printed. This fact is mentioned merely because it is sometimes assumed that the process has so worked out that without design the sectional form of the line is the strongest that could be produced, whereas such is not the case. What is necessary is that the sides of the lines near the surface do not "catch" ink when the surface is rolled up.

THE PRODUCTION OF A LINE PERFECT IN FACE AND SECTION

The method of protecting the edges of the lines is by means of a film of ink or of a resin. It is owing to the means by which the continual supply of ink necessary is produced on the image that the name "roller process" became applied. The initial coating of ink and bitumen furnishes sufficient material to resist the nitric acid in the first etching or "passing bath." Much of the success of the process—so far as fidelity to the original is concerned—depends upon the first etch. After this etching is done the plate is gummed and then rolled-up with a roller charged with good lithographic printing ink, and is then washed, dried, and dusted over with finely-divided colophony. The plate is now slightly etched until the lines are left in appreciable relief, withdrawn, washed, dried, and very gently warmed, when the ink and colophony melt and run over the lines. This operation must be carefully done, or the ink and colophony will spread too far. The plate is now gummed up and carefully rolled-up with a soft etching ink—which is a mixture of lithographic printing ink, lithographic varnish, bitumen, bees-wax, and tallow, a composition truly honoured by usage but one which might be considerably simplified. When the plate is rolled-up it is washed and dried and again powdered with colophony; it is then etched, removed, and the ink

run. These operations are repeated until the relief of the line is sufficient, the concentration of the acid being increased from time to time. The next stage is to remove the whole of the image, which is now completely covered with ink. The appearance of the line, in section, is now as in (*a*) Fig. 40, the steps or "shoulders" being caused by the "runnings" after the successive etchings. Were the plate to be printed in this condition, some of the ridges would certainly take ink from the roller, which ink would be

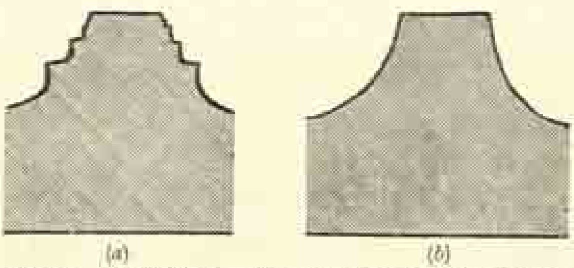


FIG. 40 SECTIONS OF ETCHED LINES ON ZINC RELIEF PLATES (*a*) SHOWING "SHOULDERS"; (*b*) AFTER THE "SHOULDERS" HAVE BEEN REMOVED

transferred to paper. The next stage—the "finishing"—is for the purpose of removing the ridges; these are etched away, starting from the bottom. The clean plate is now rolled-up with a soft ink, dusted with colophony, and "run" to cover, say, the first two ridges. The plate is then placed in the mordant until the uncovered ridges disappear, when the plate is cleaned. It is next rolled-up with a "glazed" leather roller charged with hard finishing ink (composed of lithographic printing ink, bitumen, colophony, and bees-wax), so that only the top of the line is coated. This ink must be of such a nature that a thin coating will suffice to resist the nitric acid. The roller is hard "glazed" or polished, so as to avoid any "dip"—only the surface of the lines themselves must be inked. Such is the process of "finishing," but it is observed that it

may be much more complicated and difficult if the plate has not been carefully etched in the first instance so that there has been produced considerable "shoulder." Equally, the plate may have, when etched skilfully, little "shoulder," and in this case the plate may be rolled-up at once with the hard ink and one bath only given. The section of a well-etched line after finishing is shown in Fig. 40 (*b*).

It will be seen that the process is complicated, and that it requires, if good work is to be done, judgment and manipulative skill. There have been etchers with taste and a feeling for line who have even been so successful as to receive the praise of artists whose drawings they rendered—a rare distinction.

THE DRAGON'S-BLOOD PROCESS

Many years ago a modification was made in the roller process which has led to a considerable simplification, and which has now become the standard process. This is the "dragon's-blood" method. This process is quicker than the roller process and, moreover, calls for the exercise of less skill.

"Dragon's blood," which gives its name to the process, is a naturally-occurring resin which is the exudation of certain trees, as *Dracaena draco* (Canaries) *Calamus draco* (East Indies).

It comes into commerce, frequently adulterated, in the form of red, irregular-shaped masses. It is employed as a staining agent for wood, and for this purpose is employed by the french polisher. For the use of the photo-engraver it is reduced to a state of fine powder. It melts at about 120° C., which is a much higher melting-point than that of colophony (ordinary "resin," 80° C.). Dragon's blood, on heating, softens and adheres to the surface upon which it may be resting. Unlike many resins,

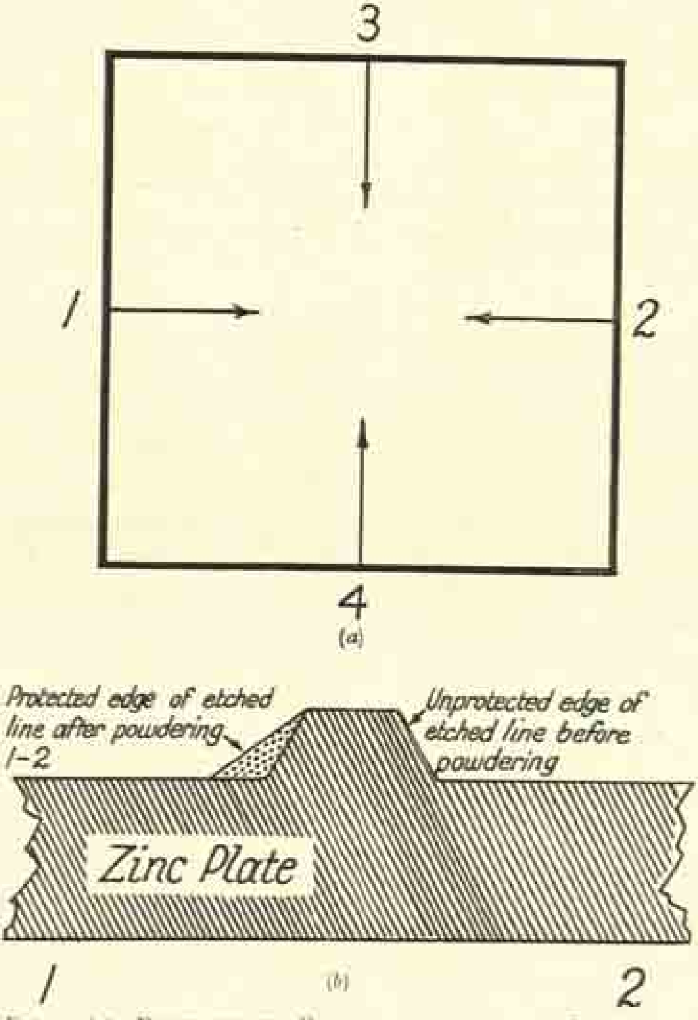


FIG. 41 (a). DIAGRAMMATIC REPRESENTATION OF THE POWDERING PROCEDURE; (b) SECTION OF PARTIALLY ETCHED LINE PLATE SHOWING PROTECTED AND UNPROTECTED LINES

colophony, for example, it does not flow readily on melting, and this property very largely constitutes its value as an agent in the etching process. An artificial "blood" has been introduced of good uniform character, which is reliable. In this method the dragon's blood serves as an agent for the protection of the sides of the line in lieu of the "run" ink in the roller process. After the plate has been etched into slight relief it is dried, is then covered with the fine dragon's-blood powder, and is afterwards gently brushed in four directions from opposite sides of the plate (the excess coming away) by means of a soft badger-hair brush, being heated after brushing in each of the four directions (see Fig. 41 (*a*)). The powder "banks up" against the slightest element in relief and there remains. It is fixed by gentle heat and cooled after each direction is treated. The powder softens and the particles cohere, but the absence of flow ensures that there will be no spread, in which case an excessive shoulder would be formed. The plate is now etched, and the melted dragon's blood acts as a resist to the sides of the lines. The operation is repeated until sufficient relief is obtained, after which the plate is finished in the ordinary way. A further method used by some etchers is a combination of the roller and dragon's-blood method, for which advantages are claimed.

In the enamelline process, when used for line plates, the resist will withstand for an appreciable time the action of the etching mordant without any further protection to the surface. After slight relief has been obtained, the surface is protected by means of the glazed roller charged with finishing ink, for the reason that the enamel may not stand for the whole of the time that the plate is in the etching bath, and this rolling-up may be repeated. After further relief has been obtained the plate is dusted with dragon's blood in the usual way, and the etchings and dustings are repeated until the necessary relief is obtained.

In the combined process the plate may be rolled-up with a glazed roller and dusted with resin (colophony), and then warmed carefully, so that the coating runs slightly; thus the sides of the lines, ever so slightly in relief, are protected. After this, the plate is etched and the dragon's-blood treatment is now begun. It is claimed, and the claim is probably a just one, that in this way the surface of the line—the image—is more carefully preserved than by etching until a sufficiency of relief is obtained to enable the dragon's blood to be used.

In the etching of half-tone plates on zinc the operation is carried out by the roller process. There is, however, a difference in the character of the negative used in this process as compared with the enamelline method. In the latter process undercutting is permitted, for it is part of the process, and to allow for this the negatives are made more "open" in the light tones and with more minute dots in the shadows. If finished as printed the tones would be wrong, for the dots would be incorrect in size, but by undercutting they reduce in size and so approach more nearly to the correct area. Any modification is then effected by means of the process of "fine etching" (see pages 318–20).

In the roller method the dots are preserved, and so the negative must be such that they print more nearly the size since undercutting does not occur. The plate, however, is corrected for the proper rendering of the tones by "fine etching," in which case undercutting must be permitted to take place.

THE RENDERING OF PENCIL WORK BY THE HALF-TONE PROCESS

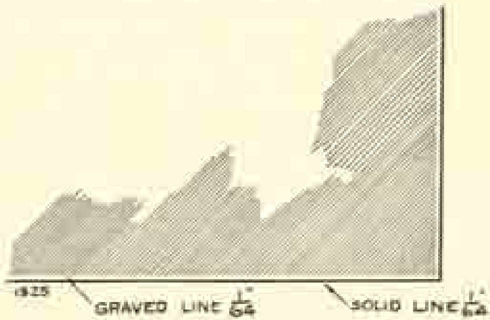
A pencil drawing is a drawing in line, but the lines are graduated. It is, therefore, a continuous-tone subject, and must be rendered by the use of the ruled screen. The plate,

when finished, will show the gradation of line, but the ground will still have the tint; in some cases it is very light but still not equal to the white paper. To eliminate the tint, the whole of the drawing is now painted out with "stopping-out" varnish, and the etching is continued until the ground is got rid of, the work of deepening being completed by the cutter in the router or by deep etching. It will be readily understood that the painting-out work takes considerable time and skill, and is, in consequence, expensive, though not excessively so. In some cases not the whole of the ground is eliminated but only in the larger areas, much depending upon the particular drawing and whether or not the ground is prominent. With delicate pencil drawings, where the whole of the ground is eliminated and where the drawing is of a high-class character, very considerable skill is necessary, together with the ability, and humility, to follow another's drawing. In some cases a saving of labour may be effected by stopping-out on the negative. Good renderings may be obtained by printing on the metal with a combination negative—the screen negative on which is superposed a continuous-tone negative of the drawing, in register. During the "printing down" exposure the "ground" is held back, any faint effect being removed from the metal before etching. Whatever be the method used for these renderings, the necessity for *some* skilful hand-work remains.

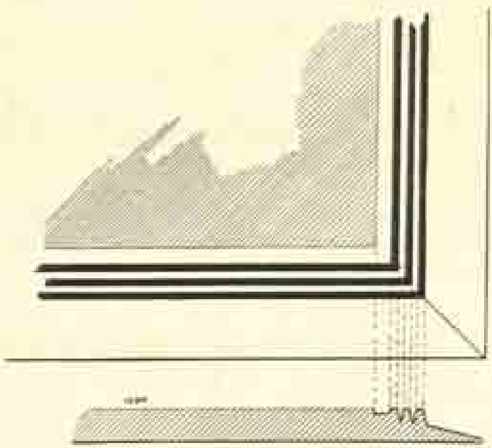
FINISHING RELIEF PLATES

Methods of finishing show considerable variety. A simple photographic portrait original with, for example, a plain light background sent to the engraver, may be rendered with the background plain and "squared up," that is trimmed with a certain amount of margin, or it may have a marginal line or lines introduced. Such lines, if they are to be solid, may be cut through the film of the

negative and will print the necessary resist to give the solid lines, or the lines may be cut out of the ground on the plate by means of the lining attachment on the



(*a*)



(*b*)

FIG. 42. TWO EXAMPLES OF THE EFFECTS WHICH MAY BE PRODUCED BY THE USE OF THE LINING BEVELLER
(See page 329)

lining beveller, router, or the bevelling machine. Sometimes a line is ruled on the plate with bitumen varnish before etching, which produces a solid line in the finished plate, and this line may be split by the liner on the lining attachment, or any combination of lines

of different widths may be produced. Examples of the work which may be produced on the lining beveller are shown in Fig. 42 (*a*) and (*b*).

The portrait may have the background wholly cut away by means of "stopping-out" on the negative or cutting with a graver around the image, or the background may be vignetted by means of fine etching.

These methods can, of course, be applied in object work, and much of the result of this kind of activity is seen in catalogue illustration. An object may have the background "squared up," "squared up" with a line, vignetted, or entirely cut away.

There is an advantage in a squared-up block with a line in that it is a definite solid edge which prints clean. With vignetted work much of the effect is due to the printer, without whose skill the job would be very unsatisfactory. Further, it is necessary always in vignetted work that the background at the commencement be a very light tone.

It is sometimes desired that the margin of the block should have a line in a tone distinct in depth from the ground and accompanied by a dark line, or lines. This is drawn in by the artist in the engravers' studio, on the original, before the negative is made.

HAND ENGRAVING IN LINE AND HALF-TONE BLOCKS

It might be thought that the skilful engraver with his graving tool could make considerable modification on a line block, and that that modification, if well and tastefully done, would be an improvement, and this view is correct. Many years ago, when there existed a number of very able pictorial wood engravers, much really interesting work was done, especially in the U.S.A., and it is well worth the effort on the part of the student to examine, for example, the pages of *Harper's* and *Scribner's*

magazines. There was also a very pleasant treatment accorded to certain types of drawing rendered by the screen process. Naturally, such work is expensive, and it unfortunately went out of fashion. It is difficult to see how it could be easily revived in view of the fact that the school in which men learnt the use of the graver, the pictorial wood engraver's studio, is now, alas, practically non-existent. But, without the exercise of excessive skill, much may be done to improve line blocks of pictorial subjects by means of the graver where a facsimile of the effect of the drawing is desired. Where lines, especially their terminations, print too heavily—it must be remembered that in the line processes a line is either reproduced or is missed out, and a grey line and a black line, if reproduced, will both be rendered the same with respect to *intensity* (see page 9)—they may be lightened by cutting away some of the line by the tool, and though fidelity of line be not there, by such a method it is practicable to secure *facsimile of effect*. In some cases, by the exercise of considerable skill, the same appearance may be secured by fine-etching the lines, using the principles of undercutting, but the method is risky.

In line-colour processes, where a colour original is presented to the engraver, the dissection may be quite easily done by selection filters (see Chapter XI) in some cases, so that negatives are made direct from the original for the separate printings. But drawings, alas, are seldom made with a view to meeting optical possibilities, and more often than not the selection must be made by hand. Thus, negatives are made to contain all the drawing, and then, for each printing, the colours *not wanted* are stopped-out upon the negatives, so that what remains is the colour to be printed from the plate made from each negative. In certain cases the stopping may be avoided, thus a blue may be easily "lost," and similarly a red, a yellow, or a

green. It is with the nondescript shades that difficulty arises. By far the better and more economical plan is for the artist to work in conjunction with the engraver, making the drawing in black on white, and let the colour selection be made before etching upon plates prepared from the black negative, by removing from the plates those parts of the image not wanted, which is a perfectly simple operation.

In half-tone colour work there are many treatments. In the simplest case two printings may be employed, the main printing—generally a black—and a very light tint from one and the same block, and in this case "pattern" (see page 387) is not obvious. More often than not, however, a second block is made, and this is modified; for example, a part may be removed so that there be no tint on that portion, or the tint block be confined to the object and the background cut away or vignetted. Such blocks, where there are two, are termed "duplex half-tones." A method of producing a variety, compared with plain monochrome printing from one block, is to employ an ink having a soluble constituent which eventually "bleeds," so that each dot becomes surrounded by a faint halo of a tint that harmonizes with the body ink. The success or failure of this form of printing "double tone" depends upon the particular ink and the paper used, and is not invariably successful. Effects are frequently produced by means of two-colour blocks, where the selection is made sometimes by selection filters (see Chapter XI), and sometimes by hand, or both. In all cases fine etching is necessary for the complete effect. In work of this kind, where strong colours are often associated, provision must be made against "pattern" by making the two negatives at different screen angles (see Chapter XII).

But in colour work the main effort is made in the direction of three printings, the so-called "tri-colour" process,

of which yearly there is an increasing use. Where cost is not a matter of moment, and a better result is desired, however, a fourth printing is added—often in a neutral tint—from a plate prepared to give a good monochrome rendering of the subject, and here there results a four-colour block process.

The theoretical and certain practical aspects of the tri-colour printing processes are discussed in Chapters XI and XII.

PROCEDURE IN ETCHING

In the actual process of etching, the mordant for zinc is nitric acid, whilst for copper ferric chloride is employed.

The concentration of nitric acid employed changes with the progress of the work. At the commencement, the concentration may be from 2½ to 5 parts of commercial acid 38° Beaume hydrometer (sp. gr. 1·36)—according to whether the work is fine or coarse, the weaker acid for the fine work—to 15 to 100 parts of water, increasing to 24 parts acid to 100 parts of water for the final etching. It must be remembered that as the etching—a chemical action—proceeds, there is a considerable rise in the temperature of the bath, and so a given acid concentration is more effective than when at a lower temperature. It is much more systematic to work to given strengths of acid, as measured by the hydrometer, than to measure the volume of an acid (the concentration of which will differ one batch with another, and where frequently in any case the concentration of the original acid is not known) to water. The specific gravity of a *good* sample of commercial acid, as would be used for etching, is practically 1·42, corresponding to about 70 per cent of real acid, and this would show on Beaume's scale 43°. A litre would contain, approximately, 1,000 grams of real acid, actually 991 grams. If, with any batch of acid, the etcher mixed the

acid in the decided-upon proportions and then took the degrees that each dilution measures, by means of the Beaume hydrometer, he would have a guide for future work, so that if successive batches of acid varied it would not matter, because he would dilute to strengths to readings on the Beaume scale. In the etching of enamel plates on zinc it is not prudent to employ a greater concentration than 5 per cent, otherwise the enamel may succumb and the surface of the image would be left unprotected.

When nitric acid comes into contact with zinc, mutual action takes place. The metal is attacked, is dissolved, and the acid suffers. Zinc nitrate is formed, and the nascent hydrogen liberated by the action reacts with the excess of acid, reducing it by removing oxygen and itself being oxidized to water. As a result of this reduction various gaseous oxides of nitrogen are liberated, the composition and character of these being dependent upon the strength of the acid and the conditions. Red fumes of the higher nitrogen oxides are produced, partially resulting from the combination of the oxygen of the air with nitric oxide, which is, or may be, one of the products. These unpleasant fumes consist mainly of nitrogen peroxide.

The etching action proceeds more rapidly and evenly when the plate is frequently uncovered during the process. The motion does tend to prevent the formation of adherent films of gas which would protect the metal from the action of the acid, and brushing the plate serves the same purpose. Any nitric oxide in the evolved gas is converted into nitrogen peroxide by contact with the oxygen of the air, and this, in contact with water, produces nitric and nitrous acids, the latter being ultimately converted into nitric acid.

In machine etching with "splash" or "spray" systems the mechanical action of the impinging stream of the

mordant eliminates the necessity for brushing and it is much better so.

With copper and ferric chloride the chemical change is more simple. The copper reduces the ferric chloride, itself being chlorized, and cuprous chloride is formed; and the latter, being soluble in a solution of ferric chloride, dissolves. The rapidity of the action of the ferric chloride varies with the concentration. When the solution is highly concentrated the action is slow; the copper becomes coated with a film of cuprous chloride, which does not dissolve in the highly concentrated ferric chloride but remains as a film on the copper, preventing further action until mechanically removed by brushing. If the solution be gradually diluted, it will be found that the action increases in rapidity. It is usual to prepare what is practically a "saturated" solution, and this at normal temperatures registers about 48° Beaume hydrometer. The Beaume hydrometer (Fig. 43) is one of the several forms of instrument which supply a simple means of quickly ascertaining the specific gravity or density of a solution, and from the figures obtained the concentration of the solution can be found on reference to tables. The instrument consists essentially of a glass bulb blown at the end of a sealed tube (or stem), which bulb is weighted by mercury or fine shot. Inside the tube, carefully fixed, is a paper scale, which may be a plain scale of figures with decimal places, as 1·01, 1·0125, 1·015 and so on, or an arbitrary scale of certain figures (as in the Beaume scale), the length of the tube in either case determining the range of the instrument. It is usual for instruments to be made for a certain range and with an open scale where the

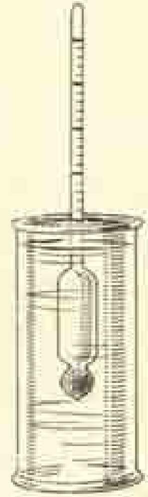


FIG. 43. THE BEAUME HYDROMETER AND JAR

graduations are relatively far apart, thus enabling accuracy to be obtained, or closed scale when the instrument suffices only for an approximation. On placing the hydrometer in the liquid which is contained in a narrow cylinder, the instrument sinks and comes to rest at a point depending on the concentration. The figure coinciding with the surface of the liquid (ignoring the meniscus) is the figure of value required. The instrument is made to read for the liquid at normal temperatures. A change in temperature would cause a variation in density, but this, in workshop practice, is ignored. These hydrometers are made for liquids lighter or heavier than water, and it is the heavier that is required. There are several Beaume standards, and American standard instruments are generally in use by photo-engravers. It is advantageous to add ammonia to the ferric chloride solution, until a permanent precipitate of ferric hydroxide is produced, allowing the solution to stand for several days before filtering. In this way a solution is obtained which does not attack the resist. For etching purposes the solution is diluted until it registers 40° Beaume or a lower figure when desired.

ETCHING MACHINES

In practice, the mode of application of a mordant is a matter of moment. Zinc plates are frequently etched in earthenware troughs, which are supported, so that they can be rocked, and there should be only that amount of acid in the "tub" which will allow that at each tilt the plate is left bare, so that the surface of the metal is exposed to the air. Etching is now generally done by means of etching machines, of which two forms are important, the "Levy" and the "Mark Smith." In the Levy machine acid is forced against the horizontally supported face-down plate by means of a jet of air, hence the name "acid blast." It is claimed that by this machine there is less tendency

to undercutting than with the "tub." In the "Mark Smith" machine there is a paddle rotating in a pool of acid, which causes the acid to be splashed against the horizontally supported face-down plate. With these machines etching proceeds much more rapidly than with

FIG. 44. "NEW SERIES" ETCHING MACHINE FOR ZINC AND COPPER ETCHING (HUNTER-PENROSE)

the "tub" method. This is a matter of considerable moment when there is deep etching to be done and, consequently, etching machines are in general use. But the additional use of the router has caused there to be much less necessity for deep etching by acid, for metal can be much more quickly removed by a rapidly rotating

cutter than it can be by the use of an etching mordant, and, moreover, at less cost.

During recent years considerable changes have taken place with regard to etching machines. Many of these previously in use, the "Levy," the "Holt," the "Albert" and the "Revolvax," are now obsolete. Only the "Mark Smith" remains, and this has been considerably altered.

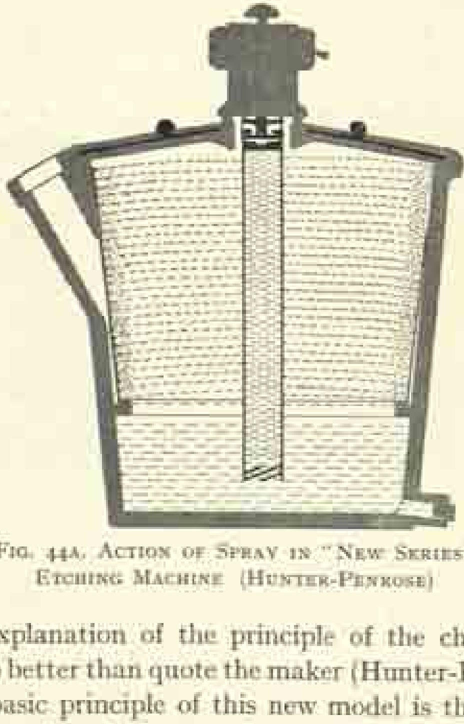


FIG. 44A. ACTION OF SPRAY IN "NEW SERIES" ETCHING MACHINE (HUNTER-PENROSE)

For an explanation of the principle of the changes one cannot do better than quote the maker (Hunter-Penrose)—

"The basic principle of this new model is the application of centrifugal force to the etching fluid, the liquid being pressed into a rotating vertical tube which is drilled with numerous holes so as to permit the escape of the liquid. The desired spray effect is obtained by the number, shape and arrangement of these holes. Air is drawn into the trough as the rotation of the tube, combined with the spraying of the liquid, acts as an air fan."

The depth of the etch is mainly dependent upon the time, the force of the spray, and the supply of air. The etching is deep and brilliant and the dots are conical and do not show signs of undercutting—a most valuable property in plates that ultimately have to go to the foundry.

The machine and the mode of action of the spray are shown in Figs. 44 and 44A.

Much attention has been paid to the etching of half-tone plates, especially those upon copper, for it has been found that the mechanical way in which the plate is etched has an influence upon the appearance of the finished work. In order for the etching to proceed, it is necessary that the product of the action of the ferric chloride—the cuprous chloride—be removed. Originally, the etching was done, as in the case of zinc, in a trough containing the mordant, which was rocked, and, further, the plate was brushed with a camel-hair mop. It was found that this method produced irregular etching, and it is no longer used by careful etchers. In modern practice, when the plate is etched in a trough it is supported, face down, in the mordant, and is quickly moved from time to time, and there should be no brushing. The products of the reaction fall away, and circulation is produced naturally, fresh chloride flowing in to take the place of the reduced solution which has etched the plate.

To facilitate etching upon copper, there are several machines on the market. The "Mark Smith" is modified by changing the fittings from aluminium or duralumin to ebonite or celluloid. The "Revolvax," sends a spray of the mordant against the plate to be etched, and here, in effect, we have practically a combination between the "acid blast" of the "Levy" and the splash system, as shown in the "Mark Smith" machines.

There is little doubt that the etching machines are more

economical of material than the "tub" system, and with the mechanical action of the solution of the mordant the process is hastened. It is possible also to use, in the case of zinc, nitric acid much more dilute than with the "tub" method, and owing to the way in which the plate is etched, aerial oxidation takes place more rapidly, for not only is air carried forward to the plate by the spray, but the surface of the plate is perhaps not covered for so large a part of the time.

ELECTRIC ETCHING

There is another system of etching copper plates now of considerable importance, and it is surprising that its advent was so long delayed, although many experimental efforts were made long ago. The experiments are now bearing fruit in the extended and extending use of the system. The system is electrolytic, the plate being etched by making it the anode in an electrical circuit.[1] In this way copper is transferred from the anode—the plate to be etched—to the cathode, which receives a deposit. It is, therefore, similar to an electro-depositing system. In an electro-depositing system, as, for example, for the deposition of copper, the surface upon which copper is to be deposited forms the cathode in the electrolyte, which is a solution of copper sulphate, and a copper plate forms the anode. When the circuit is closed, copper is deposited from the solution upon the object, and to replace the copper which is deposited, fresh copper passes into the electrolyte from the copper anode. The anode, therefore, loses copper. When etching, say, a copper half-tone, we desire the unprotected parts of the metal to lose copper, and we therefore make it the *anode* in the electrolytic circuit. What happens to the copper is immaterial—

[1] Electric etching machines were introduced to the industry in England in 1927 (Hunter-Penrose). The first and second of the machines were installed and used by Messrs. Gilchrist Bros., of Leeds.

actually, it is deposited upon the cathode, which may be an iron-wire grid. The anode and cathode are placed parallel, and the direction of the current is at right angles to the surface. In consequence, there is a tendency for the

FIG. 45. THE S.D. ELECTRIC ETCHING MACHINE
(S. D. SYNDICATE)

sides of the portions which become etched into relief to be at right angles also to the surface of the plate, so that we might expect, in a half-tone, vertical-sided dots. Actually, the dots are conical, with a *tendency* to preserve the original shape of the surface of the dot, which in some of the tones is practically a square. The etching is very rapid, depth being soon obtained. This rapidity is

extremely valuable in view of the increasing tendency to employ rough stock, which calls for extremely deep-etched blocks, and ordinary deep etching on copper is very tedious. There is little undercutting, a matter of importance when plates have to go to foundry for duplication. No difficulty is found in fine etching, and the stages are carried through rapidly, although much of the fine etching is done in the ordinary way. A matter of great importance in electrolytic etching (as in electro-depositing) is the uniform and sufficiently rapid agitation of the electrolyte, which is done by means of air under pressure.

The system is also used for line etching on copper, but for etching on zinc it has so far not been found satisfactory.

One type of machine is shown in Fig. 45. The electrolyte used for copper is ammonium chloride and sodium chloride. See W. J. C. Hislop, *Fundamentals of Electric Etching*, *P.E.M.* Vol. 55, 1949, pages 270 and 302.

THE PROCESS OF FINE ETCHING

Reference has been made in the text above to an operation termed "fine etching." Fine etching, or "re-etching," is the name given to a process by means of which the sizes of a particular series of dots in a half-tone image are altered. It is, as used, a selective process, a correction process, and is employed for the purpose of altering gradation and contrast. By its means it is possible to change the whole appearance of the proof from a half-tone plate, and without its aid the half-tone process would lose much of its value. Primarily, it was applied and developed for the half-tone relief process, and only in that process does it give its best results, but it has been adapted to the intaglio process, although the technique in that process is not yet so fully developed as in the half-tone relief process. It cannot be adapted to *surface* images. The mechanism of the etching process, considered particularly with regard to the action of the ferric chloride upon the metallic copper,

is simple, and in Fig. 46 an endeavour has been made to represent diagrammatically what takes place.

THE NORMAL ETCHING PROCESS

Consider the surface of the copper plate with the "burnt-in" resist of enamel, consisting, for example, of large isolated dots. The uncovered copper will be covered with a very slight film of copper oxide, formed when the

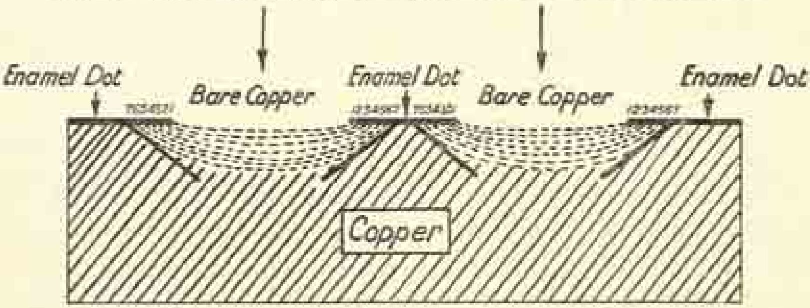


FIG. 46. DIAGRAMMATIC REPRESENTATION OF THE PROCESS OF ETCHING A COPPER HALF-TONE PLATE WITH FERRIC CHLORIDE

The large arrows indicate the direction of the attack of the mordant, and the dotted lines the copper removed after successive intervals of time, 1, 2, 3, and so on, as shown in the figure. At each increase of depth the exposed edge of the enamel dot is "under-cut" and breaks away, with the result that the top of the dot becomes smaller and the sides sloping; hence, the more or less conical shape

metal was heated by the action of the oxygen in the atmosphere. This film would soon be penetrated by the mordant, but it is the practice of some etchers to give a brief application of a dilute solution and then to start the etching proper with ferric chloride solution of the normal strength. So that in this case the attack of the solution is upon clean metallic copper. The interfacial tension between a well burnt-in glossy enamel resist and a concentrated solution of ferric chloride is such that it is problematical whether or not the resist is really wetted by the solution. This is an advantage. It is found by experience that a very open, spongy or porous resist is more readily penetrated by the mordant than one where

the resist is glossy and continuous, and, in consequence, with the former there is a liability that some of the dots may be etched through and leave the metal. When the ferric chloride touches the copper there commences, owing to its action, the formation of little cavities, and there is then the upward action by which the edge of the dot is undermined ("undercutting"), beginning at 1. As the action proceeds the cavity becomes deeper, and edges 2, 3, 4, and so on, successively give way. The sides of the cavity are sloping, and this gives the conical shape to the dot. The sequence described goes on until the plate is removed from the bath, which removal takes place when the plate is judged to be sufficiently deeply etched. Were the process to be continued, the whole of the dots would etch away. In consequence, the dot image has smaller dots in the lights and larger cavities in the darks *compared with the condition when the etching was commenced.* To allow for these changes the negative must be made so that it will give larger covered portions in the light parts and smaller uncovered parts in the darks than are required in the end. The plate after etching may have a slight "burr" to the dots owing to the fact that the edges do not wholly come away, and it has been the practice of some etchers, when the plate is etched, to scour the surface gently with a *soft* bristle brush.

In an albumen printed image this undercutting does not take place, because the ink is allowed to run over the edges, and so the sides of the dots are protected, and, in consequence, allowance must be made in the negative.

THE PRACTICE OF FINE ETCHING

When, in an enamel plate, printing depth has been obtained, the etcher washes the plate and examines it, comparing it with the original. It is not necessary that he take a proof; by his experience he can judge whether or

not the sizes of the dots are right to give the correct tones. If only a slight correction be required, he can now apply the mordant locally to the plate by means of a brush. Now, by reason of the undercutting, the dots in that portion become smaller, and this action is allowed to continue until the size of the dot is correct. Much can be done in this way, but if, as is probably the case, more elaborate treatment is necessary, the etcher now proceeds to stop out with a protective medium all those parts which have been etched far enough, and then places the plate in the bath and etches for the next set of tones, stopping, washing, and painting out all those parts that are done, and so on until the whole plate is etched. He then cleans off the stopping-out medium and examines the plate. To judge the effect it is not necessary to proof the plate, but he may rub over it a little magnesia, which is a white powder which sinks into the cavities, and this gives sufficient contrast with the dark-coloured enamel to enable the etcher to judge whether or not the etching is complete. By this valuable process the whole of the appearance of the plate may be altered until the tones are correct as compared with the original or, as is frequently the case, the gradations are altered with the object of effecting an improvement. In the ink albumen process, fine etching of the zinc half-tone plate requires the whole of the ink resist to be cleaned off, and the plate is rolled-up with a glazed roller charged with hard finishing ink. This protects the surface of the dots, and the etcher now proceeds, by the stopping-out system, to etch those tones which require correction. The process is, however, not so satisfactory in working as the enamel process, whether on zinc or copper. Various "stopping out" media for the local protection of parts of the plate are employed, as bitumen in benzene, or shellac in alcohol; some etchers use with success a lithographic crayon (a fatty crayon)

for stopping out, this being, in their hands, a more flexible tool than the brush with stopping medium.

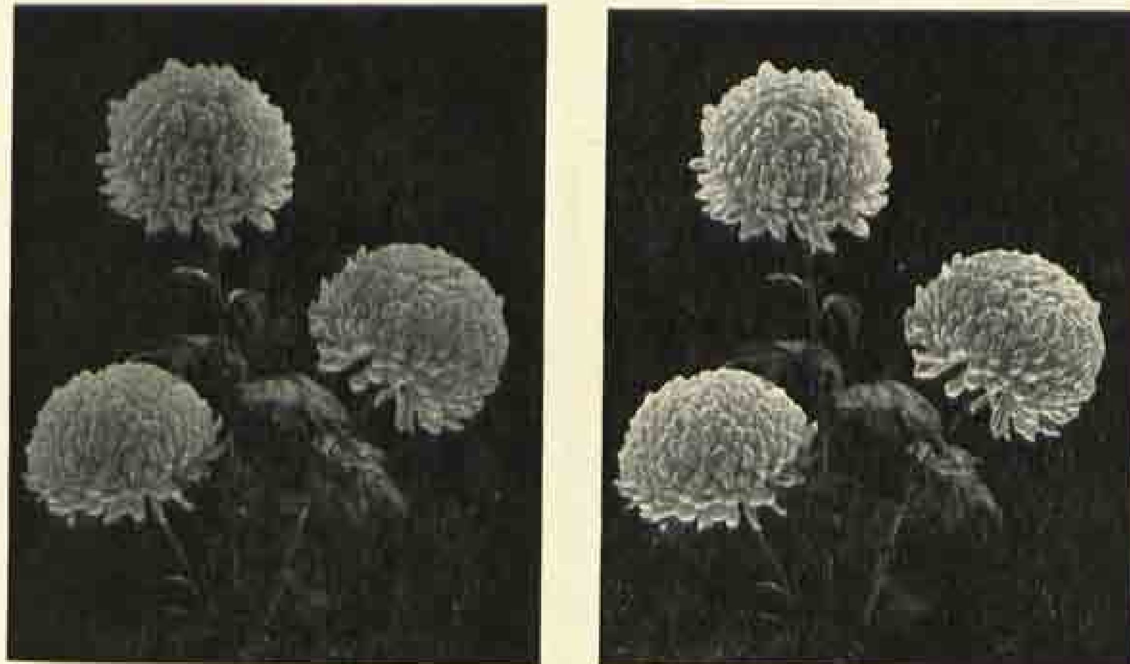
The fine etcher has a difficulty because the aim is not constant. The originals which come to the engraver are very varied in character, and the desires of the buyers of engravings vary also, so that the fine etcher may be pardoned if he be sometimes bewildered. Cases have often occurred in which the careful suppressions of the pure photographer—say, the background in portraiture for aesthetic reasons—have been rendered nugatory by the misplaced activity of a fine etcher. On the other hand, another customer, who might be without any aesthetic leanings, would welcome that kind of activity.

A good deal of the possibility that aesthetic sins in rendering may be perpetrated by the fine etcher is avoided by the modern method of work. In times past there was a "rough etcher" (who often honestly lived up to his title), who took the plate down to printing depth, and a "fine etcher," who took over the plate from him and proceeded to carry out the selective etching. Now, there is always the possibility under a system of that kind that marring will take place in both hands, and also that the "fine etcher" will do more than is necessary, looking, as he naturally does, upon his work as something which has to be justified and, therefore, doing too much. Incidentally, he may receive the plate when it has been taken further than it should have been by the "rough etcher," and he may be doing what he considers to be the best to retrieve a bad job. Now the plate goes to the etcher, whose business it is to do the whole of the work in accord with the copy and his taste and judgment, and, as might be expected, the results are far better than under the former system.

Whilst the process of "fine etching" is one of considerable value—indeed, it would not be practicable to

avoid its use—there are considerable dangers in its application. There is the mechanical difficulty, by which is meant the avoidance of a distinct line of demarcation between the different stoppings and etchings, if etching after the stopping is to be prolonged, and this is a matter of skill in manipulation and judgment as to the length of time the plate is etched, for if there be too long an immersion in the mordant the demarcation will show. There is an "art" in the way the stopping is applied (in the brush work, or example), and when it is necessary to stop, and when the etching can be done by the simple application of the mordant to the bare plate. As an example of the effect which may be produced by "fine" etching in a simple case, Fig. 47 (*a*) and (*b*), and the diagrammatic representation of dot change in *a*–*e* in Fig. 48, are shown. The process could not be applied satisfactorily to the flat dot "f," which represents fairly well the section of the form of the dot in a photo-litho plate.

An interesting application of the half-tone etching process is seen in the use that is made of the etched plate as an intermediary in the production of surface plates for either monochrome or colour photo-lithography direct or "offset" printing. Here, an image is produced on copper and fine etched to give the desired appearance. The fine etched plate is then filled in with magnesia. This gives a white ground. If there be not sufficient contrast, owing to the fact that the enamel is not a dark enough brown, the plate is rolled-up with a glazed roller charged with finishing ink, when the black tops of the dots give, with the white ground, sufficient contrast of tone. The plate is now placed on the copy board of the camera system, and an ordinary wet collodion negative is made and carefully intensified. This negative is used to produce the print on zinc for photo-lithography. Such a procedure



(a) (b)

Fig. 47 Examples of a Simple Case of "Fine Etching." (a) Before; (b) After

enables corrections to be made indirectly for a photo-litho plate which it is not practicable to do directly upon the plate. Strange as it may seem, it is economical in practice, and by users is stated to be more so than the elaborate retouching of positives and negatives necessary in photo-lithography, for the reason that there is no *satisfactory* way of fully correcting a photo-litho plate

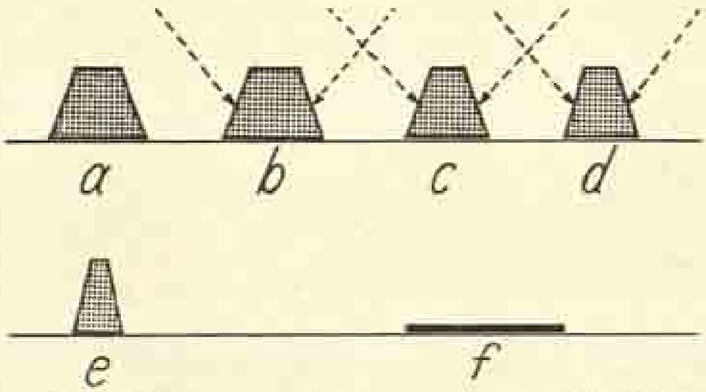


FIG. 48. DIAGRAMMATIC REPRESENTATION OF THE CHANGE IN DOT SIZES DURING THE PROCESS OF FINE ETCHING

The arrows show the direction of attack of the mordant. For comparison, in *f* the practically flat dot in a photo-litho plate is shown

when once printed. Be this as it may, the increased attention which is being paid to the subject is causing the evolution of methods of correction more direct and logical.

With the passing of the proof and the supply of the trimmed plate, the work of the photo-engraver may be said to have ceased, but not so that of the printer. For his purpose it is necessary that the plate be mounted, and although the mounting is done in the majority of cases by the engraver, it is a mechanical task. But to meet the requirements of the printer is not easy, and it is seldom that he is satisfied, though, generally speaking, he is frequently justified in not being satisfied.

THE MOUNTING OF PLATES

The materials employed for the mounting of plates are wood and metal, although from time to time composition mounts are suggested but have never proved of practical value. Of wood, mahogany and oak are used, though sometimes teak is employed; of metal, the permanent mounts are always stereo metal, but iron is used for temporary purposes. Usually, plates are mounted by the photo-engraver and delivered ready for use, but some printers prefer to receive unmounted plates and to mount them themselves, in which case there are employed for the purpose special articulated boards—to prevent warping—or iron mounts, the plates being fixed by clamps which work to-and-fro in channels in the wood or metal so that they can be fixed in any position, or they are sometimes held on the wood or metal by a thin smear of "elastic glue." In certain cases low quads are assembled to make a mount of the correct size. In the case of blocks turned out by the good engraving houses, the assumption may be made that the back and front are parallel. It is much to be regretted that, though printers work to standard sizes on the point system, and expect and receive from their supply houses all materials, where size is of moment, fashioned to "point sizes," the block-makers have not followed suit.

THE NEGLECT OF REAL ACCURACY AND OF STANDARDIZATION IN MOUNTING SYSTEMS

If an order were placed with a number of different photo-engravers for a block from a given original to be made to a certain size, no doubt the images would be the same in size. But it is fairly certain that the sizes of the mounts would differ. If two portrait blocks from two similar originals to the same size, intended to be printed in the same column, were ordered from the same engraver,

and equality of width was not distinctly specified, they would probably differ. Actually, the photo-engraver does not in many instances know the accuracy which now obtains with many items of the letterpress printer's equipment. If known, it is certainly not sufficiently appreciated or the implications understood. This lack of knowledge or appreciation is not understood by the printer who is accustomed to standardized material, and it causes undue labour and irritation, both of which could quite easily be avoided.

But though the block, when issued, may be true, it does not long remain so owing to the changes undergone by the wood under the ordinary atmospheric conditions to which it is exposed, and there follows, as a consequence, a large amount of totally unproductive labour on the part of the press-man or machine-man.

To avoid this difficulty, the wood has been dried and treated with some substance, such as paraffin wax or oil, to make it impervious to water, and, in addition, tongued and grooved boards, clamped boards, articulated boards of various degrees of complexity, laminated boards, section boards, boards tongued with metal, and channelled metal mounts, have all been employed, and naturally at an increased cost. Of all methods, probably the most satisfactory is to mount on solid stereo metal, in which case the block can be made practically as true and as durable as the type with which it is so frequently associated.

Where articulated boards are used, considerable differences in the resistance to warping are shown. For example, two pieces joined together by a loose tongue have been found to give less warping than if the tongue forms *part* of one of the pieces. Some composite boards are soft, and the heavy parts of the plate—the solids in a line plate, for example—tend to sink into the wood.

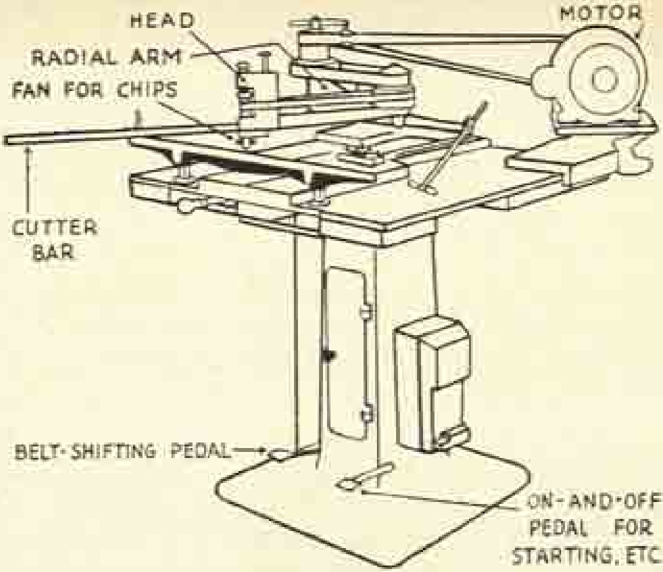


Fig. 49. The Radial Arm Router (Royle)

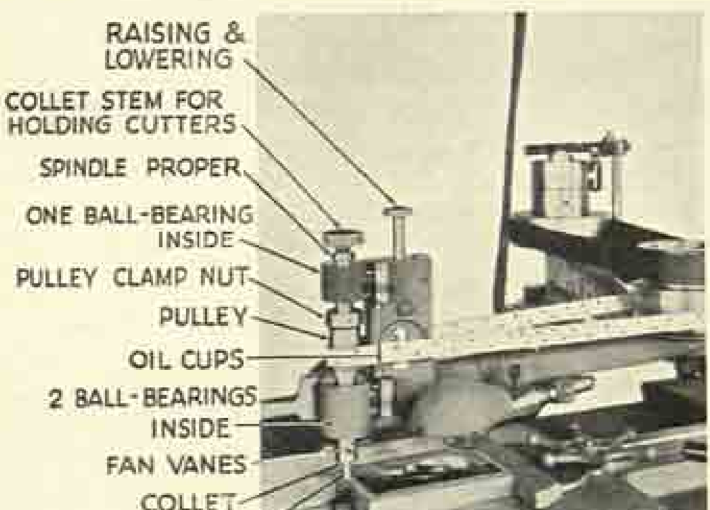


Fig. 49a. The Radial Arm Router (Royle), showing Plate Temporarily Mounted ready for the Routing Operation

PLATE-FINISHING MACHINERY

The plate-finishing equipment consists of a radial arm router with or without a lining attachment, a beveller or a lining beveller, a saw table, a jig saw (which may be combined with a drill), a rotary planer, an edge trimmer, a notching machine, and an eliptograph.

The router (Figs. 49, 49A) is essentially a device for rotating a cutter at a high rate of speed (16,000–18,000 r.p.m.), its object being to remove from the plate superfluous metal—either to remove it altogether from the wide spaces or to deepen parts already etched—and to cut away wood in the broad spaces of mounted plates. The router provides a bed-plate to which the plate is rigidly clamped, whilst the cutter is held in the router head, which is supported upon an arm. This arm, and, consequently, the cutter by means of the arm, can be accurately and delicately moved in any direction, and thus metal can be removed from any part of the plate. If the router be a "straight line," not only can it be used without difficulty for routing of a geometrical character, which sometimes arises, and where the ability to rout to a straight line is important, but it can be used for cutting a bevel upon plates, an advantage in a small engraver's business, because it saves the cost of a beveller. If, in addition, there be a "lining attachment," then the lining on the plates, referred to on page 305, can be done, otherwise a lining beveller would be required.

The beveller (Figs. 50, 50A) is employed for cutting the bevel, or rebate, at the edge of the plate, to provide the recess in which the mounting pins are placed to secure the plate to the mount. According to the cutter, the rebate may be flat or with a sloping edge. A lining beveller will do the work of a plain beveller, and, in addition, will cut lines at the edge of the plate, as described on page 305. There are two types of this machine, the one which will cut a

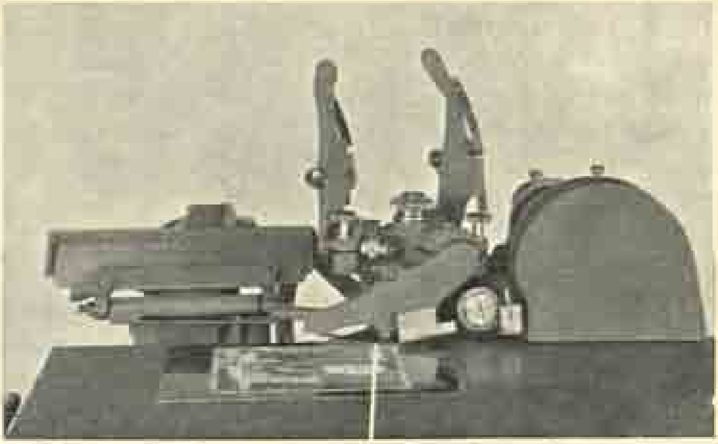


FIG. 50. THE LINING BEVELLER (ROYLE), THE LINING TOOL BEING SET TO CUT IN FORWARD MOTION. THE CLAMP HOLDING THE PLATE HAS BEEN REMOVED IN ORDER THAT THE SETTING OF THE LINING TOOL MAY BE SEEN

FIG. 50A. THE LINING BEVELLER (ROYLE), SHOWING THE CLAMP FOR HOLDING THE PLATE IN PLACE

line, or a series of lines, in the solid metal margin left at the edge of the plate, this being called the "graved line" beveller, and another form which will produce a ridge of metal in any half-tone tint there may be at the edge of the plate and shave it so that it will print solid, this being called the "raised line" beveller. The latter will do both kinds of work.

A saw-table is used for cutting up the metal at starting, for trimming the margins of etched plates prior to bevelling, and for trimming flush when the plates are mounted. If a guillotine be provided—as will be the case in most instances—metal will be cut by this means; if a beveller is used, when the bevel is completed, the space between the bevel and the margins is so thin that the margins can be removed by bending and then breaking, and so the cutting of the mounted plates is all that there remains in the way of work for the saw. In the early days of photo-engraving the trimming of the edges would be done by a shooting plane, but this is a laborious tool to use—as was the hand-bevelling plane with which it was usually associated—and is now seldom used except in very small engravers' finishing rooms. To-day, in an establishment of any size, the trimming of the edges of mounted plates would be done upon a rotary edge trimmer, which is a device for rapidly rotating a cutter held in a heavy rotating disc against the side of the mounting, which trues up, at one and the same time, the wood and the edge of the metal plate. A jig saw is employed for cutting-up plates assembled in a "flat" (see Fig. 39), for cutting out pieces of metal from a line plate, such as a large area of white—it will do the work more quickly than a router—and for piercing the wooden mounts, which is often wanted, for example, for inserting type. The drill replaces the laborious hand-drill for piercing plates, electros, and stereos, for drilling the hole, and for mounting screws or pins.

The Eliptograph is a device for inscribing circles and ovals, and for graving lines as guides for cutting-up plates into the same forms.

The rotary planer is a most important piece of machinery, for by its aid the plate is trued up so that the back of the mount and the face of the matrix are parallel, a most important necessity from the press or machine-man's standpoint. When the plate is mounted it is placed, face down, upon the bed of the planer; there is then passed over the back a rotating disc holding a cutter, which planes away any mount above a certain height, and thus back and front are made parallel. The thickness can be made either strictly type-high or slightly less. The planer will plane stereo metal equally well, so that stereo-metal mounted plates may also be "trued up."

It is desirable to reduce, as far as may be practicable, the number of special machines where the task of each machine is only small; though it may fulfil an entirely necessary purpose it will not be always in use, such, for example, as a notching machine to notch mounts to meet the occasional demands of printers. There is upon the market a useful machine, known as a "saw and trimmer," which will saw, trim, notch, and cut metal into fancy patterns as may be wanted, and a machine of this type takes up less space than a number of separate machines of equal efficiency.

To meet the "wear and tear" on the surface of type-high blocks, which is considerable with long runs, more especially where the machine conditions are not what they should be, the surface is frequently protected by electro-depositing a coating of nickel, which adds considerably to the life of the plate. Further to this, nickel facing prevents the change in tone of the printing ink which occurs when certain colours come into contact with copper, and, in addition, the nickel withstands more

perfectly atmospheric influences which lead to corrosion. More recently, chromium has been utilized for the same purpose, and as a protection is very much more effective in every way than nickel; indeed, for maintaining the surface of the matrix during very long runs it is almost essential, and its employment, although relatively costly, is otherwise economical.

CHAPTER XI

COLOUR AND ITS FUNDAMENTAL PRINCIPLES

A BEAM of light, from the clear unclouded sun at its zenith, falls upon the surface of recently-deposited snow lying in the open country, which is, as yet, uncontaminated by the smoke from chimneys of the home or the factory.

The wayfarer, glancing at the surface, were he called upon to describe what he saw, would probably say that the ground was covered with snow, and he might, were he questioned as to whether or not the sight caused him any particular sensation, say that it was "bright," that it was "dazzling" to his eyes, and that it was very "white." He would, were he still questioned by one who was, let us say, a stranger to our modes of expression, as to what he really meant by the word "white," probably have to admit that the only thing that he knew was that this thing which came generally in abundance year by year at a certain season was "white," he had learnt so in his childhood days, and had never thought further on the matter. In addition, he might say that things which had, in one respect, the same appearance were always, to him, "white," and so for him, at least, the matter was settled.

To the large majority of people this word "white" remains for ever merely a term of description. What it is, and what may be its cause is never asked, it is like a piece of token money which, so long as it has the power to procure, never raises in the mind of its user any question as to its origin or its relation to any fiscal system—the thing itself suffices.

THE APPROACH TO THE PROBLEM OF COLOUR

For the student who desires a knowledge of colour and the mechanism of its production, an inquiry into what is meant by this word "white" may conveniently be made the starting-point. There are many ways of approach to the problem of "colour" and all that it means, as there are to other branches of knowledge, and each way presents some kind of difficulty, more particularly to those who have had no training in the fundamentals that underlie all forms of physical knowledge, and who do not know the meaning to be applied to its terms; and any preparatory training on the part of readers the Author prefers not to assume. Perhaps without this knowledge it may be found possible to convey to a patient student some idea of what "colour" really means, and to give him, in the course of the explanation, information as to elementary principles which will suffice to simplify problems met with in the work in which each day he is engaged.

COLOUR APPEARANCE

Let us assume that we have placed upon the surface of the snow some pieces of paper, or of fabric, of different "colours," one, let us say, that we call "black," another that we say is a "blue," and still another that we know as "red." These materials—their nature does not matter—are now under precisely the same conditions as the snow, and that being so, it will be conceded that the differences in their appearance, as compared with the snow and with each other, are due to *something* in the things themselves, apart from their other nature. We are not concerned with the particular kind of paper or fabric so far as it is paper or fabric; if so, we might put aside other substances which we call "black," "blue," or "red." The thing we are trying to make plain is that under the same conditions certain things which we call paper, or fabric, have a

particular kind of appearance, that is, they affect our eyes, and this *appearance*, this blackness, this blueness, this redness, is for the moment the object of our study.

WHAT IS MEANT BY "COLOUR"

Let us now take one of these substances in our hands and feel it. It conveys to the touch a certain sensation. It is soft or hard, smooth or rough, as the case may be. Now let us shut our eyes and we no longer perceive the colour; instead of two sensations one only remains, that conveyed by the touch, and the paper, or fabric, will still feel the same. Open the eyes and the "colour" is there—it has not vanished. So we see that "colour" is something requiring the use of our eyes. It is a sensation; it can be appreciated only by the organs of sight—to the blind it has no existence. If the sun were to sink and be succeeded by a dark, moonless night, this colour would vanish, but our sense of touch would soon tell us that these pieces of material were the same as they were during the sunny daytime—only the colour, this particular quality, had gone. And so we perhaps begin to see that this attribute, unlike the other attributes, is something which depends upon there being "light" and upon the use of our eyes. It is purely a physiological effect, and, since it is produced by means of our eyes, a visual sensation.

Now, if we take a reasonable standard, what any small group of people would see would be seen without difference by any other similar group taken at random. But here and there will be found individual differences, some slight, some considerable, and we say that these people are not normal, that, in this respect, they are different from the rest; and we say that they are "colour-blind" to different degrees. We know by well-confirmed statistics that a small percentage of the population of the world

is so affected, and we know, further, that the defect is either congenital or produced by disease.

ABSORPTION AND REFLECTION

We may now try to arrive at the cause of this phenomenon of colour—the reason for the difference—and we may at the outset consider how that which we call "light" comes about—how it arises. The great source of light in nature to which we refer phenomena of colour as to their source of origin is the sun. From the sun—in the instance taken—the light has come and it has fallen on the snow and on the materials, and has thus given rise to these appearances we are considering. When light from the sun or any other source—a candle flame, a glowing coal, an arc lamp—falls upon any body, several things may happen. A large portion of the light may be quenched, and we say then that the substance which receives the light is "black"; or the reverse may occur, there may be little or no quenching, and in this case if the origin of the light be the sun, we say that the substance is "white." Between these two extremes there are many degrees of blackness or whiteness, and the differences depend upon the nature *and the condition* of the substance—largely upon its coherence. Now we may, as in the case of the materials resting on the snow, get, side by side, differences in appearance which we call "colour," and these differences, too, depend upon the nature and condition—only on a different kind of nature. There are two simple everyday terms used in explaining these happenings. When the light is quenched we say that it is *absorbed*, and when it is not absorbed we say that it is *reflected*; and it can only be the light which is reflected that comes to our eyes. Disregarding colour and taking the simplest cases, there are considerable differences possessed by substances in their power of absorbing or reflecting light. Perhaps the

greatest power of absorption is shown by the "carbon black" which is employed in making high-grade printing ink. This substance is obtained by the imperfect burning of the natural gas from the oil wells. A loosely coherent heap of this black will absorb about 97 per cent of the light that falls upon it; on the other hand, perfectly pure calcium sulphate (which, in a state of commercial purity, is known as *plaster of Paris*) will reflect about 97 per cent of the light which falls on its surface. This power of reflection or absorption—of which there are several kinds following particular laws—is the constant accompaniment of the things which may happen when light falls upon bodies.

Now assume that the light from the sun—or other source—meets with no material, what then happens? The light, if it meets with no obstacle, passes on through space. Largely, the study of light is the study of what happens when light meets with obstacles, for if there be no obstacle, then the light passes onward, dying away into nothingness—the energy is dissipated. It is a form of energy which has no physical demonstration for us unless it meets with our means of detection, and our detector is the eye.[1] But we have seen that this light which, as it comes to our eye from the snow, we call "white," does differ when it does not come from the snow, but from the materials that we have laid on the snow.

If we glance momentarily at the sun we receive the same *quality* of sensation as we do from the snow, but the effect is stronger, more intense—so much so as to be dangerous, so evidently the sun's light itself is white, and the snow is merely giving us the same as it receives. Taking one of the materials, the "blue," we get a different

[1] This is not strictly correct, for there are instruments for detection, but the case has been kept simple.

effect. If we shut off the sun's light, if we, for example, take the blue material into a room to which no light is admitted, we obtain no "blueness," so that evidently the blue has something to do with the sun's light. Similarly with the red material. So far, we have not tried to ascertain the real nature of this white. We have made the assumption that it is of simple character, that the effect it produces on the retinae of our eyes is therefore simple, but these differences produced by the materials suggest that it may not be so. What should we do under these conditions? We should experiment, we should submit the light to analysis to ascertain whether or not it be really simple. We have, fortunately, an easy way to do this. Let us place before a *small* circular source of white light a thick slab of white glass with parallel faces, and then receive on the retina the light which has passed through the glass. We find no difference. Now let us take, instead of the plain slab, a slab with the faces sharply inclined to each other. Such a slab is technically known as a "prism." We then find that the light which falls on the prism and has passed through its substance has been deviated in a direction towards the thick end of the prism, so that we have to alter our position, as the direction is no longer in the same straight line; and we find now that the light is no longer wholly white, but that there is a patch of white with a rainbow fringe of colours. Now, the glass is colourless and a plain slab made no difference, but a prismatic one did; and so the only conclusion that we can draw is that the light is not simple, but that it is complex, and that the different constituents behave differently to each other when they pass through this glass prism. We can refine this experiment and make it more telling if we use what is known as a "spectroscope," of which a very simple and elementary form is shown in the diagram (Fig. 51).

In Fig. 51, *A* is a small source of white light which falls upon a simple lens *B*, *C* is a prism of 60°, *D* is another simple lens which receives the light which has passed through the prism, and *S* is a screen of white cardboard. Under these circumstances we shall find that the path of the light is diverted from a straight line (it is always bent in a direction towards the base of the prism—the thick end of the prism), and we shall

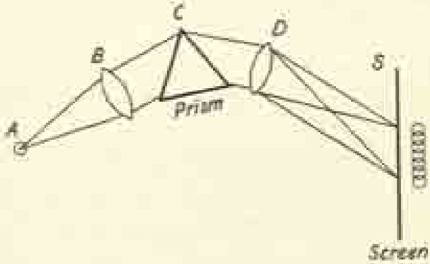


FIG. 51. A SIMPLE ARRANGEMENT TO SHOW THE COMPLEX CHARACTER OF WHITE LIGHT—THE BASIS OF THE CONSTRUCTION OF A "SPECTROSCOPE"

The small circular patch of white light at *A* is rendered as a series of overlapping circles, red at one end and blue at the other. The blue being the most deviated falls at the bottom of the screen and the red at the top

find an image of the source we have selected—which is the small white light—upon the screen. If the light were simple in character we should have one image, and it would be the colour of the source; but the light has been shown to be not simple but complex, and we obtain as a consequence a series of images of different colour. These will be differently diverted, and so, in consequence, a confused picture is produced on the screen.

At one end of the series there will be a red image, and at the other extreme there will be a blue, and between the two we shall have orange, yellow, yellow-green, green, and blue-green. They will not be separate images, but they will overlap, one merging into the other, thus giving the

confusion. These effects are due to the fact that the path of the light is altered when the light enters the glass; it chooses the path which will enable it to accomplish its journey in the minimum time, and this differs for the different constituents; different paths are followed and the light is said to be *bent* or *refracted*, and, in consequence, not being on emergence reunited, the constituents fall in different places on the receiving screen. We may still further refine this device, as in the figure below, by taking

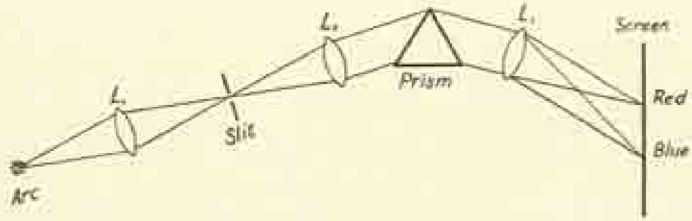


FIG. 52. A MORE COMPLETE ARRANGEMENT FOR THE DECOMPOSITION OF WHITE LIGHT BY WHICH ITS COMPLEX NATURE MAY BE SHOWN

The source of white is the arc, the light from which falls on the lens $L1$, which concentrates this light on the slit. The slit is placed at the principal focal point of the lens $L2$, and from this lens in consequence a parallel pencil emerges and falls on the prism. The decomposed pencil is received by the lens $L3$, and a series of images of the slit is formed on the screen of different colours."

a suitable source of light, placing in front of it a lens and then a very narrow rectangular opening, say, $\frac{1}{100}$ in. wide (termed a "slit"), and placing a second lens at a certain distance away. From the lens will now emerge a parallel beam, and this beam will fall on the prism face. The light will be "decomposed" by the prism, and on emerging will fall upon a third lens, which will form an image upon the screen. This image will be a succession of images of the slit, each illuminated by light of a different colour. We obtain a band of colour—red, orange, yellow, yellow-green, green, blue-green, blue—which will be the "spectrum" of white light. Actually this will be a succession of slit images, each illuminated

by some constituent colour of the source, there being no sharp division, but each one melting into the other, forming a continuous band. In this way any source of light can be "analysed" and made to yield its "spectrum," but, in practice, much greater instrumental refinement is needed for a true spectrum band of any particular source of light. We have, however, proved that the one light we took is not a simple thing, and, therefore, the sensation it produces in the retina is not a simple sensation. Each colour produces a particular sensation to which we give names, thus a "yellow" or a "blue." We drop the word sensation, but it should be understood that it is a certain yellow, a certain blue, and the white is the resultant of the many sensations produced in the retina.

We are thus in a position to explain why the snow is "white," and why one of the materials is "red," another "blue," and the other "black." The source of light is the glowing body of the sun, the ultimate particles of which are in a state of rapid vibration, these vibrations varying, so that we may say we have a body whose particles are all moving but at different rates. It is these movements which ultimately cause the sensation we term "light"; it is the difference in the rate of movements that causes there to be a difference in the "lights" (and, consequently, in the sensations), which difference we express as "colour." We have to account for the way in which a vibrating particle in the sun affects the retina of our eye. We know that between the earth and the sun there exists the atmosphere. Even if the atmosphere, instead of forming, as it does, a relatively thin layer around the earth, were to fill all space, it would not account for the transmission of the energy of a vibrating particle in the sun. We know, as a matter of fact, that the atmosphere has no part in the transmission of light energy. To account for this, as well as many other phenomena, physicists have been

compelled to postulate the existence of a highly-elastic inert medium, filling all space and all material bodies, to which the name "the ether" has been given, and it is by means of the vibrations of this "ether," which is set in motion by the vibrating particle of the sun's material, that the energy is transmitted. There is thus set up a wave motion where the particles of the ether are moving transversely to the direction of the wave path, and these waves pass out into space. The simple wave theory of Huyghens is selected for explanation rather than the language of the generally accepted electro-magnetic theory, because it is thought that it will be more easily understood by the elementary student, and it involves no alteration of the facts. In the particular case cited, the waves ultimately fall upon the surface of the snow; they are then reflected, their direction is altered by reflection, they take up a new direction, and they eventually reach the eye of the observer and there produce the sensation we name "light."

WAVE-LENGTH, PHASE, AMPLITUDE, FREQUENCY, UNITS

Now every wave motion has certain properties; the waves have *length*, which is the distance between two successive points *in the same phase*, as between crest and crest, trough and trough, *amplitude*, which is the extreme limit of the vibration, i.e. the vertical height between trough and crest, and *frequency*, or the number of successive complete waves that pass a given point in a unit of time; and since light has a constant velocity in any particular medium, this latter number depends upon wave-length—the shorter the wave-length, the higher the number representing the frequency. In the wave motion set up by the particles of the glowing sun, there are vibrations of all frequencies within limits, but only a small portion of these give rise to the sensation of light.

Below is a table representing roughly the range in wave-length of a portion of the whole series, and the colours to which these vibrations give rise. The unit of length of wave-length is the one ten-millionth of a millimetre—the Angstrom unit (signified Å)[1]—and it will be noted that,

Colour	Wave-length in Angstrom units
Red	7600°–6300°
Orange	6300°–6000°
Yellow	6000°–5600°
Green	5600°–4900°
Blue	4900°–4400°
Violet[2]	4400°–4000°

roughly, those vibrations which give rise to the sensation of light lie between 4,000 and 7,600 Å. Any one of these will give rise to a simple sensation, and to this sensation the name "monochromatic light" is given. It depends upon the region what is the sensation produced. For example, light of wave-length 5,896 Å (0·5896μ) gives the sensation of a particular yellow, being the hue produced when a compound of metallic sodium is vaporized in the non-luminous flame—the well-known "sodium light." Between the extremes there are vibrations producing different sensations, and it is the sum total of these effects that is expressed when we use the term "white." Now this "white" may be referred to as the *neutral point*, and if any vibration in the series be missing, then, theoretically, colour will be produced, though actually to the human eye, being the judge, there may be many vibrations missing, and, consequently, many sensations, before one is able to see any difference in the effect. Thus it is wave-length or frequency that determines the physiological effect, and, therefore, the colour, or, to use the more

[1] Wave-length is often now represented by the unit μ, which is the thousandth part of a millimetre. (1μ = 1 micron = 0·001 millimetre.)

[2] It should be noted that the term "violet" used as an indication of a spectral region tends to pass out of use in technical literature, the term "blue" being used for the whole region.

rigid term, the "hue." Now, the intensity of the "white" produced will depend upon the amplitude of the wave motion. So the intensity or brightness of a light is a function of the amplitude of the wave. When the light falls upon the particles that constitute the snow, there is no quenching, no absorption, save to a slight degree, and similarly with the powdered calcium sulphate—and the light not absorbed is reflected back unchanged.

SELECTIVE ABSORPTION. COMPLEMENTARY COLOURS

We say that these substances are white, and, moreover, they are intense white. But it must be remembered that white is a quality apart from intensity; it means that the white light of the sun is reflected unchanged, whiteness being that there is a certain balance producing a sensation which we have agreed to call "white." On the other hand, with the black material there is the reverse—almost all the light is quenched or absorbed. But, be it noted, the *quality* of the light reflected is the same as that light incident—the sun's light—and unchanged. It is now merely a matter of quantity. So we are entitled, and it would be a perfectly true statement, to say that the black is the same as the white, the only difference being in the brightness. But with the blue and red materials something of a different kind has taken place. Both these materials, by reason of their nature, have the property of *selectively absorbing* some of the constituents of the incident white light, so that the reflected light differs in composition—its quality is changed. The material we call "blue" has the power to absorb red, orange, and yellow, which, added together, give a sensation of reddish yellow. Now white − reddish yellow = a certain "blue." And the red substance absorbs selectively the blue and green. Now white − bluish green = a certain "red." So the colours of the substances seen in the white light

are the colours that are reflected, the colours that are *not absorbed* by the body. If from white light we abstract, say, "reddish yellow," the colour of the remainder, a certain blue, is said to be *complementary* to that which is absorbed, and this, then, is the meaning of the term *complementary colour*. Simple examples of complementaries are as follows: red to green blue, emerald green to purple, turquoise blue to orange yellow, and violet to yellowish green; but always it must be remembered, since colour nomenclature is in the nature of things rather vague, a *certain* red to *a certain* green blue, a *certain* turquoise blue to a *certain* orange yellow.

PURE COLOURS AND MIXED COLOURS

Pure simple colour, colour which is the light of one wave-length, is never formed by any system of absorption—the colour is always mixed. Further to this, there is always reflected from the surface of every body a certain amount of light unchanged. Some part of the light does not enter the material of the body, but is reflected from its surface unchanged. If the incident light be white, and there is some selective absorption exercised, then the emergent light, which is coloured, mixes itself with the unchanged surface white light, and by it is *paled*—the colour is less saturated or pure. So the *purity* of a hue means its relative freedom from admixed white light. In some cases the dominant hue may be completely changed in this way. For example, crystals of cupric sulphate are deep greenish blue in white light. If, however, the substance be very finely powdered, the reflecting area for a given mass is greatly increased, and, in consequence, the amount of white light is increased, and so the natural colour of the substance is very much paled. A coloured material, be it paper, fabric, or a film of printers' ink on paper, is, in white light, always less pure—less

saturated—when its nature is such that the surface is glossy, because of the increased amount of surface reflected white.

THE SCATTERING OF LIGHT BY SMALL PARTICLES AND THE PHENOMENA THERETO

That which takes place when light falls upon a blue powder also happens when we have a blue material and allow the light to pass through it. The material, in addition to its blueness, may have certain properties which will affect the result. For example, we may take a piece of blue glass. The surface may be well polished, and the material itself may be "clear." In this case the light passes through with its direction unchanged, and there need only be considered the absorbing properties. But if the body be not clear, then some of the light will be scattered. Now a turbid medium—one which scatters light—if the scattering particles be very small, will always exert a selective scattering, whilst this selection will not take place when the particles are above a certain size.

The reason for this is that the small particles have a differential scattering effect, scattering the small waves—the blue, for example—more than the green, so that if we look at a source of white light through a clear medium, and if, by suitable means, fine particles are produced in that medium, for example by precipitating fine particles of resin as by the addition of a resinous solution to clear water, at once the light begins to appear yellowish. It is for this reason that the sun appears to be yellow when looked at through a turbid atmosphere, appears orange when the turbidity increases, and red with a still more turbid atmosphere. Thus the "scatter" also affects the colour of the sun's light transmitted. If light transmitted by coloured glass be examined in the spectroscope, it will

be found that the region is not a narrow one but broad, and this is due, as before indicated, to the fact that the light is not simple—broad bands, comprising a considerable range of frequencies, are transmitted. The light transmitted is always purer, and, consequently, richer, than the light obtained from a heap of coloured powder or a piece of fabric having the same absorption. This is due, in the case of comparison with fabric, to there being no reflected unchanged white light when colour is formed by transmission in a transparent medium, such as glass.

We come back to summarize the way in which colour is formed. We started, originally, with the luminous body which is the source of light and life—the sun. The glowing mass of the sun sends radiations—owing to the movements of its particles—into space, the radiant energy being carried by means of the ether. The particular effect produced is due to the rate of vibration, and the rate of vibration is a function of the temperature. We may assume, to commence with, that the body selected eventually to radiate is black. All black bodies at the same temperature have the same emission. We may take the black rods of carbon carrying an electric current, by means of which the terminals opposed to one another are raised to a high temperature, as a substitute for the sun. This gives us a light approximating to that of the sun but not quite the same quality, because the temperature is not the same. Because the temperature is not the same, the light is not the same—it is not so *white* because the radiations are not in the same proportion. Actually, as compared with the sun's light, the light emitted by the glowing tips of the carbon rods is distinctly reddish.

COLOUR BY SUBTRACTION

It has been shown that a pencil of white light can be resolved or decomposed by means of a colourless prism

into its constituents, and, further, that from a pencil of white light we may produce colour by means of different substances which have specific absorption or the power to quench certain constituents of the pencil, leaving the remainder. In the first case we ascertain the composition of the white light—or, indeed, any other light which is submitted to the same influence—and in the second case we form colour by a process of subtraction. We may, by a suitable choice of materials, successively absorb from a pencil of white light all the constituents and so have no light at all. By the choice of suitable yellow, red, and blue pigments we can, by superimposing these in correct quantity, produce black. But we do not, as is so often stated, *turn* white into black. We start with something which itself is a mixture, and by successive subtractions by the process of absorption we take away the whole of the constituents, so that there is nothing left. This case is most important for the printer, for it is by this means that all his work in colour-printing is produced. If he wishes to produce a certain green, he takes a sheet of paper he calls "white" as his starting-point. This paper is white for the reason that in a white light it reflects all the hues which, when mixed, produce, on the retina of an observer, the sensation of white. He now proceeds to lay down, by any suitable means, a film of a certain pigment. This pigment he calls "yellow," so that where the paper was white it is yellow wherever it is covered with the pigment. Now this pigment absorbs blue, and most of the blue-green, and reflects the green, yellow, orange, and red. After this pigment is dry the printer lays over it a film of a certain blue. Now the blue absorbs most of the red, orange, and yellow, so that the two combined leave nothing but the green, which is reflected. Thus a certain green is produced by the superimposition of this yellow on the white and then the blue on the yellow,

because there is nothing but the green left unabsorbed. When we produce colour in this way we are said to do so by a process of *subtraction*.

PRIMARY COLOURS

Reference has been made to certain colours as *primaries*. This term needs some explanation because, in the minds of many students, more particularly those who have had any training in drawing and painting in an art school, the term "primary colour" is used in the old and quite erroneous sense in which it was used by Sir David Brewster, although the idea did not originate entirely with him. According to the old idea there were three *primary* colours, a red, a blue, and a yellow, and by mixtures of these in different proportions all other hues could be produced. This idea is quite wrong, and could have been proved to be wrong at the time by simple experiment. Every ray in the spectrum may be regarded, if we wish, as a "primary," having all the attributes to which we may rightly attach the term. Nevertheless, there are reasons, largely connected with the nature of the eye, which have caused physicists to select certain regions of the spectrum, generally *three*, a red, a green, and a blue, and to refer to these as the *primary sensation hues*.

If we produce a spectrum, isolate by suitable mechanical means—a simple thing to do—regions of the spectrum as above, and mix them by superimposition in certain proportions, then the effect on the retina will be such that the sensation, the effect, of "white" is produced. The more simple plan, and the one generally adopted, is to produce from a beam of white light, patches of the proper red, green, and blue by means of isolating colour filters, and to mix these in the proper proportion. This is what Ives did in his Krömscop table apparatus, and that "white" forms the basis of his system of colour photography.

COLOUR BY ADDITION

Let us now assume that we have a triple lantern with one source of light, that we divide the beam into three portions, that we so modify these beams by means of colour filters that there will issue from each, light of a hue corresponding to the primary red, green, and blue, and that we form, side by side, three patches of colour on a screen that has no selective absorption—a *white* screen. Then if we cause these beams to overlap we shall produce mixtures. If the red overlaps the green, then results yellow. If we reduce the luminosity of the green, keeping the red as it was at first, then the yellow inclines to orange; if we reduce the red, then the yellow inclines to a green. If we superimpose the green on the blue we produce peacock blue; if we superimpose the three, then a white will result, always provided that the balance be correct. We have in this way *synthesized* "white" (or colour, as the case may be), and this is the opposite way to *subtraction*. If we laid on white paper, successively, one above the other, transparent pigments to match the primary hues, we should produce black,[1] for that is the process of *subtraction*, which is the opposite to *synthesis* or *addition*.

There are certain regions of the spectrum of white light that physicists are in reasonable agreement may be taken, as before stated, to represent these fundamental sensation hues. These are a certain position in the red, one in the green, and another in the blue, and by means of the retinal stimulus produced by mixtures of these, it is possible to imitate the effect of any region of the spectrum (though slightly paler), and, for that reason, to produce the effect of all colours. The regions in the spectrum of white light that are in reasonable acceptation are a red of $0{\cdot}700\mu$,

[1] The student must not become confused by the two statements. Both sets of triads, if properly chosen, will yield black by superimposition.

a green of 0·546μ, and a blue of 0·436μ.[1] (Guild, J., Nat. Phy. Lab.) Now, as before stated, *quantity* of light is measured in terms of brightness or luminosity, and by determining the quantities of these hues that are required to produce a *neutral white*, we arrive at what is known in colour nomenclature as the "equation to white."

Taking the spectrum of white light as the standard, if we choose for the red a hue approximating to that of the red lithium line (6705°), a green to that of the magnesium line little "b" (5183°), and a blue of the hue of the blue lithium line (4603°) to represent the red, green, and blue sensation hues respectively, then according to Abney (Hurter Memorial Lecture, "Colour" Abney W. de W., *J. Soc. Chem. Industry*, Vol. XX, 1901, page 1060 *et seq.*), we have—

$$\text{R.S.} + \text{G.S.} + \text{B.S.} = \text{white.}$$
$$68{\cdot}14 + 31{\cdot}38 + 0{\cdot}48 = 100$$

the figures representing quantities in terms of luminosity. If we mix the R.S. and the G.S. we produce a yellow when in certain proportion, if we increase the R.S. we incline to orange, and if the green, we incline to greenish yellow; whilst the G.S. and the B.S. produce peacock blue, which is a greenish blue, and this greenish blue is complementary to the R.S. The hypothesis was first enunciated by Dr. Thomas Young in 1809, but was later modified by Helmholz, and has been further added to by other physicists, principally by Wünsch, by König, and by Abney. There are, to-day, many hypotheses as to the nature of colour vision, none of them by any means meeting with general approval, and the Young-Helmholz is not accepted as one that can explain the most important observed facts of colour vision; but the fact remains that it does explain many features of an intensely complicated

[1] These correspond to 7000, 5460, and 4360 Angstrom units respectively. The precise regions selected by different investigators differ, but *essentially* the hues are the same.

subject, and it does serve as a valuable guide in explaining the observed facts of *colour mixture*. It is of interest to printers as being the hypothesis upon which the three-colour process of photography was initiated, and by its aid the process has been very largely developed. The fact is not discounted, because, in many respects, the hypothesis fails to explain all or even a large number of the facts of vision that have been claimed for it by its principal supporters.[1]

If by any means we could express the components of a subject, say a picture, in colour in terms of the "primaries," we should be able, by suitable means, to build up the tones of the picture and so produce a replica, so far as appearance to the eye is concerned. We may say, as a beginning, and roughly, that the colour-tones of the picture are made up of different quantities of the primary sensation hues, or, more accurately, that the tones of the picture stimulate the retina in such a way that different quantities of the sensations are affected. If that be so, then we must strive to imitate the conditions, for then the same effect should be produced. Suppose that we have a greenish yellow patch of tone in our picture. This will stimulate the retina, and the R.S. and G.S. will be affected and so produce a sensation which we term "greenish yellow." If we can isolate that region of the spectrum which stimulates the R.S. and the G.S. to a maximum, it only remains now to regulate—by some means—the quantity of each, and these being superimposed will give the effect. This can be done, but the instrumental means to the end are complicated, and, moreover, the use of a system of that character requires considerable manipulative skill, and, at the best, is far

[1] The most scholarly and rigid modern account of the theory of trichromatic vision is given by Guild. (See "Colour and its Measurement," Traill Taylor Memorial Lecture, Guild J., *The Photographic Journal*, Vol. LIV, 1930, p. 22.)

from convenient. It is usual to proceed in a more simple manner by making colour filters with stained gelatine, which will—starting with white light—give, by a process of absorption and transmission, a hue which, as close as need be, matches the sensation hues. Let us assume the possession of a set of these filters and a triple lantern. If these filters be, severally, placed in front of the condensers, three coloured beams will be projected, and, by adjustment, the discs of coloured light formed on a receiving screen may be superimposed, when a composite effect will be produced. By adjustment of the relative intensities —and thus the quantities—a white can be obtained.

Our filters transmit only very narrow bands of light about a certain well-defined wave-length. If, however, we compare the spectral curve, showing how the different quantities of the sensation hues go to make up "white," we shall see that broad bands are concerned. If we prepare filters to correspond, as near as may be, to the curves, we have the means to divide up the spectrum according to the primaries; that is to say, we shall have a red, a green, and a blue filter. The transmission of the red filter, for example, will show maximum transparency for the red, a little less for the orange, and less for the yellow; the green filter will transmit little or no red, more orange, and yellow and green; whilst the blue will show blue, green-blue, and a *little* green.[1]

THE PRODUCTION OF A PICTURE IN COLOUR BY SYNTHESIS

Let us now take patches of full colour, red, orange, yellow, and green, and produce an image, by means of a lens, upon the focussing screen of our camera. Place the

[1] It is usual, when an attempt of this character is made, to use one source of light to divide the beam into three parts by optical means, and to adjust the relative intensities until a white can be obtained by superimposition. This is the principle of the Ives Krömscop Lantern.

red filter on the lens and produce a negative on a suitable dry plate. What will be the result? For the red patch we shall have considerable density, somewhat less for the orange, less for the yellow, and no density for the green. If a transparency or positive be made, it will be the reverse of these densities. Now consider the same done for the green. The negative will show no density at all for the red, slight for the orange, considerable for the yellow, and full for the green, and the positives will be the reverse. Let us now place in our projecting lantern the sensation filters, and in front of these place the positives we have produced, the R.S. positive in front of the red sensation filter, and the G.S. positive in front of the G.S. filter. Now superimpose the two images. On the red for the red patch we shall have full red, a little less in the orange, a little less in the yellow, and none in the green, whilst in the green positive the red patch will show no green, but the orange a little, the yellow a considerable quantity, and the green full, and the superimposition of the two will give us a replica of the original patches.

Thus it will be seen that, given the means to regulate the intensities of the colour of the fundamentals falling upon a fully-reflecting surface, we may—the eye being the judge—by the use of these means, build up the hues of the series forming the original picture. What are the "means"? If we consider the case of a subject in monochrome we can, by means of photography, make a something in the camera which we, for short, call a negative. This negative is a pictorial record of the form of the object expressed in different quantities of silver embedded in gelatine—the ordinary photographic negative—a reversal, so far as light and shade are concerned, of the original. From this negative record we make a positive record. If we regard this positive as properly made, and, therefore, a

correct record, it will, if placed in the optical lantern, enable us to project a series of gradations of light which will correspond to the original, and we have, therefore, so far as the eye is concerned, succeeded in producing the same effect on the retina as the original monochrome picture. Now, in the case of a coloured picture, we have agreed to regard it as practicable to build this up by means of three images in colour. We require three regulators of the quantity of these colours. If we now place in front of our lens the red sensation screen, all that which requires the red component will be passed and will register itself upon the sensitive plate. This will be the negative red record, and from this a positive or transparency must be made. A similar procedure is followed for the blue and the green records. Now, with these three positives, given a lantern—or other suitable optical device for forming from our source of light three images equal in size—capable of projecting, on a perfectly-reflecting screen, three beams of light, which together form a neutral white, we can, by placing these positive records in this lantern, so vary the amount of colour in each beam that the superimposition of the three will give us a replica in colour of the original subject. Assuming the "taking" and "projecting" filters to be properly adjusted, the first with respect to the narrow region taken for the fundamental hue, and the second with respect to the width of the spectrum band transmitted, and if the luminosities be such that the prime condition for the formation of a neutral white be satisfied, and the mechanical and optical condition of three equal-sized images be fulfilled, the method is capable of giving admirable results in practice. Each filter, to give perfect "decomposition" of the colours of the subject, must transmit one of the selected sections of the spectrum, absorbing the other two sections. These may be termed the standard filters, and are to be used in the additive process,

as described, when we have the theoretically perfect projection colours. The divisions of the spectrum will be about 5,800° and 4,950°. The extreme red and violet are eliminated. When, however, we come to the production of coloured pictures by means of the superimposition of coloured pigments, and the means of this character are not what they should be, then the use of the above filters would lead to the necessity for considerable modification, and so a variation in the spectral character of the filters is made. The green filter is more blue, and the red filter more yellow. They have to be made by trial and error on a coloured chart, and the work is tedious and difficult. Although, on account of the difficulties and the somewhat complicated apparatus required, the process of making colour photographs by the superimposition of coloured light is one that has never had great vogue, yet in the hands of Ives, who was responsible for its modern development, it has given some very beautiful results, and his renderings of the original subjects have never been equalled by any other photographic colour process. There are many reasons for this. In the first place we deal with continuous-tone negatives in photography, there being no falsities introduced by any specialized form of translation (as the use of the cross-line screen), and the photography is simple and straightforward. Again, on account of the large variety of colour-stuffs available, and other optical means for producing or modifying colour, it is practicable to produce screens which are a good approximation to that which has been shown to be theoretically necessary, and the mixture of coloured light is a much more satisfactory method for producing colour than the superimposition of coloured pigments, which, in the best of circumstances, are far from what they should be, not only with respect to colour but in their permanence towards light—which does not apply in the case of the

transient pictures produced by the lantern or other instrument employed for the purpose of producing colour effect.

PRODUCTION OF A PICTURE IN COLOUR BY SUBTRACTION

The simple understanding of the synthetic method is the best way of approaching the study of the production of prints in colour with photographic means by a subtraction process. If we could produce films of colour from our negative records, and these colours were complementary to the hues taken for the sensation primaries, and were superimposed, we should mechanically have satisfied the conditions necessary for the making of the print in colour by photography. For this purpose the positive of the R.S. negative would be in a certain greenish blue, of the G.S. negative in a certain crimson, and of the B.S. negative in a certain yellow. It may be said that pigments of the necessary hues are not obtainable, and those in closest approximation are far from correct and without a reasonable degree of permanence. Further, the best colour filters have imperfections, and to some extent this applies to the best of the sensitive materials available. When it is remembered that all technical processes have many imperfections, even when carefully worked, and that photographic colour-reproduction processes are worked under the ordinary conditions of trade, it will be seen that there are many difficulties in the way. It would be idle to seek to prove that the best is obtainable, even with the difficulties being what they are, for a very cursory acquaintance with "shop" conditions demonstrates that it is not so. In point of fact, the colour processes of to-day have a practical value in proportion as the method adopted lends itself to modification by hand. It is for this reason that the relief half-tone colour process is by far the most important, for by means of the skill of

the fine etcher the limitations of the colour process may be, to some extent, mitigated, and the effect of errors and carelessness of the photographic operator and metal printer, and the vagaries of the letterpress printer, who so frequently follows his own ideas as to the printing colours instead of using those for which the plates have been prepared, may be, as far as practicable, removed. For an understanding of the procedure in making a photographic colour picture, *as a procedure*, the collotype process is probably the best, for though difficult in execution, the routine of the process of collotype is more easy to follow in description than that of any other photomechanical process. We produce a set of three negatives through colour screens, thus recording the colour components of the picture in terms of the primaries. From these three negatives we make three collotype printing plates. These are printed in colours which are complementary to the sensation hues. Thus the plate from the blue screen negative is printed in a yellow, from the green screen negative in a crimson, and from the red screen negative in a greenish blue, the impressions being superimposed. Assuming the workmanship to have been good, we should have only the faults due to the process—the incorrect rendering due to imperfect screens, to sensitive plates, and to printing colours—principally to the last. Now it is possible with skill, in masking and retouching, to correct many of these errors, and some good work has been done by those means. But the care and skill necessary renders it not a competitive process, but one mainly of technical interest. Even under the best of conditions the collotype process is not one which would be deliberately chosen if it were sought to employ a process in which constancy of result were readily obtainable, because it is not easy to secure constancy in printing in this process. Variations which, when printing monochrome, would be

accepted, could not pass when the subject was in colour, and it should be understood that when the *number* of printings in a colour job is reduced to three, as in the tri-colour process—the intensity of the printing colours being greater than those used, as a rule, when more printings are employed—any error in quantity delivered to the sheet will be quickly noticed, as compared with a similar excess in the 8–10 printings normally used in good commercial hand lithography, where a little excess or deficiency of colour in printing is not so noticeable. It may be observed, in passing, that very good work has been done when the main "drawing" is supplied by collotype, with which is associated colour from hand-drawn stones in lithography.

CHAPTER XII

THE APPLICATION OF COLOUR IN PICTURE-MAKING PROCESSES

In Chapter VII, when speaking of the basis—the principle—of the half-tone process (for without it the result of the operation of the ruled screen would be valueless from the aspect of the technician's effort to render gradations of tone by means of opaque ink), it was explained that dots of less than a certain angular value (actually one minute of arc) would not be perceived as such by the normal eye, but would merge to form a shade with the hue of the surface upon which the dots rested. Thus, a series of black dots on white paper would yield a grey, the depth or darkness of this grey depending upon the proportion of black to white. This defect, if we may describe it as a "defect," due to want of resolving power of the eye, is the beginning of the half-tone process. That which leads to a grey will give a tint of colour if the dot be of a hue, instead of black. Obviously, if we place a coloured dot on white paper we dilute the colour and obtain a paler tone—we are mixing coloured lights, and the effect is synthetic.

SCREEN PLATE COLOUR PICTURES

If we arrange a series of square dots chequer-board fashion, or a series of lines in close juxtaposition, and one series is blue and the other yellow, and the chosen hues are complementary and the proportions are correct, then the retinal effect of the mixture will be a white of low brightness; it will be a grey. The feature to notice is that it will be neutral if the proportions and hues of the constituents be right. Now, if we take an assemblage of hues, in proper proportion, of the fundamentals, red,

green, and blue, the same effect will result. If the method of doing this be to form an assemblage of transparent elements upon glass for examination by transmitted light, we then have the so-called "screen plate" employed in certain colour processes of photography, such as the Lumière and the Finlay, originally introduced as the "Thames Colour Plate," and later offered as the "Paget."[1] If now, by any means, we blot out one set of colour elements, we have the hue formed by the remainder. Thus, the three, red, green, and blue, will give white (actually, it is a grey), and by blotting out the whole of the blue, a yellow results, but by blotting out a part only of the blue we have *some* white formed which gives, in the end, a whitish yellow—a pale yellow. If the whole of the blue and a part of the green and red be blotted out, then a dull yellow will result. Other hues may be at once produced by different combinations.

Here we have the principle of the production of colour in the screen plate colour process, the blotting out being done by the photographic image which is formed upon the screen plate,[2] the result being a photographic "transparency" in colour.

MAKING PICTURES IN COLOUR BY LITHOGRAPHY

It is convenient at this stage, having given in the previous chapter the principles involved in the production of colour, and the photographic principles utilized in the production of *photographs* in colour, to consider the procedure which is adopted when it is sought to produce a picture of any subject in colour.

It is observed that though the final results differ in their appearance one from the other, the same end is

[1] Now again known as "Finlay Colour." This process is no longer worked as the materials are not available.

[2] In one and the same plate in the Lumière process, and as a separate thing—a separate plate—in the former Paget process.

sought. In one case it is the thought and hand of the artist—it is, in consequence, quite individual—and in the other, of one who directs certain chemical and physical processes which are, when once started, of a more or less automatic character, for two photographers doing the same thing will produce essentially the same effect or appearance, whilst no two draughtsmen, particularly if they be artists, will, or indeed could, do so. It should be recognized, therefore, that, given a scene of which a pictorial representation be desired, the two representations would be entirely different. The two men are, as representing the two methods, when in industry, in continual conflict, and which one is chosen is very often decided purely on economic grounds. The photographer is cheaper, but really it should be recognized that he obtains a different price for what is, after all, an entirely different article, and one very frequently inferior. Given a picture of the selected scene in colour, it is desired to multiply that picture. For the purpose of explanation of the principles employed, the process of chromo-lithography is considered to be the best to select, and, further, it is a process which has been in every-day use for many years.

It has been explained, as a principle, that colour is produced from "white." Coloured pictures are made by taking a white surface, say paper, and depositing upon that surface of paper layers of pigments which have certain absorptions. Their colour is therefore what they reflect—what they do not absorb. Ultramarine is a certain blue because it abstracts from white all those hues which are not required to produce that effect which we call "ultramarine blue"—the orange, the yellow, nearly all the red, and the greater part of the green. At the outset, for the sake of simplicity, it is well to think of the substances we employ as being transparent, although very few are really so.

In the lithographic process, as already explained, the affected stone is not in any way selective as regards the *quantity* of ink it will take during printing, so that if there are to be, as is generally the case, gradations, they must be made in a particular way. In hand-drawn lithography gradations may be produced on a smooth stone by means of "fatty" ink stippled dots, where the effect to the eye is produced by the same principle as that governing the production of tone in the half-tone process, viz., by varying dot size; or by drawing upon a roughened or grained stone by means of a "fatty" crayon (generally called "chalk"), when variation in the pressure of the chalk, as the artist is drawing, determines the area of the stone grain affected, and thus the depth of tone; or the artist may employ the half-tone image produced by the screen, modifying the tones by different methods either for increasing or decreasing ink area; or he may use a mechanical tint or shading medium. Finally, he may employ a combination of any number of the four methods—a procedure which is very frequently adopted. The production of gradated areas of any size with accuracy to the original is laborious work, and may be frequently avoided by the use of photographically-prepared images.

The kind of gradation produced by drawing upon a grained stone with a fatty crayon is shown—greatly enlarged—in Fig. 32, page 226.

Given that it be desired to make a reproduction, or, to use what the Author considers the more appropriate term, a *rendering*, or, as argued in an earlier part of this book, a "transcript," several important questions may be asked to which answers are necessary. If the picture is to be produced by the superimposition of different colours, what are the colours to be used, and how are the different impressions or images to be made to fit each other, to be, to employ the term used, in "register," and, further, what

are the means adopted for securing that the several partial images are what they should be, that the selected blue, for instance, only comes in the picture where it is required? Some of the picture tones will require the full strength of the colour, but in other tones it must be gradated. The principle on which gradation is produced has already been given, and it was shown that there are several methods for its attainment. With respect to the choice of the colours, that is a matter solely for the decision of the lithographic artist, who, studying his subject, decides that a certain number will be required, and then chooses the colours he will employ. In this choice he will be guided by certain circumstances largely, but not wholly, economic.

It would increase the expense to increase the number of printings, and it may be decided that for the effect gained the increased cost is not justified. Many things in a sketch—particularly a sketch which has been bought for advertising purposes, but not made for that purpose—are features that do not necessarily enhance its value for the ultimate purpose, and the reproduction of these, perhaps, little features is therefore omitted. On the other hand, as perfect a rendering of, say, a water-colour drawing as may be practicable, may be asked for, and in that case an increase in the number of printings may be considered. In some instances, during the days when high-class chromo-lithography was practised, the transcripts in what was known as *facsimile* work were so near to the originals that only an expert could detect the difference.

THE PHOTOGRAPHIC TRI-COLOUR PROCESS COMPARED WITH CHROMO-LITHOGRAPHY

A question may now be asked. If it be possible, in the tri-colour process, to produce a transcript by means of

printing in three colours, a red, a yellow, and a blue, why should it not be possible in ordinary lithography, which usually employs many more? The answer is that in the first place it is not possible to produce the effect that it is often thought may be produced with three printings; and, in the second, the conditions are not the same. It would not be practicable to gradate images—and so eventually the printing colours—with so long a scale by hand as by the mechanical process, and even were it to anything like the same extent practicable, it would be extremely laborious. This limits what can be done with respect to the drawing, for in the drawing lies the way the colour is gradated, and, secondly, it limits the range of shading in the colour employed for the particular printing. Starting, for example, with ultramarine, it limits the range from full colour to the tint, for one cannot secure the palest tint by hand; one cannot produce, by hand, sufficiently fine elements on the stone or metal which will give, when printed in blue, a tint as pale as may be required. This fact brings us to one of the principal causes for increase in the number of colours—they must be employed so as to give the lithographic artist reproducer the range required in the rendering of a particular sketch. He may, in an extreme case, consider it necessary to use as many as three blues. A blue which will yield, with a red, purples and violets, will not give, with a yellow, bright greens; a yellow that will give these bright greens must be associated with a greenish blue, but the same yellow will only give, with the red, rather dull orange tints. Another feature of importance lies in the *dichroism* of many colours—the fact that their paler tones are not true tints of the full colour. Certain crimsons, in diluted quantity, do not give the pinks that might be expected, for owing to the dichroic quality of the colour, the pinks so produced may incline to a yellow shade.

MAKING "KEYS" IN CHROMO-LITHOGRAPHY

Given that the number of printings has been decided, the first step will be to ensure (*a*) that the separate images are the proper size, and (*b*) that when printed one above the other, they will fit, i.e. be in "register." This is ensured by working to a "key." A "key" is an outline tracing of the subject, and the preparation of the "key" is the first step. It must contain all the drawing, every little element being outlined, and, in consequence, it will be simple or complicated, according to the character of the subject. This "key" is made by placing over the surface of the original a sheet of "tracing gelatine," and scratching with a tracer all parts to be keyed. When completed, the incisions are filled in with transfer ink, the excess cleaned off, and the ink in the lines—the image—is transferred to a stone. This stone, when "register-marks"—crosses close outside the major dimensions—have been added by the transferrer, becomes the "key-stone" of the picture. Another method, but one not so good, is to make a "tracing transfer-paper" key and transfer the lines of the key to stone. If the transcript is to be a different size, is to be larger or smaller than the original, a black impression is produced and is copied by photography,[1] printed on metal as in photo-lithography, and this becomes, then, the actual working "key-stone." Now, for every "printing" or colour, impressions are taken on a non-stretching transfer paper in a special set-off ink, containing *methyl violet*, and each sheet of metal or stone to which an impression is to be transferred is rubbed over with methylated alcohol, and the impression laid on the surface and pulled through the press. A sufficiency of the violet colour dissolves out of the ink to give a print of the key on the surface, observing that this image is of

[1] This is not the only method, for an impression may be taken on the rubber sheet of an enlarging and reducing apparatus; but this is an expensive piece of plant and not found in all printing offices.

no value as an ink attracting agent, so that any parts to be effective must be drawn over with litho ink; those that are not so drawn over—the parts not wanted—do not eventually "roll-up" when the stone is being printed, and so are harmless.

These images are now the "offsets," and, coming from a common matrix, are all the same size. Another, but not nearly so good a way of preparing the offsets, is to dust over the images of proofs from the stone on paper, while the printing ink is still "tacky," with red "set-off" powder, and then transfer these powder images to stone or metal. The object of all these proceedings is to produce images matching the key on the several stones necessary for the job.

In some cases where there are line or half-tone negatives, keys can be photographically produced and a saving in labour effected. Let us take a very simple case, a drawing in outline with flat, or gradated, fillings of colour. If such a subject be produced *from the first* for lithographic or photographic reproduction, the drawing in line, which itself constitutes the key, would be made first, and eventually one of the prints would be coloured by the artist as a guide to completion, which is a more economical proceeding than making the sketch and then dissecting it later. The simple photographic procedure is to blacken zinc with moist antimony oxychloride (see Chapter X, page 293), or with a solution of copper sulphate, then produce an ink print on the metal, and afterwards treat with dilute hydrochloric acid, which takes away the antimony or copper black images from the uncovered parts. The ink image may then be removed with turpentine or other suitable solvent, when the black key will be left as a guide. This method has the advantage of being quite accurate and also of eliminating hand-work. It will be found when the images are drawn to the keys and are

ready for printing that, generally speaking, one or two will have more "drawing," more form or shape, than the others. These are known as the "cutting-up" colours, which really means the stones or plates containing the "drawing" of the subject.

OUTLINE OF THE CHROMO-LITHOGRAPHER'S TECHNIQUE

Given the "keys," all the work of translation is done by the lithographic draughtsman—the result depends upon his skill and *judgment*. He must appraise what weight of colour is required with his yellow to give with his red the oranges, and with the blue the greens, and also with the red and blue any greys there may be in the subject. If he be employing stipple on polished stone, or chalk on a grained stone, he must be able to decide what "weight" of this to place in a particular part, as for economical reasons he must be sure, for costs will not permit, with ordinary work, a system of "trial and error," which might mean expensive repeated proofings. Through long experience the lithographic draughtsman has developed a varied technique for producing his effects, all of which, however, are based upon identical principles to the stipple or chalk. He may "spray" tints with lithographic drawing ink, may use the air brush for the same purpose, or may cover large areas—as in poster work—by a "rubbing pad," each of which has advantages in providing a particular texture necessary for an effect. These are, more or less, mechanical methods which do not always give a mechanical appearance—which is a thing to be avoided. But the dominant and most-used method for reducing hand labour is the "medium" generally known by the name of the original inventor, Ben Day "Shading Medium" (see Fig. 38), which is a transparent somewhat flexible sheet, about 9 in. × 7 in., mounted taut on a light wooden frame—a right-angled corner frame—one side of

the surface of the sheet being impressed with a pattern in relief. Originally the sheets had either fine or coarse stipple, a narrow or broad line, or fine or coarse irregular grain, but they have now been developed to such an extent that there is quite a large variety of textures, even going as far in this direction as textures to imitate cloths which are used in the preparation of tailors' fashion plates. The mode of employment of these media is to roll-up the texture side with a *smooth* composition roller charged with stiff lithographic transfer ink, and then lay the surface on stone, transferring the ink from the prominences by means of pressure, either with the finger, a stylus, a burnisher, or a small roller, whichever may be the most suitable or convenient. By varying the pressure, different effects may be produced. The medium frame may also be mounted in a registering device so that it may be removed for re-inking, and may be replaced and caused to fall in the same place—it is generally necessary to give more than one inking to secure the requisite strength—or it may be by screw devices given a slight shift. In order to avoid transferring the tint to places where it is not required, these parts are "gummed out," that is painted out with coloured gum arabic solution. The tint which falls on the gum comes away when the stone or plate is treated by the printer, leaving bare stone or metal. It will be seen that the use of the medium saves a great amount of labour, but it does not dispense with the necessity for skill. Judgment must still be exercised as to the "weight" laid down on stone or metal to produce in the end the desired shade of colour.

Examples of the tints which are provided by media are shown in Figs. 38 and 38A.

It is contended that a device of the character of the shading medium must lead to "mechanical" effects, and largely this is true. But then the hand stipple, which it

has replaced to a very considerable extent, is also mechanical in its effects, so that there would not appear to be, if one is to be used, a reasonably grounded objection to the other. Indeed, all copying methods of this character lead to mechanical results, and under the commercial conditions in which they are used can scarcely do otherwise. The originator does not, as a rule, reproduce his own work, and the reproducer has seldom the same sympathy as the original artist. He may not be, and, indeed, often is not, able to draw. In consequence, the impersonal methods of photography have considerable recommendation, for whatever be the drawbacks and limitations of the photographic process, it can at least be said that it does not alter the drawing, a matter upon which an artist is naturally sensitive. Nevertheless, in the days when the art of chromo-lithography was at its best there were men of great skill and taste, and sufficient feeling and good sense, as reproducers, to sink their own ideas as to what the thing should be, who made transcripts which, when compared with the originals, could not, as before stated, be recognized save by experts.

The artist having decided upon a scheme of colours, these colours are given to the printer to be followed. In an establishment where a great deal of colour reproduction is done, as in a Christmas card producer's, it is an undoubted convenience to work to a standard range of colours, and this is done. In that case the originator of the sketch, the lithographic artist reproducer, and the printer all know their limitations. It is quite easy for an artist to introduce effects that would, were they copied, increase the number of printings, and it is also easy for the reproducer to do the same.

The stones or plates having been finished, the artist decides the order of the printing. Since the colours are of different transparency it is necessary that the more

transparent pigments rest upon the opaque, which are printed first. For high-class work, a smooth absorbent uncoated paper, which has been artificially smoothed by rolling, is employed—the so-called "plate paper." For commercial work very frequently there is used a coated paper, which came to be known as "chromo" paper. Frequently an artificial texture of sorts is given to the finished printed sheet by passing it through the press in contact with a grained surface, or it may be a stone bearing a canvas texture, the so-called "roughing stone."

Finally, to give the appearance of oil paintings, which were so frequently, in the early days of lithography, the originals, the surface of the print, when from an original in oils, is varnished. Sometimes a printing-stone itself is prepared to varnish certain parts, and is rolled-up in varnish instead of ink. Such is the process of ordinary chromo-lithography, a process which, so far as it gave the possibility of making admirable copies of pictures in colour, was in the past greatly employed, and in spite of many adverse criticisms of the way it was employed, at least it may be averred that it gave to many a home, which otherwise would have had relatively bare walls, pictures that the owners considered to be pleasing. The process is to-day also greatly employed, but generally for commercial work. If to-day the print-sellers' windows contain transcripts in colour, the student may be certain that, in the majority of instances, they are not made by the old process of chromo-lithography. It is one of the regrettable things in picture-making that chromo-lithography, and, indeed, lithography in general, has generally been employed as a reproduction process and not for itself as an originative process, except in very few cases. But in those cases where it has been employed as an originative method, there is shown what might have been done had artists turned their attention to the subject and

made original pictures *in* and by means of the process. As it is, the pictures, excellent as they sometimes have been, show that they are more or less mechanical productions—mechanical in aim as any copying process must be, and mechanical in effect, for any method in which one man sets his hand to copy the handiwork of another must end in being mechanical.

We may now turn to the consideration of the processes of photographic colour printing as actually worked in the industry to-day, where the object is to give transcripts of pictures in colours.

THE THREE- AND FOUR-COLOUR PROCESSES

We take the method of colour printing as done by the artist lithographer, and we replace his work in the making of the component colour surfaces by the more or less automatic photographic process. There are established to-day in the industry two standard processes, the "three-colour" and the "four-colour," and the former is relatively the more practised. In the former, the reproducer seeks to give a good rendering by means of three printings in red, yellow, and blue pigments; in the latter process he adds an additional "grey" printing—a "grey" to suit the particular subject. While in the three-colour process each printing may be said to be the colour component, the red, yellow, or blue component of the picture, the terms in which the picture is rendered taking the three colours superimposed to yield a black, which is the negation of the white upon which the colours are laid, in the four-colour process the fourth printing is generally merely a monochrome rendering of the subject. But whilst four-colour printing *generally* means the addition of a black or grey, as the case may be, the four-colour printing is really, *strictly speaking*, much more than this simplicity. In one "four-colour" process the fourth negative has from

it everything eliminated which is contained in each of the three-colour negatives, the fourth negative containing only the black or grey, whilst the colour negatives do not contain any black or grey. The production of a set of this character follows the method of Albert, which, while being very ingenious, is complicated and expensive, and to-day we find the elimination of the black or grey from the colour negatives is done by retouching, *or* more generally it is done as much as possible in the fine etching, leaving the fourth printing to represent the black or grey. Actually, in the best work it is adjusted to give the three already superimposed printings the tonal condition of the particular colours. In this way a grey or a black should really be obtained, and these are not left in the state that too often they appear to be in in ordinary three-colour printing. (See also the Appendix.)

The rendering of dark originals is not by any means generally satisfactory in the ordinary three-colour process, because of the weight of colour as compared with the originals. Here the fourth printing is an advantage. All three-colour prints tend to be crude; the colours are brilliant, far more so than are those generally employed in chromo-lithography, and, as before pointed out, any slight excess of the one or the other over that required to produce a particular hue gives a crude appearance. Now the crudity of any colour scheme is reduced by reducing its intensity or brightness, and this reduction is secured by printing a grey over the other colours. This is probably the reason why four-colour prints, as at present produced, whatever be the principle at work in their making, are generally far more pleasing than those produced by three colours only. This, of course, does not preclude the fact that the four-colour print may be nearer to the subject than a three-colour print would be.

In addition, we have multi-colour block work. Here,

five, six, or seven printings are employed, using the same methods, as, for example, yellow, two blues, two reds, a grey, and a colour which is determined by the particular original. This practice is more generally adopted, however, in chromo-photo-lithography, or in collotype and lithography, or by transfers from collotype direct on to zinc for surface printing, which is the method adopted in one successful but somewhat expensive process.

TWO-COLOUR BLOCK WORK

In the most simple aspect of colour work, viz., "two-colour" half-tone, generally speaking two plates are made of the subject, and what difference there is to be between the two printing plates is made by the fine etcher, for the reason that the subjects so frequently do not lend themselves to the use of colour selection by means of filters. Where they do there may be considerable economic advantage in the use of filters. The principle of their use is simple. Given an original produced by means of two colours, these colours can be isolated by making the two negatives with colour filters on the lens, of a hue complementary to that it is desired to isolate. Thus, consider for the sake of simplicity, a drawing in a dull brown and a dull green. Now, brown is a degraded red, and the complementary of a red is a particular green; and so the negative of this is made with a green screen which does not transmit the brown. Again, the complementary of the green is a certain red, and the negative is made with a screen of this red. In this way the dissection may be made. It is not necessary to go to the expense of the standard type of filter. There is, to-day, taking the several makers, a considerable range of plain gelatine filters, and a reasonable stock of these should enable the intelligent operator, by inspection with the particular drawing, to decide the most suitable film to use. The most

convenient position to place the film is between the combinations of the lens. A thin good film will not disturb definition as would an inferior screen or film where glass plates were used. Although by reason of the nature of the drawing the plan is not of universal application, yet there are many instances where it can be used, and with an obvious saving of time.

Similarly, the same method may be applied to the dissection of drawings in coloured line, or, what comes to the same thing, in flat tone.

There are many possibilities in two-colour block printing other than those of the simple nature indicated. Tritton has considered the problems involved in the production of pleasing pictures not only where "it is not essential that the colour shall give a natural representation of the subject illustrated," but also for "photographic reproductions in which the full tones of the subject are represented." (See "Systematic Reproduction in Two-colour Printing," *Penrose Annual*, Vol. XXXVII, 1935, pp. 115–118.) Tritton rightly emphasizes that there is a field for two-colour printing, and points out that drawings should be prepared suitable for the purpose—a truth applicable to all originals for photographic printing methods, whatever they may be.

PROCEDURE IN THE THREE-COLOUR PROCESS

We have then in the three-colour process to photograph the original three times, placing in the optical path, in each case, a transparent filter which permits the transmission of one-third of the spectrum whilst the remaining two are absorbed. Actually, there are five regions that are recorded, three where the light is recorded only through one screen or filter, and two where they overlap. Each of these two latter regions is recorded in two negatives, and is reproduced by a single printing colour, that is by the yellow pigment where the red and green records overlap,

and by the blue-green pigment where the green and blue records overlap. Thus there is a tendency for the spectrum to be rendered by a band of five colours, in which the more delicate shades of the spectral band are lost, but, on the other hand, it must be noted that in practical three-colour work we have not to deal with pictures of the spectrum, but pictures in common selective absorption colours, each one of which actually represents, in varying amount, the colours of the whole spectrum (Bull).[1] The negatives so made may be regarded as records of the colour of the subject. The colour filters are produced by staining gelatine films with coal-tar colours of the most suitable hue. It is not possible, though it is desirable, to secure abrupt regions of absorption (particularly at the edge facing the less refrangible end of the spectrum—the red), and, consequently, of transmission, because all the colour stuffs obtainable show gradual absorptions. It is practicable to limit the red filter, but in the case of the green and the blue there is general absorption, that is there are not abrupt regions. The densities of the gradations in the three negatives represent the amount of the particular hue reflected from the original. Thus, a negative through the red screen represents the amount of red—broadly—reflected from the original, and the transparent parts those parts where red is not reflected.

With respect to the relation of the colour filters to the way in which these results are to be expressed, viz. the colours that are to be used as printing inks, the condition is that the hues of the filters and inks should be complementary to each other. This is the theoretical postulate, but marked variations are necessary in the practice, dealing as it does with available materials, and not with those that are theoretically desirable. In

[1] *Photographic Journal*, 1923, Vol. LXIII, p. 404.

every-day practice three-colour work is a series of compromises.

WEAKNESSES IN THREE-COLOUR BLOCK-MAKING AS PRACTISED

There are two processes for colour reproduction work, the *indirect* and the *direct*. In the indirect process ordinary continuous-tone colour-selection negatives are made, and from these transparencies, and from the transparencies screen negatives are produced, which screen negatives are employed for producing the resist prints upon metal. In the direct process the two stages are combined; the screen negative is at once a colour-selection negative. Reverting to what was said on page 115, it will be seen at once that the indirect process must be employed for all subjects in relief, for screen negatives cannot be made from relief objects direct, for the reason that the range of tone is in these subjects generally too great. Now a dry plate for this purpose, seeing that the subject may possess considerable range and gradation, should have the necessary qualities for rendering these—it should be a plate having a long scale of gradation. Fineness of grain is not essential, but while the plate gives a good scale of intermediates between the extremes it should give it *over a good range*. For the making of half-tone screen negatives dot formation is of importance, and hence has arisen the practice on the part of the dry-plate maker of making plates which will give a good dot formation in the finished negative. Such plates are generally slow, clean, working plates with a thin film, with fine grain particles of the halide silver salt, such as will give a sharp and not a "fluffy dot," the thin film ensuring quick washing and drying, both so very necessary. The range, or contrast, given by these plates is very good, but the intermediate tones are generally not well rendered—the gradations are abrupt. Now, while for

black and white process negative making this plate satisfies, it is not nearly so good in colour work, for the abrupt scale means bad gradation in the colour rendering. In the early days of direct work—which, be it noted, came about after the first process had been in use some time, and was introduced solely for economical reasons, the cutting-out of an operation—the ordinary rapid colour sensitive plate employed in the indirect process was used, and the making of screen negatives upon plates of this character caused much tribulation both to operators and resist printers. To-day a plate is employed which is almost equal in its dot-giving character to a true process plate, and is far better than the plate formerly employed. At the same time it is capable of giving some of the other characters wanted.

It is interesting to remember that the departure from the indirect method, which is a logical process, was made purely for economical reasons. In making the change, no question seems to have been asked whether or not the union of two dissimilar processes was likely to yield a satisfactory result—the change was simply made, and so we have a hybrid operation in place of the former plan. In a screen negative process, negatives are made under set optical conditions, and these dominate the result—a certain formation in the negative results from a given screen distance and stop aperture, both of which are related, followed by the dark-room operations. No such conditions operate in the making of a continuous-tone colour-selection negative, for the negative is the same, whatever be the aperture, provided that the exposure be in the proper proportion, and the rendering will suffer if the exposure or development be incorrect. But there is not the slightest *prima facie* reason for assuming that if the conditions for screen negative making be satisfied those for the colour selection will be fulfilled, or vice versa.

The fatal weakness of the three-colour process is paradoxically that which is its strength, and by which alone it has become a *practical* process capable of earning money in the industry—the process of "fine etching." Whatever be the errors within reason that result from the operations in the process, they can be corrected by the fine etcher. In consequence of this, attention is taken away from the operations of the negative maker, and his results are not examined from the aspect of whether or not they are the best that can be obtained; the negative is not examined from that standpoint. There is a routine, and the end is reasonably satisfactory. Whether or not each stage in the routine is made to give its best, whether or not the process is less economical than it might be, does not appear to be asked. In any ordinary pure photographic process, if the results emerged as they do in the three-colour process, attention would at once be focussed upon the negative with the object of seeing whether or not it was what it should be; but in the three-colour process it, unfortunately, is not so, for the simple reason that it has come to be the thing for the fine etcher to be regarded as the corrector of errors, either inherent or acquired. In this respect the procedure in a pure photographer's business is far ahead of that which obtains in a process studio.

FILTERS OR COLOUR SCREENS

The filters, or absorbing screens, whose dominant hues are red, green, and blue, are to-day films of gelatine cemented between glass, all other forms having been abandoned. These films give the absorptions necessary, or at least those so considered. The glass is either carefully selected "patent plate," or, what is better, only much more costly, "optical flats," i.e. slabs of glass which have been worked to uniform thickness with plane

surfaces. With the latter there is not the danger that the definition given by the lens will be impaired. At one time, when making the filters, the coloured gelatine was poured on the levelled glass, allowed to set, and the film was dried by evaporation and allowed to remain, the two "screens" then being cemented together by means of Canada balsam. It was found that this plan caused, owing to the contraction of the gelatine film on drying, a curvature of the glass plate, with the result that the definition in the image was disturbed, and to-day, in the case of "properly" made screens, suitable glass is first coated and the layer dried, and the resulting film is then stripped and afterwards cemented between the flats. The screen is supported either behind or before the lens, whichever may be the more convenient.

Reference has been made on page 69 to the "yellow screen." The yellow screen is the simplest form of "filter," and is in regular use by the pure and applied photographer. Its purpose is to absorb the ultra-violet and to reduce the excessive action of the blue.[1] The sensitiveness of the *ordinary* dry plate is an extremely limited sensitiveness. However, by the addition of certain colour stuffs to the emulsion (see Chapter VI) the spectral sensitiveness of the dry-plate surface is extended, but by no process sufficiently so to make a spectrum record upon the treated plate to correspond with the effect on the eye, and, consequently, photographs of coloured objects are not true to the original with respect to rendering colour into monochrome.[2]

[1] The intensity of the "yellow" will depend upon the plate and the amount of correction desired. Sometimes it is sought merely to absorb the ultra-violet and give slight correction for the blue; in other cases fuller correction is required. With panchromatic stock, full depression of the blue may allow too much action in the red, and here a greenish-yellow filter may be used.

[2] The student is strongly recommended to read Dr. Rawlings's "Colour Filters, with special reference to their uses in Photography," *Photographic Journal*, Vol. LXXIV, 1934, pp. 293–305.

DETERMINATION OF FILTER "FACTORS" OR RATIOS THE "BLUE" RECORD IN TRI-COLOUR

It is necessary that the "filter factors" or the exposure ratios should be determined, both for the particular plate, and *strictly* for each batch. The method employed is a practical method to which in principle objection might be made, but it is used. If a pure black and white object be taken, then it is usually assumed that the relative exposures which will give equal densities in each plate upon development represent the filter factors, and that these are the relative exposures which should be adopted when making a set of three-colour selection negatives of a coloured object under the same conditions. This forms a working hypothesis, although it is not by any means certain that it is strictly correct, but in a process where so much is compromise it is probably sufficiently near for practical purposes, and it is one, moreover, easily understood by the ordinary photographic operator, to whom the simplicities are quite necessary. To ascertain the values, many simple methods suggest themselves, the best of which is probably a rapidly-rotating disc with circular rings, each one painted with different proportions of black and white pigments. This disc, on rotation, will give a series of rings of grey of different luminosities. If, by means of a simple repeating back system, an exposure be made without the filter and then several with increasing amounts with the particular filter, we shall find, on developing the plates, which series of densities resulting correspond to those given by the unscreened exposure, and then from the relative exposure of the match we can determine the factor for the particular screen. An attentive operator doing this will very soon discover for himself an important fact, which is that, although in the comparison series of patches there are individual densities that match, a complete match over

the whole scale is not found. This is because the gradation given by light of different wave-lengths is not the same, the scale by the blue filter, for example, being different and "flatter" than that given by the other two filters.[1] In the practical work of the shop, this has led to there being a difference in the procedure in making three-colour records from that dictated by the generally proclaimed theory of the process, which is that the same plate should be used throughout, and that filters should be used in each instance. If this be done it will be found that the blue screen negative gives a plate the scale in which is very flat, and that in order to produce "colour" in the yellow printing much extra "fine etching" is necessary. Now, since the fine etching of three-colour sets is, in any case, considerable, the extra work involved by this procedure is of moment, and in attempting to avoid it, a regression has been made to the practice of early days, when plates and colour filters were far different from what they are to-day. This was to make the otherwise blue screen negative (the blue record)—the yellow printer—upon an "ordinary," preferably "vigorous," plate, using no filter, taking advantage of the fact that since the plate was sensitive to the blue and was not sensitive to anything else, the use of a blue screen for absorbing the yellow was superfluous. In this way more vigour is secured, and there is far less fine etching. But operators often fail to understand that this takes no account of the effect of the ultra-violet light,[2] of which some arc lamps provided form a rich source. To overcome this difficulty

[1] To some extent compensation may be effected by increased time of development.

[2] It is curious how some writers on photography seem to assume that ultra-violet light is seldom found in the process studio, and also, when it is there, that it is immaterial, because it is wholly absorbed by the glass of the lenses. This is entirely an error. The writer has worked with a lens that transmitted so much ultra-violet light from the arc lamps—to which the lens was uncorrected—that the definition of the image was seriously affected.

an ultra-violet absorbing screen is desirable, and one good for this purpose is *naphthol-di-sulphonic acid* in gelatine film, which gives a colourless filter. This, in practice, replaces the blue screen, and with it a slow, ordinary dry plate is employed. It is sometimes the practice to use wet collodion, but this is undesirable.

The objective should be fully corrected and have identical Gauss planes for the images produced when the three filters are used, otherwise the three images will not be of equal size. (See remarks on the Cooke Lenses, page 131.)

A report, principally upon the theoretical aspects of the determination of "filter factors," has been recently made by the British Standards Institution, 24 Victoria Street, London, S.W.1., entitled "Methods of Determining Filter Factors of Photographic Negative Making," No. 1439, 1948.

ILLUMINATION IN THE STUDIO

The source of light is the arc lamp, which should be well governed through regulating resistances, controlled by ammeter or voltmeter, or both, a method easily attained. It is entirely a fallacy to think that the line voltage of the public supply—still less of many private supplies—is constant, nor in practice can it very easily be so, but given instruments and a regulating resistance, the operator has one important means for securing constancy.[1] Three-colour negatives should be made with open-type arc lamps. It is the practice to introduce mineral cores to the carbons for the purpose of producing a white flame. If the flame be really "white," then it is an advantage and the practice is a good one. Not very easily defended was another practice, viz. that of using

[1] Integrating exposure meters at the camera are now coming into use, and these, being more independent of the personal element, are a more reliable control. See Appendix, "Exposure of Sensitive Surfaces."

coloured flames, which merely introduced another complication into a process which embraces a sufficiency of difficulty.

DIRECT AND INDIRECT PROCESSES

If the direct negative process be used, as it may be for flat objects—drawings, paintings, rugs, carpets, linoleums—then when the negatives are made they are sent to the resist printing-room. It is a practice in screen negative making to reduce or "cut" the image by means of a reducing solution, and then to intensify. Such a procedure may yield a "better" negative—one more easy to print. But the cutting process may easily alter tone, and, consequently, colour values, more particularly when the operator carries out the operation of cutting without regard to the subject, and with the main intent to produce a negative that can be easily printed. Moreover, it leads to the practice of making negatives "at the sink" instead of by correct exposure and development, and, unfortunately, in screen negative making, particularly for colour, unlike ordinary negative making, a lot of work may be done and wasted before the negative is found to be the cause of the failure. If the cutting be disregarded, then the negatives are harder to print, for several different kinds of print may be produced, depending upon the degree of exposure given to the bichromated fish-glue film. More responsibility, therefore, is thrown upon the resist printer.

If the indirect process be employed, then from the negatives transparencies must be made, and in this operation there are many pitfalls. Prints cannot be used since it is impracticable to produce with certainty a set of prints upon paper which will be identical in size. There is a gain in one respect in having to employ transparent positives, since screen negatives are always better when

made from transparent positives than from those which are opaque, as, for example, from prints. But the scale of tone is determined by the exposure and development, and there is the fatal tendency of transparency makers to commit two faults—to make the transparencies so that they look "pretty," having the idea of a lantern slide possibly before their minds, and to make them too dense, which causes the operator to resort to excessive "flashing" when making the screen negatives, thus producing a decided tendency to a loss of tone. Another objection, plaintively voiced to the writer some time ago by an operator, is that the transparencies in the set are often not of the same scale of contrast, one being "thin" and another "dense." Under the latter condition the difficulty in making screen negatives which will give properly comparable prints on metal, with tone correspondence to the original continuous-tone negative, is greatly increased. It is worthy of note, more especially since it is an important economic matter, that all these faults and errors have to be expiated in the fine etching room, in which branch the work of producing sets is costly enough, even with the best practice.

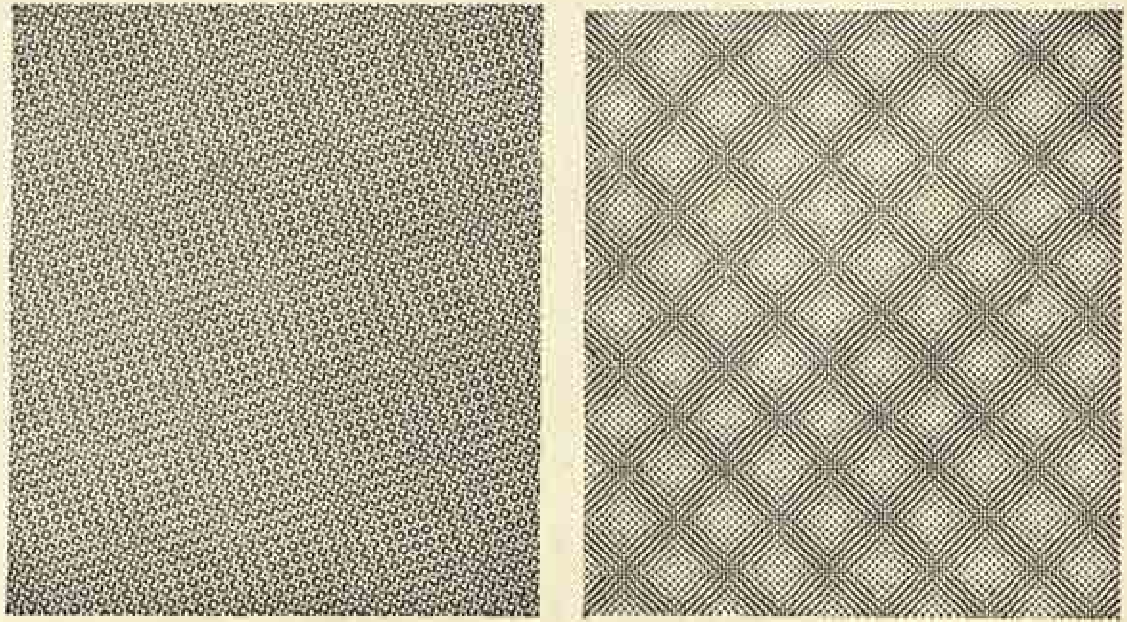
The work, when printed, passes into the etcher's hands, who is responsible for producing plates the colour values of which are correct. It is the practice of the etcher to judge tone values by dot size; he, therefore, fine-etches the plates until the dot size, tone by tone, is correct. Theoretically, he should be able to do this since it is only what the chromo-lithographer has to do when stippling to give a certain tone. But, in practice, it is not by any means easy. Failing this, recourse must be had to stage proofing—a costly operation. There are some firms whose assistants, by long practice, by judgment, and by, probably, a particular *flair* for the work, are able to do without this stage proofing, but in many places it is found to be

necessary. In large establishments the work is often subdivided, so that one man deals with only one colour instead of all the three plates, a practice which has been strongly condemned by other practical men.

PRODUCTION OF "PATTERN" OR MOIRÉ IN COLOUR BLOCK-MAKING

A feature of importance when making the screen negatives is to see that the screen angles, or "angles of crossing," are correct. The superimposition of images made up of *regularly* disposed elements leads to the production of "pattern," the so-called "moiré," and pronounced moiré at once condemns the work as useless.[1] If two cross-line screens be superimposed and one rotated above the other, this moiré (Fig. 53) will be seen. In certain positions the pattern will be small—the tiny assemblages giving the pattern are very small and unobtrusive—but as the angle is changed it becomes more pronounced, giving widely-apart clumps of dots, forming designs which disappear and re-appear as the screens are rotated. The practice is to choose such angles of crossing that the pattern is at a minimum and *uniformly distributed*. If a strong colour be superimposed above another strong colour, then the pattern shows in its most pronounced form, whereas the same angles used with a strong and a pale colour would scarcely be noticeable. In practice it is found that if there be 30° difference, say 45° (the normal) for the blue, 75° for the red, and 15° for the yellow, the pattern is not objectionable. This variation of angle may be secured by having screens ruled at the particular angles or, a much better plan, by having a circular screen with a metal rim moving in a metal mount

[1] The student desiring to learn more as to the causes of moiré will find the subject adequately treated in a paper by Samuel Lees. (*Memoirs and Proceedings of the Manchester Lit. and Phil. Soc.*, 1919, Vol. LXIII, No. 4.)



(a) (b)

FIG. 53. EXAMPLES SHOWING MOIRÉ. (a) MINIMUM PATTERN; (b) MAXIMUM

(see page 119), so that the screen can be set at any angle desired. It is usual to fix on the rim a datum line, and to engrave on the mount the standard angles, so that the screen can be quickly set. By this means pronounced pattern is avoided. As the number of superimposed images increases, the general confusion which results causes any pattern produced to be less noticeable. It may be observed that the engraver meets with a similar difficulty when he is called upon to produce a half-tone block from a half-tone screen block print as the "original." In such a case he must arrange the angle of crossing so as to avoid moiré. Examples of moiré are shown in Fig. 53 (*b*), where the pattern is large and pronounced, and in Fig. 53 (*a*), where it is at a minimum, and unobjectionable.

CORRECTION METHODS AND THE FUTURE

It is difficult to anticipate what is likely to be the development of colour printing processes, but the *trend* is in the direction of surface methods, and of intaglio for large numbers. The relief process holds sway largely because of the power of the "fine etcher." A skilful fine etcher, given time, can make from three monochrome plates a tolerable transcript of a drawing in colour—he needs no selection by means of colour filters. Such a power applied to a process like the tri-colour process, be it in competition with chromo-photo-litho—where the power of correction is very slight—gave the relief process a very great advantage. But there are no advantages possessed by the relief process, bar the power of control by fine etching, that are not possessed by the photo-litho offset method, which has only been held back by the absence of the power of *adequate* and *economical* correction of the plates. When this has been attained, as it probably will be attained, we may expect to see great extension in the employment of the surface method. The

Author may perhaps be excused if he sees in negative correction the best and most economical way out of the difficulty.

It is usual, when flat objects are portrayed, to employ in photo-lithography the direct process. Now the direct process is very limited in the opportunities it offers for modification, and until the introduction of the "Peridak" method of dot control by reduction, very little could be done in the way of systematic control, although selective dot reduction was done before the introduction of the "Peridak" method. If, however, the indirect method be used, although it is more lengthy and, therefore, more costly, it offers greater opportunities for the original continuous tone, and the transparency can be modified, so that when the half-tone screen negative comes to be made considerable correction has already been made.

It would appear that if the methods indicated on pp. 267 and 396 be adopted, and properly applied, they would go a long way towards removing the disabilities from which the process of offset photo-lithography has in the past suffered. The more general appreciation of the advantages of the "recessed," "deep etch," or "offset deep" plate as against the original pure surface plate has led to its increased use. Concurrent has been the critical attitude towards all problems involved in surface printing, and the constant urge to improvement, so that the opening years of the second century after Senefelder's discovery see an increased vigour in the application of his principles and extensions of their use.

In commercial gravure valuable work has been done in the standardization of technique. The masking method has been shown to be applicable to the correction of negatives. The important contribution of Cartwright and his collaborators on control shows the way in which some of the principal difficulties in colour etching may be

eliminated (see "Control in Colour Photogravure," *Photographic Journal*, Vol. LX, 1936, pp. 558–572, and *Penrose Annual*, Vol., XXXIX, 1937, pp. 135—139). The same worker has also communicated the conditions for successful positive making for the process (*Penrose Annual*, Vol. XXXVIII, 1936, pp. 119–122).

In the early days of gravure it was considered that the power of correction was only slight. Hand-work on the cylinder was never satisfactory and was expensive. The problem has been attacked in other ways and "skilled guessing" is giving place to measurement. There is no photo-mechanical process that offers so many problems as gravure or one where the procedure requires so much detail consideration.

"ORIGINATOR" AND "REPRODUCER" IN COMMERCIAL COLOUR WORK

In the work of colour picture "reproduction," where the aim is strict fidelity in appearance to the original, there is not wanting either the method or the ability to meet the necessities and so to satisfy the demand. But this is a distinctly limited demand and is not to be confused with the requests so often made by the ill-informed for a "fac-sim" by the three-colour process from totally unsuitable sketches and at schedule rates.

By far the greater amount of commercial colour work is done in three or four printings for publicity purposes of one kind or another, and experience has shown that good effects can be obtained within this limitation. Satisfactory and economical production, however, requires complete collaboration from the preparation of the original to the final presentation, and this whatsoever the process may be. One of the things militating against "satisfaction" is an incomplete recognition of the fact that our methods have limitations (or, if recognized, the implications are

not respected) and that it is only by working within them that complete success can be attained. We have in our midst artist designers of high ability—but unfortunately too few—who recognize the limitations, and their influence may prove to be the "little leaven that leaveneth the whole lump."

So much for the technical aspect, but that is not the whole story. Unfortunately, the artist does not decide the nature and form of the pictorial appeal—the dominant voice comes from another quarter. In many branches of production to-day, in wallpapers, in fabrics, in pottery, to some extent in furniture, and in the hundred and one articles of real (or assumed) necessity, the *aim* at least is how to combine pleasant colour and design with utility. The ordainers—so many of them—of printed picture matter appear to be immune to aesthetic influence. It is not a little unfortunate that our industry should be expected to bend its efforts to the production of so much that is aesthetically negligible, "pictures" that are active agents in lowering the standard of public taste.

LIMITATIONS IN PHOTOGRAPHIC COLOUR BLOCK METHODS

To refer briefly to the faults and limitations of the photographic colour processes, excluding those which arise from the imperfect working of the different stages of the processes, it may be said that they arise from three things: (*a*) Imperfect colour sensitiveness of the sensitive surface, although the fault at present is comparatively small; (*b*) imperfections in the filters; (*c*) imperfections in the hue and transparency, and the fastness to light of the printing colours; and of these three (*c*) is far and away the most important. The lack of sharp "cut" in the filters is a serious drawback; with filters having strongly-vignetted edges to the absorption bands, it

means that with errors in over-exposure, and notably with the increased exposures that the operator gives when working the direct process, in order that he may obtain a "firm dot"—his common practice—there is included in the negative far more than should be included, with consequent falsity.

It is desirable that the subject of the printing be considered quite apart from any printing process. The effects we make are produced by the superimposition of layers of coloured inks, or by their side-by-side association (it is held by Bull that if the colours were truly transparent it would not make any difference whether the dots were side-by-side or partially overlapped), or by both, and a minute alteration in the "lay" will cause a variation in the proportion. Now if we take two colours and superimpose layers of these, the effect is not the same as it would be were we to mix the two together before printing. This is due to the imperfect transparency of the pigments. In consequence, the last colour printed always imparts a particular tone, so that the final effect of A on B is not the same as B on A. If we take red upon yellow we produce an orange, but it inclines to red. This peculiarity of superimposition should always be considered, for it is most pronounced when three printings are superimposed. The final printing will always give a "cast" of its own colour.

When all is said and done, there can be little doubt in the minds of many educated people that the photographic methods of colour printing do prove a little trying to aesthetically minded people and those with a refined colour sense who take their ideas from colour in nature, although to the general public they are quite pleasing and wonderful and this may be regarded as a justification from a business standpoint to their producers. In the tri-colour printing process this, shall one say, defect is

overcome to some extent by the fourth printing when skilfully used. In colour transparencies the same drawback is manifest. We have the vivid brilliance of the coal tar colour, and whether or not it would be practicable to have some method of subduing the crudity of colour so as to make these pictures more acceptable to the educated person of taste and judgment and to those with colour sense while not destroying their attractiveness for the "man in the street" remains to be seen.

The colour judgment of people is formed by the objects in nature surrounding them and by works of art of different kinds, and is affected by the brilliance of illumination of the particular place by temperament, taste and education. The taste is certainly not formed in a colour chemist's laboratory, though his sense of wonderment may be heightened. Plainly many of these colours with their high saturation and brilliancy are simply crude. A walk through a gallery of paintings after one in a colour room at a photographic exhibition is something more than a relief—it is a confirmation of a prior formed taste.

DEFECTS DUE TO PRINTING INKS

There are certain grave difficulties on account of the hues of the pigments themselves, and though these difficulties are to some extent remedied by the use of a set of subtraction filters which are different from those used in the additive process of colour rendering (the standard set of filters), yet faults remain, and they remain even after the extensive fine etching usually employed.

THE MODERN MASKING METHOD OF COLOUR CORRECTION

On pages 392–3 is given an account of the limitations of the photographic colour process of printing, and on pages 392–4 is detailed the effect of these limitations.

It has already been stated that part of the limitations which reside in the negative may be overcome and, since the correction is not full, how mitigated. In the half-tone block process correction may be made upon the plate by the process of "fine etching" (see page 319), and by this means in the hands of a skilled etcher good results are obtainable. But the process of "fine etching" is not applicable to surface methods, such as photo-zincography and photo-alagraphy, and these processes are of great importance and their use for illustration—especially in conjunction with "offset" printing (see pages 396–9)—is daily extending. Consequently it behoves the worker to seek other ways to overcome the limitations and the defects in the final picture which ensue from these limitations. The method now employed mainly is hand correction by masking in various ways upon the negatives and positives. But at present the number of skilled workers available is small, and the total capacity for the correction of plates is very limited. With the result that the opportunities for output in an expanding branch of the industry are somewhat limited.

In modern process literature the term "masking" frequently occurs—often enough without any explanation of what is really meant and when it comes to photographic "masking," merely as a bald statement. Confusion is marked in what at the best is rather a difficult subject. Now as regards the operation of "masking" there is nothing new. "Masking" has been employed from the earliest days of portrait photography when the photographer sought with the faces of his sitters to overcome defects and blemishes—largely due to the lack in the sensitivity of the plates employed—by means of the retouching pencil. On pages 396–9 is given a brief account of the different ways in which "masking" or covering up is effected. But these ways are limited in

effect and this is soon found when it is sought to use them—and they take considerable time with expensive labour, too—for the correction of negatives and positives for colour work. It was Dr. Albert who first proposed a method which was purely photographic, and his proposal has received considerable attention from workers, and particularly from the Research Department of Kodak. We have come within view of a satisfactory scheme. But the student must beware of taking the word "satisfactory" too literally. If he will refresh his memory by reading the matter on page 399 *et seq.* he will see that even though the negative or positive be corrected (and the Albert method applies only to these) there still remain the imperfections in rendering due to the inks used when the surfaces come to the printing press, where great confusion exists. The advice which an old-time Prime Minister gave to the members of his Cabinet "all to say the same thing" applies equally to the makers of ink for tri-colour printing. Fortunately, there has been of late considerable heart searching, and it may be that soon it will come to pass that ink makers will all say the same thing and so remove, in so far as they may be able, a defect which has existed since the birth of three-colour printing.

To understand colour masking is by no means easy for frankly the subject is difficult. The Author, largely with the aid of Mr. D. C. Gresham of the Research Department of Messrs. McCorquodale and Co. and Mr. L. E. T. Branch (Kodak Ltd.), has sought to remove the difficulty and to make this subject easier to be understood.

AUTOMATIC COLOUR CORRECTION

Theoretically, for subtractive three-colour reproduction what is required is a set of inks, namely, a true yellow, a true magenta, and a true cyan-blue. A true yellow

should absorb blue light completely and reflect red and green light completely, and some yellows are tolerably correct in this respect. A true magenta (blue-red) should absorb green light completely and reflect red and blue light completely, and a true cyan (blue-green) should absorb red light completely and reflect blue and green light completely. However, a vast number of colouring matters have been investigated and it seems to be impossible to find a true magenta or a true cyan. The principal defect in cyan inks is unwanted absorption of green light, and the principal defect in magenta inks is unwanted absorption of blue light. In other words, "cyan" inks are too blue and "magenta" inks are too red. This is the same as saying that the cyan inks are a mixture of true cyan with a considerable proportion of true magenta, and available magenta inks are a mixture of true magenta with yellow.

From this it follows that wherever the cyan ink is printed, a certain amount of magenta is in effect unavoidably printed with it, and wherever the magenta ink is printed a certain amount of yellow is in effect printed with it. Although it is not possible to remove this unwanted magenta colour from the cyan ink and this unwanted yellow colour from the magenta ink, it is possible to remove corresponding amounts of magenta from the actual magenta ink and yellow from the actual yellow ink, or, in other words, reduce the printing strength of the magenta printing plate wherever cyan is to be printed and reduce the printing strength of the yellow printing plate wherever magenta is to be printed. Although this is not the way the fine etcher or retoucher considers the problem this is, in fact, what he is doing when he "takes red out of greens" or "takes yellow out of purples."

Since the necessary reduction of the magenta plate at every point is proportional to the printing strength of the

cyan plate and the necessary reduction of the yellow plate at every point is proportional to the printing strength of the magenta plate, it is fairly obvious that it should be possible to achieve the result automatically in the photographic stages of the process.

This has led to many proposals for so-called colour "masking" processes of colour correction. In its simplest form this process of automatic colour correction is done by using two masks as follows—

(*a*) A low contrast positive mask corresponding to the cyan images. This mask is made by printing from the red filter negative. In use it is bound in register with the green filter negative, hence the effect of this mask is to reduce the magenta printing wherever cyan is printed.

(*b*) A low contrast positive mask corresponding to the magenta image. This mask is made by printing from the green filter negative. In use it is bound in register with the blue filter negative, hence the effect of this mask is to reduce the yellow printing wherever magenta is printed.

Obviously, the system is only applicable to "indirect" work. The procedure is to make a set of separation negatives in the usual way except that they should be developed to higher than normal contrast. Low contrast positives are made by contact from the red and green filter negatives and these are bound in register with the green and blue filter negatives respectively. For practical convenience it is desirable to make a second positive mask from the red filter negative to be bound with the red filter negative to reduce its contrast to the same level as the other two negatives without altering its colour values. From the combination negatives, positives are made by projection for use directly in the photogravure process or for making screen negatives in the half-tone block or photo-litho processes.

It is important to produce and maintain the density

range—the relation of the lowest to the highest density —required by the process in each combined negative and positive. This means that there must be at hand some means of measuring "density." For the accurate measurement the instruments used, such as the Kodak "Transmission Densitometer" and the Cartwright "Comparator," are expensive, but a density "Comparator" such as the Kodak "Densigrade" (7s. 6d.) which is easy to use gives information sufficiently near for the desired purpose.

Those who are not acquainted with the Hurter and Driffield notation, which gives the meaning of the terms "density," "opacity" and "transparency" as employed in photography, will find simple explanations in Le Clerc's *Photography; Theory and Practice*, page 135 (Pitman). See also *P.E.M.* Vol. 55, 1948, page 369, on density, opacity and transparency.

Bull has very carefully examined the problem of what are actually the effects produced by the employment of the ordinary filters and, similarly, representative inks such as are ordinarily used, and, where the renderings fail in comparison with the originals, the reasons for these failures. The earnest student is referred to the paper "The Relation of the Selective Absorption of Printing Colours to the Errors Occurring in Three-colour Photography,"[1] but it is worth while here to reproduce some of the principal conclusions.

It is noted in the paper that the author states—

The measurements of the spectrum reflection curves of the original colours and of their reproductions indicate that orderly changes are taking place in the reproduction of several classes of colours. These changes are most marked in the cases of those colours which reflect considerable proportions of violet and blue light, and whose individual hues are therefore dependent on that reflection. There are also marked changes

[1] Bull, A. J., *Photographic Journal*, Vol. LXIII, September, 1923, p. 403, *et seq.*

in the colours having green as a dominant factor, while closer and closer approximation to the original hue is secured as the colours become more predominantly red or yellow.

And further—

The colours in which a reflection of blue or violet plays an important part are represented in their reproductions by a lower reflection of this light, so that blues may be converted into greys and purples into browns, while the small proportion of blue light which is characteristic of many reds is sufficiently lost in the reproduction to alter the hue appreciably. The colours that are predominantly green are reproduced with so much loss of this green that in most cases the reproduction is no longer definitely a green. On the other hand, those colours that are predominantly red suffer less change in the course of reproduction, and especially is this the case with brick reds, yellows, and browns.

And that—

It would thus appear that the loss in tone and the change in hue in the reproduction of colours whose dominant reflections occur in the green or blue regions of the spectrum are due to the imperfect reflection of green light by the blue ink, and also to imperfect reflection of blue light by the red ink. An inspection of the curves also indicates that the blue ink, with its slight rise at the red end of the spectrum, is the cause of the greys and blacks becoming warm in tone. It is probably this low reflection of blue light by two of the inks that has led to the use of a yellow ink that does not absorb the blue completely, and so helps a little in the reproduction of purples and blues, even though it lightens the yellows.

And at the close of this interesting paper Bull summarizes the results (in so far as anything so complicated can be effectively summarized) by saying—

It has been shown that, in the course of reproduction, certain definite changes of colour occur, which may be summarized as follows—

Blues become darker and greyer.
Blue-greens lose their greenish hue.
Greens become darker and greyer.
Pinks acquire a yellow hue.
Mauves become brown.
Reds lose any bluish tint they may possess.
Yellows are lightened without change of hue, while oranges and browns are well reproduced.

No change in the character of the reproduction takes place with variation of tone with the colours yellow, blue, and green.

In the scale of tones, from black to white, there is a tendency for the middle tones to become reddish.

The lightening of yellows in reproduction is due to a very light yellow printing ink being used.

The inks are sufficiently transparent for the visual effect of superposed printings to be capable of approximate calculation, and hence the actual reproduction accords fairly well with the calculated result of superposing the component printings.

It has been shown that the major errors of the reproductions of colours would be removed if each ink absorbed one of the three primary regions only.

In view of the general characteristics of colours produced by selective absorption, there is little immediate hope of securing printing inks of this theoretical character, and therefore it will be necessary to devise suitable methods of correction as the method of three-colour printing is extended into fresh fields.

The last paragraph is of considerable interest from a purely practical aspect, because it inferentially emphasizes the fact that under existing conditions an extension of the principles of the three-colour process cannot be expected unless there be a corresponding increase in the methods of correction, the materials available being what they are.

In the light of experience with the "Vivex" process (see p. 436), D. A. Spencer (and his associates) considered some of Bull's conclusions with respect to colour filters and printing inks, and as the result of experimental investigation (see *Photographic Journal*, Vol. LXXV, 1935, p. 337) found some ground for dissent, and more recently in "A Note on Tricolour Separation Filters" (*Penrose Annual*, Vol. LX, 1938, pp. 112–114) he has given those conclusions which are of direct interest to the photo-process worker. The two papers quoted are of importance and should be studied in conjunction with Bull's communication to which reference has been made.

RECENT ATTEMPTS TO FIND A SOLUTION OF THE PROBLEM OF COLOUR PRINTING INKS

The problem of the correct hues of printing inks to be used in three and four-colour printing processes has been before colour ink-makers and photo-engravers ever since the processes came into use. Not a little difficulty has been due to the fact that a particular ink-maker has his own standards and these differ from those of another maker. The same isolated action occurs with engravers themselves, with the result that there are considerable differences and disatisfaction on all sides—the public (who are the final recipients of the printed results) included.

With a view to ending, or at least reducing the trouble, agreement was made in 1929 between three leading associations as to the standard hues to be adopted, but general adoption by no means followed, and so there remained many different standards and the confusion and the difficulties persisted. During the recent war matters became still worse for the raw materials necessary were largely unobtainable, and in view of the serious results on colour print making, renewed efforts to obtain a general agreement were made. A sub-committee consisting of representatives from the British Federation of Master Printers, the Federation of Master Photo-Engravers, the British Printing Ink Manufacturers and the Printing and Allied Trades Research Association (P.A.T.R.A.) was formed. The result of the deliberations will shortly be published.

In conjunction with this subject it would be well for the student to study the interesting article by H. M. Cartwright on "Colour Terminology" *Process Engraver's Monthly*, June, 1948, p. 173, in which is reviewed the Report on Colour Terminology of R. K. Schofield in the *Transactions of the Physical Society.*

APPENDICES

FROM time to time in this book certain chemical and physical terms have been used which may present difficulty to the reader unused to scientific and technical literature. It has been thought desirable, because it might be helpful, to offer simple explanations of these terms in so far as may be practicable, and rather than include these explanations in the text it has been decided to place them in a separate section. Further to this some new matter has been included.

HYDROLYSIS

Hydrolysis, or hydrolytic cleavage, is a chemical reaction caused by the hydrogen and hydroxyl ions of water. The most prominent case which occurs with respect to the production of materials used in photography is gelatine. Gelatine is produced by the action of hot water upon certain animal tissues—collagenous—as skin and cartilage, and upon bones. The gelatine does not exist as such, but is formed by the process of hydrolytic cleavage during the digestion of the material. Now this cleavage is progressive, the first product being the gelatine, which is then, if the action be continued, changed to gelatose, and, finally, the gelatose is converted to gelatone. In consequence, there is always some gelatose and gelatone in gelatine, but the quantity of the two former is kept down by careful attention in the process of manufacture. Now, with gelatose there is probably some residual gelatine, as there is always more or less gelatone, which, incidentally, is a serious drawback. It is the presence of this gelatone which renders the gelatose less sensitive. In practice, the resist maker requires a certain amount of insoluble material in the image for it to be of any value.

Now, as the Author has shown, the substance gelatone will not yield an insoluble body when exposed with an alkali bichromate and, therefore, its presence is valueless. It does mean, however, that there is a less proportion of gelatose, the body which does become insoluble, in the quantity taken. In the second place, the presence of inert *soluble* bodies, and the gelatone is such a body, reduces the tenacity with which the image-forming material adheres to the metal, and to overcome this fault the exposure must be increased. In consequence, the printer says that the particular sample of fish glue is "insensitive," and in the sense described he is correct. The subject of the behaviour of fish glue with alkali bichromates was investigated by the Author in 1909, and to the original paper the student is referred. (See "On the Properties of Certain Collagenous Bodies and Their Behaviour Towards Light when Associated with Alkali Bichromates." *J. Soc. Chem. Ind.*, No. 2, Vol. XXIX, 1910.)

"Sensitiveness" and "Speed" of Sensitive Surfaces Used in the Camera

In the text the terms "sensitiveness" and "speed" have been used, but never indifferently, and it was stated that the two were not necessarily identical. By the ordinary photographer they are, however, frequently regarded as identical, and it appears desirable that there should be made clear a distinction which exists in the minds of many, including the Author.

If two surfaces be simultaneously exposed to a constant source of energy for diminishing periods, a stage will be reached when the plates, upon development, will show no effect, but that stage will not necessarily be the same for both surfaces. It may happen that one surface will show a change on development with a smaller duration of exposure and, consequently, with a less quantity of energy,

than the other, and that surface we should say was the more sensitive of the two. At the same time these emulsions may be of a different character and be capable of giving different amounts of density; one of them, indeed, may be incapable of yielding density to any appreciable extent, save with an unduly long exposure to light. Now in practical negative making, density is essential (to different degrees), and all emulsions to be of any value must be capable, on development of the negative, of giving an appreciable amount.

Now if we were to try our two hypothetical emulsions in practical negative making with exposures proportionate to the sensitiveness found, it does not follow that they would yield equal negatives, and it might well be found that to make one negative equal to the other we should have to alter the relative exposures. But there are cases in, for example, pure photography for scientific record making where the more sensitive plate would have the greater value when a "printable" negative (which requires a certain amount of density) was not required, where, in fact, a mere trace of an image was valuable—a trace that the less sensitive plate would not give. The matter might quite fairly be put in another way by saying that "sensitiveness" stands by itself, but that "speed" is something concerned in "practical" negative making, and has to be considered in conjunction with the other properties of the sensitive surface.

The whole subject of "speed" is fraught with difficulty, and, unfortunately, there is no system by means of which the maker of sensitive surfaces can convey easily to the user relative speeds. All that he can do is to give some guidance. The standard system, "H. & D.," gives numbers which are employed over the whole range of sensitive surfaces, and surfaces of an entirely different character are marked with these speed numbers as if they

represented the relative exposures that would have to be used to give similar negatives of the same subject. The idea—which is a quite natural inference—is an entirely erroneous idea, for all the plates never would be used for the same subject, and never could yield the same kind of negative. All that we can say is that if the many types of sensitive surfaces are carefully classified, the H. & D. numbers—when the product of the laboratory of the makers, uninfluenced by the advertising department—represent fairly well the relative speeds *of the members of that class.*

The Resolving Power of Sensitive Surfaces

The subject of resolving power was first critically investigated by Mees (Mees, C. E. K., "On the Resolving Power of Photographic Plates," *Proc. Royal Soc.*, 1909, *A* 83, 10), and since that time the literature on the subject has been enlarged by other workers, Jones, Nutting, Goldberg, Tugman, Ross, Scheffer, Sheppard; and from the number (and calibre of the investigators) who have paid attention to the subject, its importance may be judged. The most recent work on the subject is that of Sandvik, whose paper was read before the Seventh International Congress of Photography, 1928, and to this paper the student, critical and interested in photographic principles, is referred (Sandvik, O., "On the Measurement of the Resolving Power of Photographic Materials," *Report VII, Int. Cong. Photo.*, 1928, page 243).

High resolution in a sensitive surface is of importance to the photo-mechanical worker when engaged in negative making of fine-line subjects, in view of the use of, and the increasing tendency to use, dry plates as the form of sensitive surface, which tendency is encouraged by the fact that the plate makers have, during recent years,

paid more attention to the wants of photo-engravers in this respect. Sandvik postulates two sets of factors or characteristics: (*a*) Those peculiar to the emulsion itself, and (*b*) those which are independent of the emulsion, and there are a large number of separate items under each category. Obviously, under (*a*) the negative maker has no power of control save that which comes from choice of the surface—a position which often arises with regard to photographic material—but under (*b*) he is not so tied. It is shown that there is a marked decrease in resolving power with an increase in the working aperture of the lens, that the resolving power varies considerably with the type of developer used, and that metol-quinol (M.1 : Q9), with potassium carbonate as the alkali, is favoured. It is further recommended that, in so far as is practical, developer, fixing bath, and wash water be at the same temperature, and this temperature should preferably be about 20° C. (68° F.). The fixing bath should contain an acid hardener, the plate should not be allowed to remain in the fixing bath longer than is quite necessary, and washing afterwards should not be unduly prolonged, say not longer than 30 minutes, so obviously conditions of washing should be adjusted to permit the operation to be completed in that time. In general, it may be stated that efforts should be directed towards keeping down the swelling of the gelatine film, which has been shown by Sheppard to be quite necessary. It appears to be probable that the silver grains of the image displaced during swelling do not return to their original positions.

Recent investigations have, indeed, shown that the particles do move, and that in a much swollen gelatine film there is reason to believe that they do not necessarily return to their original positions in relation to each other. This phenomenon, while of importance in certain kinds of photography, in stellar and spectrum work for

instance, is not of direct moment in photo-mechanical photography.

Halation

A pencil of light passing through a perfectly clear medium, as, for example, air or water at uniform temperature, persists in a straight-line path. An observer at right angles is not conscious of the pencil of light, for the simple reason that none of the light reaches the retina of his eye. But if into the medium there be introduced some fine

Fig. 34. A Point and its Halo, as Obtained on a Glass Plate. (From *Photography: Theory and Practice*, by L. P. Clerc, Hon. F.R.P.S.—Pitman)

particles of solid matter—into air a little tobacco smoke, or into water a few grains of any insoluble substance which will remain in suspension—then the path of the light at once becomes visible. The light meeting these particles is reflected, its direction is changed, and some of it reaches the observer's eye. If untrained in optical language he says, if asked, that he "sees the light." What he sees are the illuminated particles which show him the direction the light is taking. Now this light is reflected in different directions, and is said to be "scattered"—it is a property of all turbid media that they scatter light. Another fact of importance is that, if the pencil be a composite pencil, if it contains radiations having different wavelengths, which is the case where the pencil is one of ordinary white light, the reflection and, consequently, the

scattering are selective, and the radiations having the shorter wave-length are more scattered than those of longer wave-length. The result of this is that the composition of the pencil changes as the light travels in its path. Rayleigh showed that when composite light is scattered by a turbid medium, the scattering is inversely proportional to the fourth power of the wave-length of the constituents. One consequence of this, in the case of a pencil of white light, is that if the observer looks at the path of the pencil at right angles (and also at greater and

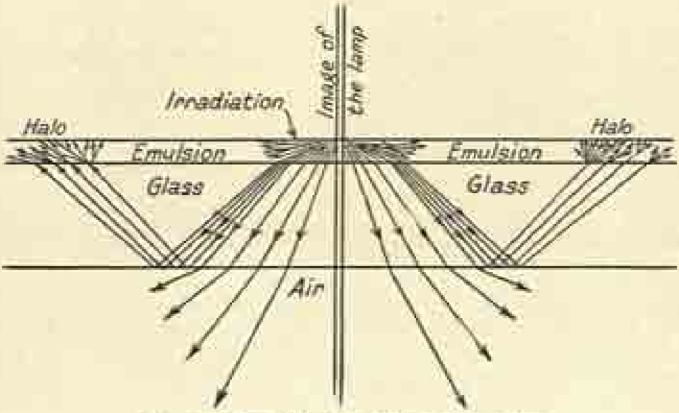


FIG. 55. THE MECHANISM OF HALATION
(From *Photography: Theory and Practice*, by L. P. Clerc, Hon. F.R.P.S.—Pitman)

smaller inclinations) the light received by the eye is pale blue, whilst if he looks along the path towards the source the light appears yellow, orange, or red, according to the number of suspended particles per unit thickness of the layer. Were the observer able to arrange for a strictly parallel pencil of light of definite width, he would find that when the pencil had entered the turbid medium, if he could measure its dimension, it had increased. This follows, as a natural consequence, from the scattering; particles beyond the strict confines of the pencil receive

reflected light from adjacent particles, and these in turn send the light to other particles, so that any effect is not confined to the particles in the direct path but extends to those in the vicinity. Now the sensitive film on any dry plate is a turbid medium through which the light of the image is passing. In consequence, the effect of the light is not confined to the direct path. Consider the image of a point of light. When the light falls upon the surface of the film it is not all absorbed by the immediate surface layer, but that portion which is not absorbed passes into the film and then suffers "scatter," and in consequence the surrounding particles are affected. As a result the point image in the negative is surrounded by a halo. This is "scatter halation." Scatter halation is always greater with dry plates than with wet collodion, because the particles in a wet plate are finer than those in a dry plate, but the principal reason is that the *affected* particles in the film of a wet plate are not developed as they are in a dry plate—they are merely attractive centres for the silver deposited. They do exercise some attractive force for the silver particles which are being precipitated by the developer (see page 64), but as they are far from the surface, this attractive force is much weaker than that of the properly affected particles on the surface. Nevertheless, wet plates do show scatter halation when very fully exposed, but never of any moment. Unfortunately, there is no cure for "scatter halation," but in plates of the orthochromatic type which have been sensitized with erythrosine by the "bath" method and are coloured pink (as in the case of plates prepared by the photographer himself) the halation is lessened. From what has been said it will be understood that because the light which is scattered is blue, any pink colour (as erythrosine) by absorbing the blue light will lessen the harmful effect. Scatter halation is one and, indeed, the principal

contributory cause of the "fog" which always accompanies over-exposure. There is no *prima facie* reason why an over-exposed negative should be fogged merely owing to the effect of the exposure itself. But scatter and reflection halation, and scattered light by the lens and the interior of the camera, are always agents to producing "fog," and the effect of these agents increases with increase in the exposure until it becomes too serious to be ignored. It remains now for the other type, "reflection halation," to be explained.

A pencil of light falling upon any surface behaves according to the nature of that surface; it is the physical condition of the surface that determines what happens. If the surface be a perfect plane, the direction of the pencil, as a whole, is changed; it pursues a unidirectional path, obeying the reflection law, which states that the incident and reflected "ray" make equal angles with the normal to the surface, and both are in the same plane. If the surface be not a plane, if it be in ordinary speech "rough," then there is a change in the effect. The unidirectional path changes, and the constituents of the pencil are sent in different directions—the light is *scattered*. This is sometimes called "irregular" reflection, but there is no such thing as "irregular" reflection—it is the surface that is irregular. The little facets of the surface present different inclinations to the oncoming pencils, and in consequence the reflected constituents pursue different paths. The *amount* of light reflected differs with different substances. For metal it decreases as the angle with the normal increases, for glass the reverse. When light penetrates into the stuff of the body some of it is quenched or absorbed, and if very little be absorbed the body is said to be *transparent*. Since no perfectly transparent substance is known it follows that there is always some absorption, though it may be very slight. If scattering

occurs during the passage of the body it is said to be *translucent*. As an example of a body of high transparency we may take glass, whilst the sensitive film of the dry plate is a translucent substance, so that we have a translucent body resting upon one that is transparent.

When light travels from one medium to another, if there be a change in density there is always reflection at the bounding surface, and there is, further, for that portion of the pencil which enters the body, a *deviation* in path; the light is said to be *refracted*. The path of a refracted pencil depends upon the medium. If the light travels from a "rare" to a "dense" medium, as from air to glass, it is deviated *towards* the perpendicular or "normal" to the bounding surface, and from a dense to a rare medium, as from glass to air, the reverse. We can now trace the sequence in the case of a pencil of light forming some part of the image which falls upon the sensitive surface in the camera. A portion of the light is absorbed by the sensitive body and does photographic work in changing the substance, which change makes it amenable to the developer. But the body is a scattering body, and that portion of the light which is scattered affects adjacent particles and produces the effect previously described; to repeat, it enlarges the area of effect, the image. That portion of the light that is not absorbed passes from the film into the glass. Strictly speaking, since the densities of the two media are not identical there is some reflection when the light leaves the film and enters the glass, but the effect here is small, and we may assume that the light passes without change into the glass. Here it suffers deviation, and travels onward. When it meets the back of the glass, the boundary, glass-air, some is reflected and returns, whilst the remainder passes out. Now this returned light enters the underside of the sensitive surface and produces an effect which shows upon development.

But at the moment of entering the underside of the film there is a change of density, and so some light is reflected. This reflected light passes to the back of the glass, and the same portion of the light is reflected back and strikes another portion of the film, producing an effect. These changes are repeated until the light has become so weakened that it fails to produce any action. These phenomena can be quite easily demonstrated. If a photograph be made of a bright illuminated point upon a black ground, such as may be made by photographing an illuminated needle hole in a piece of blackened metal, the effects observed will change as the exposure is increased. With a brief exposure there will be a tiny spot of density. If the exposure be increased the spot in the negative will increase in size, this increase being due to the effect of the light scattered *in the film*. A further increase will show this spot becoming still larger, and soon there will be seen a faintly-defined ring or halo around the dot, the diameter of the ring depending upon the thickness of the glass and increasing with the thickness. This is the first reflection halation ring. With further increase in exposure, the space between the central dot and the ring will fill in—there will be a "fuzz." This is the effect of the prolonged action of the scattered light. A further increase will now bring into existence a second reflection halation ring, and if the exposure be still more prolonged the space between the first and second rings will fill in. All these phenomena can be seen by making a series of negatives with increasing exposure.

The sceptical reader might argue that there are never these prolonged exposures in practice, and that, therefore, the effects are not produced. Exposure in photography, it may be said, means *intensity* × *time* (see Appendix, "Photography and the Reciprocity Law"), and it matters not whether one or the other be increased in value. We

may have a comparatively weak light, say 10 candles, acting for 100 seconds, or a strong light, say 100 candles, acting for 10 seconds, and so long as we keep within certain limits the effect, for all practical purposes, will be the same, disregarding the "reciprocity law." Now when a plate is exposed upon a subject showing considerable contrast, as a dark interior with a window, we have this condition, and the result is that the gradation in the window is first lost and then there is an encroachment on to the surroundings. But it is not necessary to take such an extreme case; a white plaster cast against a dark background, a white collar against a dark coat, will all show halation, even with normal exposures. It is sometimes said that halation is an effect which leads to an encroachment of the light parts on the dark parts of a subject, in the negative. This is an entirely unnecessary limitation. It may be that it is only in these cases that the effect shows to an uncritical observer, but the truth is that one part always encroaches upon another, and it entirely depends upon circumstances whether or not the effect shows as a distinct thing—it may lead only to general degradation in the quality of the negative—and whether or not it matters depends upon the standard of the photographer.

The assertion is frequently made that films do not produce halation, but this is only partially true. When the film is *thin*, as in rollable film, the reflection halation is slight, because the reflected light practically returns upon itself. But with thick film there can be appreciable reflection halation. In no case, however, does the use of film preclude scatter halation, which is a serious contributory to the total effect and is practically incurable.

Reflection halation may be *practically*, but not entirely, cured by what is known as a "backing." If upon the glass

side—on the back of the plate—there be applied a medium capable of absorbing light in optical contact—no air space—and that medium has the same refractive index as the glass, the light after passing through the glass will pass into the medium and will be absorbed. But no such medium is available, and, in practice, backing merely means the application of a black or other suitable absorbing substance held in a convenient vehicle. Sometimes a dye-stuff is employed which eventually loses its colour during the final treatment of the plate. It is necessary to distinguish between a substratum which is a contact layer between the sensitive coating and its support and a layer—similarly constituted—applied to the *back* of the support, the object being the same, viz. to absorb light transmitted by the sensitive coating which would be—if unabsorbed—detrimental. Similar treatments are applied to films with the same objects.

Surface Tension

In several places in the text the term "surface tension" has been used, and certain phenomena are said to be a consequence of this property. It is desirable that some explanation of what is meant by the term should be given, premising that the subject is one not easy either to explain or to understand. A standard dictionary gives a definition of "tension" as "the state of being stretched or strained," and in liquids "surface tension" is that property which causes its free surface to behave as if it were a stretched membrane, say of india-rubber.

Taking any body, its particles are kept together by strong molecular forces. These forces have an important characteristic in that they are only appreciable at very minute distances. The particles of a liquid at its free surface are in a different condition from those in its interior, and this causes there to be at this free surface

that stretched membrane effect to which reference has been made. This tension is the *surface tension* of the liquid.

If we place water in a *perfectly* clean glass and consider two particles, one at the extreme surface and the other in the interior of the mass, it is evident that the particle at the surface and the particle in the interior are acted upon differently by the molecular forces which keep the particles of the fluid together. The particle in the interior is acted upon more or less uniformly in different directions by the molecular attraction of the adjacent particles, whilst the particle at the surface is acted upon by those molecular forces acting mainly in a downward direction and away from the free surface. The effect is to make the free surface of as small an area as possible, and thus that surface is under *stress*. The liquid in the tumbler is acted upon both by the force of gravitation and by these internal molecular forces.

If the mass of the liquid were left to the action of the internal forces—the force of cohesion—it would, owing to the surface tension, assume a spherical form since the sphere has the smallest surface area for a given volume. Since the action of gravity is negligible when the mass is very small, a minute particle of water dropped upon a waxed surface takes at once a spherical form since the water does not wet the surface and the shape is determined by the external elastic skin. By a simple device a much larger mass can be made to assume the spherical shape. By means of alcohol and water we can produce a liquid with identical specific gravity to olive oil. If now there be introduced into such mixture oil by means of a tube immersed below the surface, as the oil runs out it will assume the spherical form, its shape now being determined by its own surface tension.

This pull on the mass, this tendency to contract until

the smallest volume is produced, is very well shown in the soap bubble. With a bubble, so long as the internal pressure is maintained, the bubble keeps its size until it breaks. If the pressure—by the breath of the blower—be withdrawn, then the elastic skin comes into force and the tension causes the bubble rapidly to become smaller in size.

If there be differences between the surface tension of two bodies in contact they will retain their form. Thus, the globule of water on the waxed surface. Of liquids, pure water has, with the exception of mercury, the highest surface tension. If alcohol be dropped on the surface of water the first effect will be to reduce the surface tension at the point of contact, but at once the superior tension of the water exerts itself, and the alcohol is pulled over the surface when equilibrium occurs. Another instructive experiment, one old and well known in the laboratory, is to drop a small piece of camphor on some still, *clean* water. Now the camphor is slightly soluble and, as might be expected, all parts of the surface do not dissolve at the same rate. When any part dissolves it reduces the surface tension of the water, and so the tension is greater on the adjacent part and, in consequence, for some time the piece moves about until the solution at the surface is uniform. If paraffin oil be dropped on the surface of water the tension pulls it all over the surface until it is completely covered. This explains why a minute trace of paraffin oil getting into water contained in a vessel will soon contaminate the whole surface. Another very good example is shown in the device adopted to ensure the wetting, which is the *spreading* of water, on paper. Many hard-surfaced papers, particularly hard sized hand-made papers, are difficult to wet, and, consequently, it is not easy to lay an even wash of colour when water-colour painting, and people say that the surface is "greasy." The draughtsman mixes

with the wash a small quantity of ox gall, and the difficulty disappears. The ox gall is then said by some to remove the grease or to enable the colour to spread on the greasy surface. But the surface is not in the least greasy; the ox gall has reduced the surface tension of the water, and so the wash has spread better. If the experiment be tried by bringing a drop of ox gall against a drop of water on a plate, the ox gall drop seems to push the other away; actually, it is the elastic skin of the water drop exerting a pull away from the ox gall. If the two be mixed it will be found that the liquid will spread more easily over the surface of the plate, and if now another drop of gall be brought up to the combined liquids the former action is not repeated—for no further reduction of surface tension can now take place with the two liquids.

When speaking of the lithographic process, the reason why a design on stone or metal can be fed with ink from a roller without the clean or bare parts being affected, is essentially due to the fact that the stone has previously been wetted with water. Now the design rejects the water, so we have only the non-design parts bearing a film of water. The ink on the roller is a highly viscous (*thick*, immobile) fluid, whilst the water is very limpid—the reverse. Now a viscous and a limpid liquid do not rapidly mix—in fact they only mix with difficulty—and they are prevented, in the case given, from mixing by reason of the high surface tension of the water, which tends, to adopt a simple expression, "to keep itself to itself." In consequence, the roller can be passed over the stone and the design "fed" with fresh ink without any being deposited upon the clean or *non*-design parts.

If we consider the system varnish-water, we have two bodies that differ very considerably in physical properties. They will not mix to form that uniform mass which we call a solution, and they are chemically inert towards each

other. One of the bodies is viscous and the other mobile, and there is also interfacial tension, and it is upon this interfacial tension that the spread of one over the other depends. The condition for spreading is simply that the particles of the liquid must adhere more strongly to the surface than they do to themselves. The particles of water have a high cohesion and, again, will not readily spread upon organic liquids, of which the varnish is an example. In this case, therefore, we have the water not spreading upon the varnish, or vice versa, and this non-spreading is greatly aided by the high viscosity of the varnish.

Although we have considered the system varnish-water as a viscous medium, it is not strictly varnish, but varnish-pigment, which is a plastic solid, but, broadly speaking, the contention holds. Inks differ in their flow, and an ink which readily flows will, if uncorrected, tend to mix with the water, and this prevents the cleanest work—there will be a tendency to "scumming" on the surface of the stone or plate.

Exposure of Sensitive Surfaces

The correct exposure for any sensitive surface is the most important factor in any photographic process, and probably the most difficult to secure. More particularly is this so in a photo-mechanical process house where, by reason of the highly specialized application of photography, there are many variables to be considered and where errors in judgment, whether at the camera or the printing frame, may easily lead to considerable loss. Exposure is now almost always made to the light from some form of electric lamp. All the lamps, from different causes, are variable with respect to output.

The "printing down" of the ordinary run of line and half-tone negatives is a simple matter, and, with

experienced workers, "spoils" due to light or other variables are soon made good. In many kinds of work, as, for example, in gravure and in photo-lithography (particularly when they are to be in colour), accuracy of exposure is essential. The surfaces are generally of considerable size, and "remakes" mean a serious loss of time and material. Many improvements in the design and construction of the different types of lamp employed and the use of regulating resistances in conjunction with volt, ampere, or watt meters have led to greater accuracy being obtainable.

Since the effect obtained upon a sensitive surface is the product of *time* × *intensity* (see p. 93), the logical way of meeting the difficulty caused by variation in light intensity is the use of an integrating device to measure the total output of light energy (the *quantity* of light), employing this to indicate in some way or other when the predetermined amount required (as ascertained by previous trial) has been reached. To secure this indication, "integrating exposure meters" (a combination of a photo-electric cell with an electrical integrating device) are coming into use. With this device (where the photo-electric cell receives the light as it falls on the face of the printing frame and is therefore subjected to the same variations) arrangements are made to give, by electrical means, an audible signal when the sensitive surface has received the correct amount of light energy, or the exposure may be ended by an automatic "cut-off" to the light source, which is the better plan.

In addition to controlling exposure for photo-printing, the principle is now utilized for the same purpose at the camera, where irregularities in the illumination cause difficulties in negative making, more especially in colour work.

The theory of the application of the photo-electric cell with integrating device for the automatic control of

exposure and the means by which this may be ensured is described clearly in *B.P.* 344,900, 10th March, 1931.

Exposures when Copying

(Note on the allowance to be made when the distance of the arc lamps from, and their angle to, the luminant—say the copy board surface—is altered.)

Assume that at a known distance and angle the exposure required has a certain value which may be termed x. Then if the distance be altered the illumination of the copy will be altered, varying inversely as the square of the distance. Thus, if the light be twice the distance the square of this value will be $2^2 = 4$, and the inverse $\frac{1}{4}$, so that the light will be only a quarter of the intensity and, consequently, the exposure must be four times as long as x. If the angle be altered then the illumination will vary because the area over which the cone of light covers varies, and varies directly as the co-sine of the angle of incidence—the angles which the source of light (the arc lamp or other light) makes with the surface of the copy board. The practical result is that as the angle decreases —the distance remaining constant—the illumination of the same portion of the area becomes less, and in consequence the exposure must be increased. Thus, if the exposure with light at an angle of 45° be 10 seconds, it will be practically 8 seconds at 30°.

A useful table has been published by Smith & Turner (*British Journal of Photography*, Vol. LXVIII [1921], p. 717) by means of which the exposures for the variations in procedure which take place in practice may be calculated.

"The lesser or additional exposure for a known exposure when varying light angle and distance is shown approximately in the table, or can be calculated by the following formula—

$$\text{New exposure} = \left(\frac{\text{old distance}}{\text{new distance}}\right)^2 \times \text{exposure at old distance} \div \text{by co-sine of angle of incidence}$$

The following is the manner of using the table, which is calculated for use with two enclosed arc lamps on a 200 volt circuit, each lamp taking 10 amps—An exposure is 2 minutes at 18 in., and it is required to know the increase of exposure when the lamp distance is extended to 24 in., the lamp angle being 60°. Opposite new distance of lamps look for factor under 60°, i.e. 3·1, multiply known exposure by this factor (2 × 3·1) = 6·2, the required new exposure. If the distance is to be reduced the known exposure is divided by the factor.

Lamp Distance		*Angles*	
inches	30°	45°	60°
18	1·00	1·23	1·78
20	1·23	1·52	2·15
22	1·49	1·84	2·60
24	1·78	2·20	3·10
26	2·09	2·60	3·64
28	2·42	2·87	4·20
30	2·79	3·42	4·66

If the distance be 24 in. at 30°, and it is required to know increased exposure for 28 in. at 60°, take reading for 24 in. under 30° = 1·78, and reading for 28 in. under 60° = 4·2. Subtract 1·78 from 4·2 = 2·42, which is the factor for multiplying known exposure at 24 in. to obtain approximate exposure for 28 in. at 60°."

Sensitivity and Dark Room Illumination

Certain limitations in spectral sensitiveness of the sensitive material—"wet collodion" or gelatine emulsion—indicates the illumination under which it can be handled antecedent to exposure or during development. It is on this principle that the lighting of the "dark room" depends. Starting with a nominal "white" light of suitable intensity a filter is employed which transmits only those regions

which have no harmful action upon the plate, i.e. in the time required for manipulation. The "ordinary" dry plate has a sensitiveness from the near ultra-violet to about 5,400 Å, and it suffices to *absorb* this region. The light transmitted will be mixed—blue-green, green, yellow, orange, and red—and the appearance will be orange-yellow, i.e. the hue of the filter or "safe-light." The intensity of the transmitted light allowable will be governed by the sensitivity of the surface to the colours transmitted. Thus for a very slow "ordinary" plate the light can be brighter than for a rapid "ordinary" plate. The panchromatic plate, on the other hand, is sensitive to nearly the whole of the visible spectrum, with a slightly depressed sensitiveness to a narrow region between green and blue-green, and so a "safe-light" filter will be a green of very low luminosity. When using the very sensitive panchromatic stock, the photographer must train himself to handle the material in the dark—which is not difficult with methodical working—at least until development is advanced and even then submission to the light is dangerous.

The larger amount of the sensitive material used in process work does not call for such onerous conditions. The "dark room" should be illuminated sufficiently for convenient working with light "safe" for the materials used. An inadequately lit room leads only to confusion and delay and, in consequence, increased costs. But such a convenience does not absolve the photographer from care in protecting the material from unnecessary exposure to the light of the room at any stage of the operations, and its protection is easy.

The Reduction of Sensitivity—Desensitization

The sensitivity of an emulsion surface is quickly reduced once the developer has been applied. This occurs with most of the developers in use and is regarded as being due

to a minute amount of oxidation products in the solution. This action is termed *desensitization.* Since the initial observation much work has been done on this subject and the literature is extensive. A number of agents are now employed in producing the effect, either in aqueous solution as a preliminary bath, or added to the developer—the procedure varying with the developing agent and the desensitizing agent selected. Such *desensitizers* are "*phenosaffranine,*" "*pinacryptol,*" "*pinacryptol green*" and "*yellow,*" and *Basic Scarlet N.* to take the more important.

The sensitivity reduction apparently takes place without *unduly* affecting an image formed by exposure but undeveloped, so that if an exposed plate be given a preliminary bath of, say, *phenosaffranine* of very dilute concentration (1 : 5000) the plate can afterwards be developed in a relatively bright light, because the sensitivity of the emulsion has been very much depressed by the action of the *phenosaffranine.* With an "ordinary" or an "orthochromatic" plate, a yellow light of such character and intensity as would be fatal for the untreated plate can then be used during development. A *desensitizer* can be added to the developer, but here the application becomes more complex.

In practice, *desensitizing* is the more valuable with panchromatic stock, in the use of which many find the absence of sufficient light for working very trying and very inconvenient. The preliminary bath of the selected agent does not entail much inconvenience, and the comfort of being able afterwards to continue operations in a reasonably bright light is considerable. One advantage of desensitization with some agents is the tendency to mitigate *chemical fog*, and, further, there is a considerable reduction in *aerial fog*, which latter is brought about by oxidation products in the adherent developer when the sensitive surface is exposed to air during development. The original

assumption that the desensitizing agent was without influence on the latent image has not been sustained. It is necessary for least action that the *desensitizer* be *very dilute* and that the period between the brief bathing and development be as short as practicable. Under these conditions it is probable that the latent image does not materially suffer.

Photo-regression

A question the student might ask is "How long can an unexposed plate be kept before development, and will it suffer in any way on keeping?"

The answer to this in the light of modern knowledge is that fading of the latent image, when and how much, depends upon circumstances.

It was found in the earliest period of photography that both the daguerrean image and the image upon a wet plate suffered on keeping. The daguerreotype plate must be developed within a few hours and the same applied to an exposed wet collodion plate, though this might have been due to physical conditions. With gelatine dry plates it has been found that exposed plates have been kept for several years and have yielded satisfactory negatives on development.

The fading of the undeveloped image is known as *photo-regression* and it appears to be a process the reverse of the formation of the latent image. According to Baekland (*Zeit-Schrift fur Photographie*, 1905, Vol. 3), it is more apparent in under-exposed images. The factors having the greatest influence are temperature and humidity, whilst the presence of alum or free acid plays an important part. The higher the temperature and the greater the humidity of the atmosphere in which the plates are being kept, the more rapid the fading. According to Luppo Cramer the size of the halide grain has influence. Small grain emulsions

show retrogression more rapidly than coarse grain emulsion plates.

The phenomenon appears to show a certain power of recovery.

"After-treatment" of Negatives

All modifications by "after" treatment depend upon a simple principle—they are methods for increasing photographic *density* and thus opacity to light. In this way the gradation and range of contrast may be modified. The modifications are brought about in many ways—by working on the film with brush (including air brush), applying pigment with pencil, and removal with knife or with abrasives locally applied. Briefly epitomized, the ways are—

(*a*) Working on the film by adding pigment in some form. Removal of image material by knife and/or abrasive.

(*b*) By adding pigment on the back of a glass plate negative, or on a base of matt varnish applied. If matt back film be used, the same procedure is followed.

(*c*) By chemical methods, as intensification or reduction.

(*d*) By masking.

When any material is added to the negative (or positive) an endeavour should be made to select a substance having the same spectral absorption as the image material. This is often disregarded and causes extra difficulty in judging the effect.

Masking means *covering up* to hold back one part as against another when printing. Thus, if one portion of the negative is slightly under *density* it will overprint while the other portion is printing through. To overcome this the "thin" portion is "masked," or covered up, by some means, as, for example, by a layer of matt varnish, or a sprayed-on layer of neutral tint pigment. Another method is the superposition in register of a thin positive from the negative. The effect is to reduce contrast

according to the range of the positive. This forms the basis of several methods of correction (see *The Modern Masking System* (Kodak).)

Correction work is frequently expensive. It should be regarded only as a supplement either to remedy limitations in the photographic process or to obtain a particular effect not practicable otherwise. Its possibilities should not be regarded as absolving from care at the camera or in the dark room.

Fundamental Difficulties in Correction Methods

The methods outlined depend for success upon the correct estimation of photographic *densities*, and so gradation and contrast. Reliance cannot, however, be placed on unaided eye measurement, for though the eye—under proper conditions—can decide *equalities*, it is not able to determine *quantity*. Problems involving gradation and contrast are continually arising in photographic processes, and their satisfactory solution involves quantitative information. This information is obtained by photometric measurement. There are particular forms of instrument adapted for use in photo-mechanical processes, such as the *T. and R. Densitometer* (Kodak) and the *Comparator* (Cartwright). If we adopt the accepted system, the tones in a negative (or positive) are expressed as *densities* and the range as the numerical difference between the lowest and the highest density. *Contrast* depends upon the degree to which development is carried—as the development is increased so contrast is increased, save when "fog" intervenes. Contrast is expressed as *gamma* (γ) + the value.

The reader desiring information on the system from which these constants are derived should study the "H. & D." system which is simply explained in *The Fundamentals of Photography* (Mees), and in *Photographic Sensitometry* (Kodak). As an example of the way in which this

system is applied to determine (and to designate afterwards) the necessary characteristics of negative and positive for a particular process, see Cartwright, "Photogravure Positives" (*Penrose Annual*, Vol. XXXVIII, 1936, pp. 119–122).

The Sensitive Carbon Tissue or Pigment Paper for Gravure

The sensitive tissue is, essentially, a suitable paper bearing a pigmented gelatine coating, containing, in solid solution, potassium bichromate, which latter acts as a sensitizer. The pigment is inert, being employed to render the image visible and to control the penetration of light into the film during the exposure. Pigment paper is issued in an insensitive state and is sensitized by immersion in a solution of pure potassium bichromate by the user as required. The behaviour of the tissue on exposure (and its subsequent treatment) is indicated in outline on pages 194 and 195. On pages 202–205 the purpose of the image or "resist" is explained. It has been found that to produce a bichromate gelatine film of full and uniform solubility—essential qualities for reliable practice—requires considerable care and attention to details—hygrometric condition of the tissue, concentration and temperature of the bichromate solution, immersion time and the subsequent procedure in drying the sheets.

In practice, the tissue after withdrawal from the sensitizing bath is squeegeed down on to polished plate glass (which has been made perfectly clean and then "talced" or treated with ox gall), "blotted off" at the back and dried by *evaporation* as uniformly as may be practicable with careful attention to temperature and humidity. The sheets, when dry, are stored flat out of contact with the air. Sensitive tissue to be at its best has a short life. Its behaviour will vary according to age and the

conditions under which it has been kept. In "pure" air, hygrometric conditions and temperature are the principal determinants. Contact of a bichromated film with air tends to produce insolubility at the surface and this must be avoided. Drying on polished glass precludes this surface change and the high surface on the coating which results enables closer contact, which is particularly important in "screening" and subsequent printing from the positive. Rapid and uniform drying at a temperature not above 70° Fahr. (21° C.) maintains solubility. Drying by *evaporation* is not satisfactory unless extreme care be taken, and the kind of care required is not simple of attainment, for with drying cabinets and other devices (which are expensive to install and maintain) difficulties arise. Even when air-conditioned rooms are available, it is not easy to obtain sheets such as are required for large cylinders of that uniformity—viz. uniform over the whole area of the tissue—which is found to be necessary, especially for colour work. The "blotting off" (see *ante*), when practised by careful carbon printers, does remove moisture—superfluous sensitizer—and fairly uniformly, too, and therefore reduces drying time. This, actually, is partial drying by *absorption*.

The principle of drying by *absorption* instead of by *evaporation* has been applied by Loening with considerable success in the Belcolor process. Here the tissue, after sensitizing, is squeegeed down on to ox gall treated plate glass and "blotted off," and is then covered with a sheet of plain paper followed by a "drying blanket"—a fabric which is impregnated with a dehydrating substance—and on this is superposed another sheet of glass bearing tissue, paper, and "drying blanket." In this way a pile is built up according to the number of tissues required. After 1¼ hours the pile is dismantled, when the tissues will be found dry and loose upon the glasses. The "drying"

blankets are afterwards desiccated in an electric drying oven. They are kept in an air-tight canister until again wanted, and can be used repeatedly if carefully treated.

It is claimed that tissues can be dried cold to perfect uniformity, free from creases and without shrinkage, independently of the moisture content and temperature of the surrounding air.

It would appear, therefore, that the production of a "full and uniformly soluble film of constant sensitivity" has become nearer of attainment.

The Rendering of Type in Gravure

When type—either alone or associated with pictorial matter—is to be rendered by gravure, difficulties arise. To the solution of this important problem considerable attention has been given. The letterpress impression from the face of any type letter may or may not show its precise form—the "face"—as its designer left it, but with suitable ink and paper and very careful press work it is a very fair approximation. When type matter is rendered in gravure what really happens is that there is represented by one method what was designed for representation by another, and the result of so doing is seldom a complete success, owing to the sum total of the losses which occur in the steps from one state to the other, some of which appear to be unavoidable under the conditions which obtain. It is the final difference from the original that causes those who desire good and legible type matter to be dissatisfied.

The breaking up of outline by the use of the ruled screen—which naturally shows more with small letters—can to some extent be mitigated by the use of an irregular grain screen or a finer ruled screen than is being used for the pictures if separate etching for these be permissible.

This latter increases the time taken in cylinder preparation and increases cost.

Type matter is not only associated with pictures for titles and captions but, as in letterpress publications, is used for body of the text. For this purpose it is usual in good publications to select a face of pleasant character. There are several faces available which meet the necessities, as, for example, "Imprint," "Plantin," "Gill Sans," simple clear faces without much variation in thickness of line—*monotone* letters. On the other hand, "Bodoni," for example, with its contrast in line, is not suitable. The letter selected should not be less than 8–10 point. The general use of machine-set matter avoids the use of worn type. The type matter should be properly imposed, well planed down and locked up. Trouble is often caused by "matter" being both badly justified and badly locked up. Each of these defects will cause parts of the matter to "rise" and, in consequence, when the forme is proofed uneven impressions result.

Two systems are used for making the positive—

A. By use of the impressions from the type.

B. By direct photograph from the type.

Modes under *A* involve proper "make-ready" and impressions at press or machine to give a sound flat print without "squash."

These may be considered in greater detail.

A (1). With *suitable* ink a print is made on *cellophane, glassine*, or *onion skin* paper. To increase opacity the "tacky" ink is dusted with bronze powder or graphite and the excess is dusted off after standing for a little time. The finished print is used as the positive. Certain faults appear in this method. The ink, unless specially made for this purpose, may not be well "accepted" by the material to form a continuous film, but segregates into globules, and images *tend* to show "squash."

There will be differences in each of the materials mentioned.

A (2). An impression is produced upon white matt baryta paper, a fine black letterpress ink drying matt. From this impression a negative is made and from this the positive, both on high contrast film. A satisfactory reversal process would obviate the necessity for two operations—the positive could be made direct.

A (3). An impression is made by printing on black paper with white ink (Rinco). A negative is made on contrast film. This negative constitutes the positive—black letters on clear ground. Given good impressions, the complete success of modes *A* (1) to *A* (3) depends upon the photographic operation—in all that this involves.

B. The systematized method is the "Texoprint" due to Erich Loening (Belcolor). The system utilizes a principle of old standing, which is that where an image produced by the exposure of a gelatino-silver halide emulsion is developed with a polyphenol developer the oxidation products associated with the reduced silver produce insolubility in the gelatine immediately surrounding. If the emulsion unaffected by light be removed, there remains a complex image consisting of the insolubilized gelatine (with the associated oxidation products), silver, and, *possibly*, some unchanged halide.

Around this principle there has been perfected a method for securing an accurate representation of a type face.

The sensitive surface employed is a gelatine emulsion film of the "wash out" kind coated on a thin celluloid base. The emulsion is "high contrast" and contains an "anti-halo" substance (Agfa). The necessary apparatus has been designed by Loening and forms an essential part of the system. In outline the procedure is as follows—

The forme of type matter is coated over its whole surface with a black pigment varnish (acetone solvent),

a "spray gun" (which is a form of "air brush") being used for this purpose. The coating dries matt. The pigment is removed from the face of the letters by flat faced wipers, revealing the characters bright against a dead black ground. The forme is *at once* photographed under *even diffuse* illumination (the arrangement of the special apparatus secures this condition), using the special film with the uncoated side towards the lens and thus securing the necessary lateral inversion without recourse to the prism. The image is developed with an alkaline solution of *pyrocatechin*, and the film is then rinsed and treated with hot water, when the soluble unaffected emulsion dissolves, leaving the image of the type face in very slight relief. This image is now dyed—to increase opacity—in a solution of *nigrosine*, washed clean, and allowed to dry. The dried film reveals a well-defined image opaque upon a transparent ground.

When separate etching is permissible, whatever be the method for producing the type positive, when exposing for the resist the illumination and the exposure must be adjusted to secure the sharpest image possible, particular attention being paid to the "screening." When etching, the depth of the type should not be more than the darkest tones of the picture.

There are, however, economic difficulties of different kinds which may preclude separate etching, save for the best class of work where time and cost are not, relatively, so important. Efforts should therefore be made towards raising the standard in all respects of the many kinds of day to day production towards that achieved in the best class of gravure work.

When type and picture are to be etched at the same time, some form of masking may be necessary. If the letters in the type positive be sufficiently opaque, they will not print through by the time sufficient insolubility

has been produced in the surrounding ground, *but* the exposure to secure this may be longer than that required for the picture part. Hence the latter must be "held back" by some form of mask, as by removal masks for differential exposure (sometimes practicable) or by simultaneous exposure with the picture portion exposure "held back" by a suitable device. Thus the picture portion may be a yellow base film and the type space be cut out and the type positive on a colourless base inserted. The photographic activity of the light is reduced by the absorption of the yellow film and so the exposure must be prolonged. This plan is not always convenient. In closely associated arrangements of type with picture a yellow base film may be employed in which the colour can be removed by the application with a brush of a solution of a bleaching agent.

Printing conditions are not always favourable to sharp rendering of the type face. The liquid ink may be partially dragged out of the cavities by the "doctor" and show blur. There are many things to be considered, such as depth of etching, nature and fluidity of the ink, the surface and absorption properties of the paper in relation to the ink used, speed of running and rate of drying, these being the most important. It is only when they are adjusted one to the other that the best rendering of the type face is secured.

"Blue Screen" and "Green Screen" Separation Negatives in Colour Work.

Reference is made in the text on p. 382 to a departure from theory in tri-colour negative making owing to the different renderings of gradation through the respective filters. The "blue screen" negative ("yellow" printer) gives a record which is too flat. This may be overcome by increased time of development, which increases contrast. A practice which has become established with

some workers is to use a different plate—an ordinary plate with an ultra-violet absorbing filter. A difficulty is also found when making the "green screen" separation negative ("red" printer) in that there is imperfect separation between the red and blue tones, necessitating an extra amount of correction. To reduce the fault, it is suggested (Ilford) that with the rapid process panchromatic plate a *suitable* type of orthochromatic process plate with the green filter should be used. This latter procedure cannot be employed for continuous tone as a suitable type of orthochromatic plate is not yet available.

It will be observed that stress is laid on the necessity for selecting the most suitable sensitive surface, and of surfaces a large variety is now offered whose particular properties are defined by their makers. Not only so, but strict attention should be paid to employing the correct relative exposure times with the filters and to times and temperatures in development, so that correctly balanced sets of negatives are obtained. These particulars are issued by the plate makers for their own materials.

For a careful consideration of the problems involved in the making of separation negatives, see Coppin, F. W., *Photographic Journal*, Vol. LVII, 1933, pp. 402–408.

Colour Photography and Publicity

In an article written some years ago the writer observes, when speaking of pictures in colour—

> Many advertisers are no longer content to have their wares represented by paintings or sketches—they want them portrayed in actual use by living persons, thereby adding "human interest" appeal to the advertising message.
> —J. S. Mertle, *Penrose Annual*, Vol. XL, 1938, page 120.

This epitomizes a tendency which has been growing for years but with marked increase comparatively recently owing largely to the better rendering of colour by the processes available, to improved services on the part of

producers, and to the more effective presentation of the object or objects by the photographer, from the advertiser's aspect.

There are many uses for photography in colour, not only for publicity of wares but also to furnish records of activities in art, in science, and in industry.

From the standpoint of the printer the colour photograph may be regarded as a valuable form of original from which the process worker proceeds.

For the production of the colour picture by pure photography several methods are available, all of them being in regular use.

(*a*) Pictures in continuous tone—subtractive colour.

(*b*) Pictures in broken tone—mosaic methods—additive colour.

Under (*a*) the chief processes are "Vivex," "Dye Transfer Process," "Kodachrome" (Kodak), "Agfacolor" (Agfa), and "Carbro" (Autotype).

Under (*b*), "mosaic" or "screen plate," there are Regular Mosaic "Dufay" (Dufay-Chromex), "Finlay" (Finlay Colour),[1] irregular mosaic "Filmcolor" and "Lumicolor" (the former autochrome) (Société Lumière).

The "Vivex" process was a rigidly controlled system for the production of pictures in continuous tone by the superposition in register of three images—made from colour-selection negatives—in the "primary" colours "yellow," "pink," and "blue-green," but is no longer worked by the company. The pictures were produced upon paper—matt or glossy—and upon glass. By reason of the conformation to principles and the strictness in method, very admirable pictures can be obtained.

By the Kodak "Wash Out Relief Process," colour prints in continuous tone are made by the dye imbibition method.

[1] The works of the Finlay Colour Process were damaged by enemy action during the war, and the materials for the process are not now available.

The reliefs are made (using a special form of emulsion coated film) from the colour separation negatives, which are dyed by immersion in suitable water-soluble colours—"yellow," "magenta," and "blue-green." The wet dyed print (commencing with the magenta) is squeegeed face down on the gelatine-coated paper and allowed to stand under slight pressure. After this standing the relief is removed (and may be used again), to be followed by the blue-green and eventually the yellow. Considerable power of control exists, the guide being the usual grey gradation scale of tones that should always be associated with any colour negative making process. After the three imbibitions the print is allowed to dry. It may be finished matt or glossy. If transparencies be required, the three dyed reliefs may be bound together between glass.

This description is retained for record purposes, but the process has become obsolete, being replaced by the Kodak "Dye Transfer Process" which is regarded as an improvement in method and result—

The principle of the method is the production of a positive gelatine relief in which the tones are represented by different amounts of gelatine which has been, through the reactions of production, rendered insoluble. The reliefs are placed in appropriate colour solutions, when the colour is taken up in proportion to the thickness of the gelatine in the relief, in fact, to the respective tones. The dyed positive is then placed in contact with suitably coated gelatine paper, when the dye wanders out and is absorbed by the colourless gelatine film and an image in colour results. This is an "imbibition" process. There have been many such processes since 1875, in fact, of which "Pinatype" was probably the most important. A very full account of these processes is given by Le Clerc in his *Photography: Theory and Practice*, 1st Ed. pp. 412–414 (Pitman).

In the Kodak process the first step is to produce a

set of three colour separation negatives of the object to be portrayed, or they may be prepared from Ektachrome or Kodachrome transparencies (see page 439). From these negatives positives are made upon kodak "matrix" film and these positives are developed in a special tanning developer, when the gelatine in close contact with the silver of the image is insolubilized. The gelatine not hardened is now dissolved away in hot water and an image in relief is left in which the tones are thicknesses of hardened gelatine. Here we have the utilization of an old and important principle. When a latent image in an exposed gelatine-silver halide emulsion film is developed by means of a polyphenol developer the oxidation products associated with the reduced silver produce insolubility in the gelatine immediately surrounding the silver particles. This principle has been often used. It was employed by Loening in his "Texoprint" (see page 432).

The unsolubilized images—the matrices—are now placed in the appropriate colour solutions (afterwards rinsed free from superfluous solution) and the blue-green matrix is brought into contact in the designed manner with a sheet of the dry gelatine-coated transfer paper; after the lapse of a short time the colour wanders out and stains the film on the paper. The operation is repeated with the magenta matrix in register and its colour is transferred and afterwards the operation is repeated with the fellow matrix, and the fellow having been absorbed the print is complete. The whole operation from the dry matrices to the finished print takes about 30 minutes. The finished prints have a semi-glossy surface. They can be spotted where necessary with oil or water colour and can be dry mounted in the same way as an ordinary bromide print.

Thus the new kodak process. There does not seem to

be an insuperable objection to adding a fourth colour and so soften the intense colour of the usual dyes employed in colour processes. A negative could be made through a fellow filter and so obtain a good monochromatic rendering. From this negative a fourth relief could be made which could be dyed in a neutral grey and then transferred to the print produced by the three primaries. A departure yes, but this departure is employed in three-colour block printing often to great advantage.

These pictures are good copy in the engraver's studio. The process is one that does not call for any special equipment of an expensive character. It is a process particularly suited for working by an individual photographer—if he be a careful and exact worker—who desires to specialize in colour photography.

The processes of colour photography invented by the Kodak Co. are now so numerous that it is necessary for the student to know and to understand the nomenclature adopted by the firm. The following explanation is given in the booklet issued by the company entitled *Colour Photography*.

The prefix "Koda" is used for materials processed by Kodak Co.

The prefix "Ekta" is used for materials which may be processed by the user. The suffix "Chrome" is used for reversible materials, and the suffix "Colour" is used for non-reversible materials—negative or positive.

Examples are—

Kodachrome processed by Kodak, reversal.
Kodacolor processed by Kodak, non-reversal.
Ektachrome processed by user, reversal.
Ektacolor processed by user, non-reversal.

"Tripack" is a combination of three films arranged as a pack for exposure in the camera. The outer films transmit certain portions of the light to expose the underlying

layers. When suitably sensitized the three simultaneously exposed films yield separation negatives for three-colour photography. "Integral Tripack" is material in which several layers of emulsion are integrally joined together in manufacture so as to be physically inseparable, the layers being differentially sensitized, etc., in manufacture to permit of recording colour separation negatives and (or) producing subtractive colour positives or negatives. Kodachrome is an *integral tripack*.

The chief material is the Kodachrome film, a special form of integral tripack in which there are three separate emulsion layers on one safety base support. Nearest to the base is a layer red sensitive. Above this in optical contact is a green sensitive emulsion, and this is overcoated with an extremely thin gelatine film dyed yellow to act as a filter. The next or top sensitive layer is a blue sensitive emulsion. These coatings are so thin that the total thickness is a little more than that of the emulsion layer upon an "ordinary" non-colour-sensitive film.

When an exposure is made the blue-green and red components are recorded independently. The exposed film is then developed in an ordinary developer to produce a black silver negative image in each layer. The film is not fixed but instead is now exposed through the base to red light, which makes the unexposed red sensitive emulsion in the bottom layer developable. The other two emulsion layers, being insensitive to red light, are unaffected by this exposure and the film is now placed in a so-called "coupling developer." During all processes of the development the reduction of the exposed silver halides is accompanied by a corresponding oxidation of the developing agent and "coupling developers" are those in which these oxidation products are capable of combining with certain chemicals included in the

emulsion or in the developing solution itself to produce an insoluble dye of a particular hue. The colour deposit forming the image in Kodachrome is brought about by the application of a coupler from the developer in Ektachrome, Kodacolor and also in the films of other firms, Agfacolor and Anscocolor, the "coupler" is present in the emulsion at the time of manufacture.

In the case of the bottom red sensitive layer the dye produced is a cyan-blue. Accordingly in the bottom layer a positive image in cyan-blue is intimately associated with the new silver image. The new image is derived from the silver halide which remains after the production of the negative image by the first development. It is a reversal positive.

The top emulsion is now exposed to blue light and developed with a "coupler" developer which produces a fellow image. The only silver halide left is that in the middle green sensitive layer. This is fogged and is then developed in a magenta dye-forming developer.

All the silver halides present in the original film have been converted into silver and when this silver is dissolved out there remains only the three positive coloured images which together form a subtractive colour transparency in perfect register.

If coloured prints on paper are required they can be produced from the Kodachrome transparencies by making a set of negatives through the respective three colour screens, using a particular technique, and from the negatives prints are made by the dye transfer process already described.

Sufficient has now been said upon these important processes which in experienced hands (who understand lighting of the subject and exposure) are capable of giving very striking results. It will no doubt be understood that certain subjects with a particular colour scheme are

better than others. It might be agreed—the examples in our Exhibitions seem to show this—that when the colour scheme is pale, soft and delicate the results of these colour processes are the most pleasing aesthetically.

There are other processes but space does not permit a discussion of the methods, and for these the student is referred to the booklet *Colour Photography* (Kodak), which is easily obtainable.

The "Agfacolor" is a transparency process. The film is issued in 16 mm. for sub-standard cine cameras and in 35 mm. for "still" cameras. The photographs are made by the photographer, but all processing is carried out by Agfa Ltd. The "Agfacolor" sensitive film comprises three superposed emulsion layers differentially sensitive to approximately the three primary hues of the spectrum. In these emulsions there are colour formers which on development develop to colours which are complementary to the sensitivities, whereby there is left in the film, after the removal of all silver, three superposed subtractive colour images.

The two transparency processes described furnish pictures which, being grainless, permit of enlargement to a considerable degree. Eventually they may appear as an advertisement, an illustration in a magazine article, or even as a colour poster. They are admirable for the photographer who uses a small camera and who wishes to produce records of current events in colour, afterwards to be transformed into print. Since the processing is done by others, the photographer is able to devote his main attention to the principal thing—the choice and arrangement of the subject and the taking of the picture.

In the "Carbro" process the starting point is a set of bromide prints made from the three colour separation negatives. The process is complicated but the means for carrying out the work are simple in character and the

results may be very good. Full details are given in the Autotype Company's booklet *Trichrome Printing*.

The methods in the broken tone—additive—system furnish transparencies. "Dufay" and Société Lumière products, "Filmcolor" and "Lumicolor," are upon film, "Finlay" upon glass. The colour systems are mosaics of exceedingly small transparent elements of the primary hues, "yellow," "red," and "blue," to which, originally, the term "screen plate" was given. The *réseau* or pattern in the "Dufay" consists of alternating blue and green squares and red lines, in the "Finlay" of alternating lines of squares, green, blue, green with blue, and red-blue in close juxtaposition, whilst the Lumière plate is a regular irregular assemblage of coloured starch grains with a black filling between the interstices of the grains.

In the "Dufay" and "Lumière" processes the screen plate is coated with the panchromatic emulsion (combined system), exposure is made through the colour elements, and after development the image is reversed. The elementary principle underlying the production of colour pictures by the screen plate system is given on p. 361. In the "Finlay" colour the screen plate is separate from the "taking" screen and is used in close contact with a panchromatic plate. From the negative so obtained a positive is made and is combined with a "viewing" screen—a similar assemblage to the taking screen with *slightly* different colours.

These processes are capable of yielding satisfying results. The "Dufay" is the simplest of the trio and the very fine *réseau* presents little or no difficulty in reproduction. For the photographer following current events the film is a very valuable aid, and for publicity work, especially with large sizes, the pictures are convincing to those who seek originals in colour for the process engraver. As guides for the colour etcher, the "Dufay" pictures are

valuable. The "Finlay" pictures have the advantage of ready multiplication, for any number of positives can be made from the original and combined with separate "viewing" screens. Fine screens are made and with these some remarkable work has been done in the colour renderings of pathological specimens and in microscopy which have furnished originals for book illustration. In still life, for instance *objets d'art*, striking results are shown and it is regrettable that the process is at present unavailable.

Colour Separation Negatives from Screen Plate Originals

The pattern in screen plate pictures is so fine as to be invisible to the unaided eye. When separation negatives are to be made for three- and four-colour printing certain difficulties arise. With any of the three filters only one of the three elements will be shown, the colour from the remaining two being absorbed by the screen. The result is that the negatives are *not quite* continuous tone. Tritton has proposed an entirely simple method (depending on diffraction) which is to make the continuous-tone separation negatives with a relatively small lens aperture, actually between F.45 and F.55. The diffusion which takes place owing to diffraction eliminates the pattern of the screen plate assemblage and thus the negatives are in more or less continuous tone. See Tritton, F. J., *British Journal of Photography*, Vol. LXXXIV, 1937, pp. 513–514.

When direct screen separation negatives are made, moiré is apt to appear, but it is found that this does not take place unless the "Dufay" image is enlarged sufficiently for its pattern to clash with that of the ruled screen. If considerable enlargement is to be made then recourse may be had to the old way of putting the image

very slightly "out of focus," but there are drawbacks to this plan. Probably the better proceeding is to employ the indirect method, using the very small aperture. Under those conditions a negative would result, and from this negative the screen positive could be prepared direct, which could—after any correction by "dot etching"—be used for photo-litho by the methods already outlined, or another negative could be made for block-making.

"Finlay Colour" recommended making colour separation negatives (for printing processes which do not involve the use of the ruled screen) in the ordinary manner, but, as pointed out (see *ante*), such negatives are not *strictly* continuous tone. With *very fine* "Finlay" screen plates the diffraction system is applicable. Another system is to employ two "stop out" screens, out of one of which passes either green or red and the other the blue. If the Bassani apparatus be available—this was used by "Finlay Colour," which undertook to make separations—then direct screen negatives can be made—with the proper angles—which do not show pattern.

The question is sometimes asked, "Which is the best process?" to which it may be said that all the methods give good colour presentation. When the end is to be a picture from the printing press, there are advantages in choosing a colour process where the printed rendering approximates in appearance to the original colour picture, and for this reason paper prints are worthy of particular consideration. There is great attractiveness in colour transparencies, particularly of large size; and they are not expensive to make. The screen type of transparency is very sensitive to illumination, and if not intelligently shown may disappoint when there is nothing wrong but the manner of showing. They should be submitted to the customer under good daylight illumination whenever practicable.

Although enlargements are easily made after submission, it is always better in the first instance to show a colour picture which is near to the size intended for the final presentation in print. There is little doubt that the large picture carries greater conviction than the small one.

With all colour processes it would be well for the proposed user to recognize the difficulties which they present. Some of these difficulties are overcome by the processing houses with the means at their disposal in the way of apparatus and what is more important, the highly skilled staff who do the work. So far as concerns the self user he would be wise to try the "Carbro" or "Dye Transfer "methods which, in the opinion of Dr. D. A. Spencer, are "to date the most hopeful processes for the solo professional worker," and further that he "should be very chary of accepting reports that some newly introduced process will provide a short cut out of the difficulties by the simplicity of its operations" (Spencer, D.A., *Colour Photography in Practice* 3rd Edition, p. 175).

Three- and Four-colour Printing Processes and the Black Printer

On pp. 373–5 will be found some observations on three- and four-colour printing processes, particularly with respect to the part assigned to the "black printer."

The three-colour printing process is not a simple or an easy method for producing colour pictures. There are some limitations in the required sensitivity of the plates and many in the transmissions of the filters. The hues and transparency of the printing inks are far from what they should be, and there does not appear at present to be much hope of improvement. Whatever be the printing process employed, it presents its own limitations, so it will be seen that the sum total of the difficulties in the

way of the successful rendering of the colour appearance of an "original" is considerable and an approximation is obtainable only by following a pre-ordained system with the exercise of considerable care in manipulation. The method is only practicable at present when a considerable amount of hand-work is done at some stage of the process, the extent of this hand-work in any particular case being influenced by many factors, such as the correctness or otherwise of the procedure, the care in working, and the fidelity required in the rendering of the original. With a good system and skilled craftsmanship, with care at every stage of the process, it is possible to produce pictures which will satisfy even the critical, but, if there be any lapse, the result is far from pleasant. In no case are the pictures produced by any tri-colour photo-mechanical printing process comparable either for rendering or quality with several of the purely photographic three-colour processes.

The ordinary commercial three-colour printing process could, however, be more satisfactory if it ceased to be used for the rendering of *any* drawing or original in colour, and were confined to the rendering of drawings or subjects in colour made to conform to the limitations of the process; drawings, for example, which could be made perfectly effective—given understanding and skill on the part of the draughtsman—from the publicity standpoint, and it is for this purpose that the great majority of ordinary commercial three-colour printing is done. Fine colour work can always be done for those who will pay for the skill and care required—it is the raising of the standard of "commercial" work that calls for the greatest attention.

In colour printing processes there are two stages—the production of the matrix and the printing of an edition. The producer of a set of three-colour plates, for example,

works to an original and endeavours to approach its appearance with his effort. Proofs are taken with care on the press (using the inks selected for his system) upon suitable paper. These proofs show what the plates will yield under standard conditions and these furnish eventually a guide for the printer. Although quite fairly produced, these proofs are, however, not made under the conditions which will obtain when the edition is printed. The two sets of pictures frequently show marked differences and these differences give rise to dissatisfaction. On behalf of the printer (who is frequently criticized) it may be said that it is by no means easy under the conditions which so frequently obtain in the machine room to maintain uniformity over even a comparatively short run. With colours of the intensity of those employed in three-colour printing any excess or deficiency in the separate printings will alter the appearance of the finished sheet, which then becomes unlike the plate maker's impression. Still greater differences may arise when there are differences in paper and ink compared with those used for the original proof. It is only reasonable to expect fidelity to the plate maker's proof when the printer is skilful, has suitable conditions in the machine room and is not unduly hurried in the work.

When "balance" in colour printing is, owing to certain conditions, not easy of attainment and maintenance, a "neutral" grey or "black" printing is helpful. It is usual to make for this so-called "grey" or "black" printer a monochrome rendering of the original, using a "yellow" filter, and to "fine etch" the plate made from this negative so that when printed in a "grey" or "black," the print will give the most pleasing tonal rendering of the subject. But this is not strictly a "four-colour process"—it is rather a "way out" of a difficulty with the "three-colour process."

There is another case where a grey or black printing is used, which is where brilliant hues paler than the usual standard inks are employed, inks which will not in full saturation produce a black by superposition. The light tones in an original can be well rendered by this means, leaving the darker tones to be produced by the superposition of the "black" or "grey" printer.

Generally speaking, originals which are light in tone are more pleasing in three- and four-colour printing than originals in dark tones, as an examination of any varied collection of examples will show. On p. 374 it is stated that in the four-colour process of Albert the negative for the fourth printing gives only the black and the greys of the subject, whilst the other three negatives do not contain any black or grey. This would appear to be the most satisfactory system. It means very careful correction by masking and by "fine etching" to eliminate the black or grey where not wanted, and, in consequence, the cost is relatively high. But since it is becoming more generally recognized that for successful and economical commercial colour work an original that has been prepared to allow for the limitations of the process is far better than one selected without any such consideration, there is a way of proceeding in the preparation of the former whereby much of the difficulty with regard to the "black printer" may be eliminated. It has been shown that certain pigments—independently of their reflections which give rise to their colour—have the property of reflecting "infra-red" radiations—viz. radiations beyond the visible red, roughly, 7,600 Å. Black pigments (which are generally some form of carbon black) absorb and do not reflect the "infra-red." It has already been stated that a sensitive plate is now available which has the normal sensitiveness of the "ordinary" plates and an *added* sensitiveness for the region 7,000 Å to 9,000 Å.

which latter includes a considerable range of the "infra-red."

Let a drawing be prepared in which the colour pigments used are those reflecting "infra-red" with the dark tones and the shadow portions obtained with the same pigments but mixed with the required amounts of "carbon black." We have then an original amenable to "selection" by purely photographic means. If for the "black printer" this drawing be rendered upon an "infra-red" sensitive plate, using an "infra-red" filter (or the ordinary tri-colour red filter may be used in lieu), the dark tones will be represented by different degrees of transparency in the negative. What has taken place is that the whole of the colour pigments used have reflected the "infra-red" and so produced deposits in the negative—only the carbon black has failed to do so. The different transparencies in the negative correspond to different amounts of carbon black, viz. to the varying degrees of darkness in tone produced by the varying amounts of carbon black admixture. In this way automatic selection is effected and much expensive correction by hand-work is avoided.

This subject has been carefully considered by Tritton, and to his paper the reader is referred (see "The Black Printer Negative," *Penrose Annual*, Vol. XL, 1938, pp. 126–129).

The Selection of Colours in Lettering on the Printed Page and some Aspects of the Custom

The student will often have the chance of observing that with certain combinations of colours in lettering the sense of complete flatness is lost. One letter (or maybe a piece of ornament) or line of letters is lost, there is, in fact, a stereoscopic effect, especially when the colours used are spectroscopically far apart. This appearance is

due to a want of achromatism in the human eye, and the effect is distressing. Another defect is found in a line of lettering of the same size and fount if the initial letter is made of a different hue. This letter will then *appear* to be of a different size from its companions. Sometimes in posters one line will be associated with another of a different colour and the effect is bad. Certain hues should not be used, for example, magenta. Here the colour reflects the two ends of the visible spectrum and lettering or ornament of this colour will not appear sharp.

The Aberrations of Lenses

The most perfect lens suffers from defects, some of which are inherent and others due to various causes. These defects show themselves in the images produced, which are less good than they might be were the aberrations non-existent. It is desirable that the student should know and *understand* these aberrations and the way in which they detract from perfect performance, and also the way in which the lens computator and lens maker overcome as far as they do the faults, making the modern photographic lens a very wonderful production. For this reason a brief résumé is given in the hope that, though the full understanding is difficult and demands much study, even an elementary knowledge is advantageous for it will be seen then how the problems requiring solution arise and how far their solution is possible and practicable. Many photographers regard the study of lens optics as "dry as dust," but this is a mistaken idea. Once by taking thought and quiet *real* study the initial difficulties are overcome, the study will be found to be fascinating. The nature of the aberrations has been carefully explained in a simple but rigid manner by E. T. Whittaker in his *Theory of Optical Instruments*, and his statements are given below with some slight modifications.

In a centred optical system the aberrations may be defined as follows—

1. Spherical aberration in the lens axis.
2. Coma.
3. Astigmatism.
4. Curvature of the field.
5. Distortion of the image.
6. Chromatic aberration.

1. *Spherical aberration in the lens axis.*

"The marginal rays, or rays which pass through the outer zones of the lens, do not meet the axis in the same point as the paraxial rays."

2. *Coma*

"The linear magnification of a very small object, situate on the axis of the instrument, is different when different zones of the instrument are used to form the image."

A small angular field is meant. Photographic lenses which are highly corrected over large angular fields for specrical aberration come under the above definition.

3. *Astigmatism*

"A thin pencil which is not homocentric but diverges from (or converges to) two focal lines is said to be astigmatic."

See explanation under previous definition. The term homocentric implies that the luminous disturbance is converging to (or diverging from) a single point, viz., the centre of this sphere which of course will be the image point of the original luminous point.

4. *Curvature of the field*

"Curvature of the field exists when the focal surface, on which approximately coma-free, stigmatically-sharp images are formed, is not flat."

5. *Distortion*

"The image is said to be affected by distortion when the object (supposed to be a plane figure at right angles to the axis of the lens) gives rise to an image which is not geometrically similar to itself."

6. *Chromatic aberration*

The physiological sensation of white is produced by a mixture of light of different wave-lengths and there is consequently a confusion in the images formed since any refracting medium behaves differently to light of different frequencies and to the

result the name *chromatic* aberration is given. Any optical system which is designed to have the same behaviour for light of two standard wave lengths is said to be *achromatic*. Optical systems in which the spherical aberration is corrected for more than one colour but in which the secondary spectrum is not removed are called *semi-apochromatic*, while systems which have no secondary spectrum and are aplanatic for more than one colour are called *apochromatic*.

With regard to the attainment of a perfectly sharp image over as large a field as possible, Lummer (*Photographic optics* (Macmillan)) says—

> The two regions of space in front of the lens and behind it must be in *collinear* relation—that is to say, all rays proceeding from a point in one region must unite again in a corresponding point in the other region, in such a way, in fact, that any extended geometrical form in the object-space in front is precisely correlated to a similar geometrical form in the image-space behind the lens. Or in other words, to every point in the object there shall correspond a conjugate point in the image, and vice versa. Of all optical systems there is only one that literally fulfils this condition, namely, the plane mirror; for only in the case of reflection at a *plane* surface are these conditions of a point-to-point correspondence between the object-region and the image-region accurately fulfilled. But since this reflection produces only a change of position, without magnification, and moreover only gives a *virtual* image, it is of no significance in photographic optics. In photography, optical systems are required which cast *real* images of objects, and which moreover cast them upon a flat surface, namely the photographic plate. One must therefore turn one's attention to *curved* reflecting or refracting surfaces. But of these it may be shown in general that they do not even produce a *small real* image, by means of wide-angled pencils (as is necessary for bright images), with accurate correspondence point for point and accurately similar to the object. But rather, they produce a truly collinear image of extended flat objects, only if the delineating pencils are very *narrow*. Never, except in the special case—which, however, is of no importance in practical use—where the effective rays make indefinitely small angles with the principal axis of the system, that is to say, when both the visible *field* and the angular *aperture of* the system are small, does the formation of a truly collinear image occur.

Determination of the Principal Focal Distance of a Lens

Many methods have been described for the determination of this constant, some of which are complicated and others are simple but scarcely accurate. All the methods require care and neat manipulation.

The method outlined below is that of Davanne, which is simple and accurate.

Requirements: Camera (back extension), lens diaphragms, calipers, pencil, metre rule, gum paper, focussing eye piece.

Erect the camera and screw in the lens. Point the lens at a distant object approximately 200 times the estimated focal distance of the objective under examination. Focus the object carefully in the centre of the screen. Attach a piece of paper to the base of the camera. Lay a metre rule against the focussing screen so that it is vertical and one end touches this paper. Mark the place with a pencil.

Now place the metre rule on some support, turn the camera so that the lens points at the rule, and focus an image so that 20 cm. is represented on the screen by a length equal to 5 cm. (¼ size original). Now remove the rule and place against the back of the screen as before; and let the end rest on the paper as in the first instance and the mark position. The distance between the two marks represents the distance through which the focussing screen has moved. This quantity multiplied by four gives the principal focal distance.

Rack back now to the first position, and put the rule so that it rests on the top of the camera and with one end so that it is coincident with a vertical plane through the ground surface of the ground glass. Measure along this rule from the end spoken of a distance equal to the focal distance found. A perpendicular line at this distance cutting the lens axis marks the back nodal point N2,

the position from which the posterior distances (node to image) are marked.

Determination of the Angular Aperture of a Lens

The "aperture" is the opening through which light is admitted.

Unscrew one combination and measure the diameter of the fixed stop by means of calipers. Divide this quantity, say x, into the focal distance. Then the product

$$\frac{\text{focal distance}}{x} = \text{the angular aperture (mechanical)}$$

Repeat this with all the apertures, when the series of values obtained are the respective angular apertures. The relative times of exposure vary as the squares of these angular apertures. The relative times of exposure for the whole series may be obtained by dividing the square of the largest (the fixed stop value) into the square of the other values.

It is generally more convenient to express the ratios proportioned to $\frac{F}{8}$. To do this divide 64 (8^2) into the squares instead of the square of the angular aperture of the fixed stop. This value is only strictly correct for a lens without a combination in front of the stop, for example a single lens. With any lens having a conbination in front of the stop a condensed pencil is transmitted and the mechanical aperture is not the true aperture—it is the effective aperture that must be determined. To do this place the focussing screen in the position of the first mark. Remove the ground glass and place in its stead a sheet of card having a pinhole exactly in its centre. Remove the camera to a dark room and place behind the pinhole a gas or candle flame. Cut a piece of bromide paper so as to fill the inside of the lens cap and then place on the lens and

expose for a few seconds. On development a circular black disc will be found, which on measurement after drying will be found to be slightly larger than the fixed stop. The diameter divided into the focal distance gives the true angular aperture. Now repeat with all the other diaphragms belonging to the lens.

Difficult Line Drawings

A property of considerable importance is possessed by some of the newer sensitive surfaces, viz. high density with clearness or no density, in other words *high contrast.* There come to the process studio very frequently drawings in line in which the lines are pale in colour or rest upon a non-white paper or even have both characters, and it is required to produce from these negatives in which the ground shall be opaque and the lines have little or no density. Before the introduction of these special surfaces the job was difficult—how difficult only those operators who had the task know. Even with great care and judgment and the use of powerful intensifiers the negatives were difficult to print on resist. This was particularly the case when the print was required for the lithographic process. It is with subjects like those mentioned that the new surfaces prove valuable. Of such is the "Kodaline" film which can be "stripped" when required. In some cases the negative has to be helped by skilled hand-work, and for this the Kodak "Photo Script" offers advantages. Here the emulsion is non-colour-sensitive, coated thin, and gives high contrast. The film can be worked upon by an engraver's needle to supplement the work of the camera. For similar purposes the Ilford Company offers the litho negative plate with orthochromatic emulsion giving high contrast and "Litho Neg" with the same emulsion coated upon film (medium base), and "Ortho Line" medium orthochromatic, which it is

stated is suitable for the rendering of originals on coloured base paper or paper yellowed with age. These films can be supplied with a matt back which permits of retouching with a pencil.

In addition to glass and film base, coated papers for negative making are available, both non-colour-sensitive and orthochromatic, and these are suitable for line and screen (especially coarse screen) negative making. Coated paper has the advantage of relative cheapness compared with the other supports for the emulsion. Fortunately for the better rendering of drawings in line where some of the detail is fine and often pale in intensity, there is a method by which great improvement over the ordinary straightforward procedure can be effected. This is by a "Masking" process known as the "Kodak Fine Line." The difficulty with some drawings is that if the negative be printed long enough to give the fine and pale lines then the other portions of the drawing are over-printed with the result that there is a loss in detail—which is most serious when the heavy lines are close together.

The principle is simple. It is to prepare an unsharp positive transparency from the negative and to superimpose this positive film upwards in register over the original negative during exposure. When making the positive the source of light should be at a particular distance and be oblique, and the system should be rotated during exposure. A suitable distance for the exposing light is 4ft and 2ft out of line with the centre. The exposure should be adjusted so that the positive on development should have a *density* about one-third to one-half that of the negative.

As an illustration of the procedure with the original negative on a contrast process film face up there is the thickness of the film base between it and the sensitive surface of the plate for the transparency (about 0·0007 in.

in the case of one film). When finished the unsharp transparency is placed over the negative with the film of the positive against the back of the negative and the print made. Equally a transparency can be made. The difference between the straight print and the print made under the masked negative—the new procedure—is striking.

"Silvalith" zinc plates (Registered Trade Mark, Kodak) consist of grained litho zinc coated with a photographic emulsion. They may be exposed to either a negative or a positive in the camera or by contact and converted directly into line printing plates by a simple processing technique. This process dispenses with the need for arc lamps, whirlers, etc., and eliminates the necessity for the usual glass or film negative, and the time which would be normally involved in its preparation and in printing it down on to metal. (As an indication of the saving in time alone, a complete demy plate, ready for the machine, can be produced within thirty to sixty minutes of receiving the copy.) The plates can, of course, be stored as can all ordinary types of photographic material. Slight modifications in processing are necessary according to whether a negative or positive original is being used.

WEIGHTS AND MEASURES

The Metric System

In the metric system the units are the gram, metre and litre. The gram gives the *mass* or weight, the metre gives the *length*, and the litre gives the *volume*.

Measures of Mass

1 milligram	=	0·001 gram
1 centigram	=	0·01 ,,
1 decigram	=	0·1 ,,
1 decagram	=	10 grams
1 hectogram	=	100 ,,
1 Kilogram	=	1000 ,,

The Standard Kilogram is the mass of a piece of metallic platinum termed the *Kilogramme des archives*, which is kept in Paris.

Measures of Length

1 millimetre	=	0·001 metre
1 centimetre	=	0·01 ,,
1 decimetre	=	0·1 ,,
1 metre	=	1000 millimetres

The standard metre is the length of the international prototype metre, which is kept in Paris (39·37 in.)

Measures of Volume

1 millilitre	=	1 cubic centimetre
1 centilitre	=	10 cubic centimetres
1 decilitre	=	100 ,, ,,
1 litre	=	1000 ,, ,,

The litre is the volume occupied by the mass of 1 kilogram of pure distilled water weighed *in vacuo* at 4°C. This is nearly equal to a cubic decimetre.

For very small measures of length the term *micro* is employed. A micro-millimetre is the one-millionth of a millimetre. A micron (μ) is the one-thousandth of a millimetre.

The British System

Measures of Mass

27·34 grains	=	1 drachm		
437·34 grains	=	16 drachms	=	1 ounce (oz.)
16 ounces	=	1 lb.		
7000 grains	=	1 lb.		

The British pound is the mass of a particular piece of metallic platinum in the care of the Board of Trade, London.

Measure of Length

1 inch	=	1/12 foot
12 inches	=	1 foot
3 feet	=	1 yard

Measures of Volume

60 minims	=	1 dram		
480 minims	=	8 drams	=	1 ounce
20 ounces	=	1 pint	=	9600 minims
8 pints	=	1 gallon	=	160 oz.

The British gallon is the volume which is occupied by 10 lb. of pure water weighed in the air at 62°F. (barometer 30") against brass weights of density 8·143.

EQUIVALENTS

1 gram (or gramme) = 15·43 grains
1 oz. = 28·4 grams
1 oz. fluid (438 grains) = 28·4 c.c. or c.b.c.
1 lb. = 453·6 grams
1 litre = 1·76 (say 1¾) pints
1 cubic centimetre = 17 minims water (nearly)
1 oz. fluid is the bulk or volume of 437½ grains of water at 62°F.
1 cubic centimetre is the bulk or volume of 1 gram of water at 4°C. (39·2°F.)
1 centimetre = 0·39 inches
1 metre = 39·37 inches
1 foot = 30·48 centimetres
1 yard = 91·44 centimetres

CONVERSIONS

To convert centimetres to inches, multiply the number of centimetres by 0·3937.

To convert cubic centimetres to fluid ounces, divide the number of cubic centimetres by 28·4.

To convert cubic centimetres to minims, multiply the number of cubic centimetres by 17.

To convert cubic centimetres to pints, divide the number of cubic centimetres by 567·9.

To convert grams to grains, multiply the number of grams by 15·43.

To convert grams to ounces, divide the number of grams by 28·4.

To convert inches to metres, divide the number of inches by 39·37.

To convert pints to litres multiply the number of pints by 0·567.

The numbers given, though not quite accurate, are sufficiently near for practical purposes.

When any formula is expressed as so many grams to a 1000 c.c. (sometimes expressed c.b.c.) (1 litre), to convert to so many grams to a fluid ounce, divide the number of grams by 2·3. To convert to grains to a pint divide the number of grams by 0·115. To convert from grams solid to 1000 c.c. to ounces solid to a pint, divide the number of grams by 50.

To convert grains to a fluid ounce to grams per 1000 c.c. multiply grains by 2·3.

To convert grains to a pint to grams to a litre multiply the number of grains by 0·115.

To convert ounces to a pint to grams to a 1000 c.c. multiply the number of ounces by 50.

To convert cubic centimetres to a litre to minims to a fluid ounce divide the number of cubic centimetres by 2·07. To convert to minims to a pint divide by 0·1035.

To convert minims to a fluid ounce to cubic centimetres to a litre mulitply the number of minims by 2·07.

To convert minims to a pint to cubic centimetres to a litre multiply the minims by 0·1035.

To convert cubic centimetres to a 1000 c.c. (1 litre) to fluid ounces to a pint divide the number of cubic centimetres by 50. To convert fluid ounces to a pint to cubic centimetres to a 1000 c.c. multiply the number of fluid ounces by 50.

MEASURES OF TEMPERATURES

Temperatures are given in all scientific literature as the scale of Celsius (centigrade). On this scale the temperature of melting ice is 0°C. and the boiling point of water is 100°C.

In most English-speaking countries for ordinary operations the scale of Fahrenheit is used, and it is still used in some technical circles in industry. Here the melting point of ice is 32°F. and the boiling point of water 212°F.

To convert degrees centigrade to degrees Fahrenheit multiply degrees centigrade by 9/5 and add 32 to the product.

To convert degrees Fahrenheit to degrees centigrade, subtract 32 from degrees centigrade and multiply the remainder by 5/9.

CHOICE OF BOOKS

THE student interested in the subject will probably wish to continue his studies on the technical aspect of the processes. Should he do so, the following textbooks are recommended—

The Wet Collodion Process for Photo-Engraving. Hislop, W. B. (Federation of Master Process Engravers.)

The Wet Collodion Process. Payne, A. (Mawson & Swan.) 3s.

The Fundamentals of Photography. Mees, C. E. K. (Kodak, Ltd.) 5s.

Photography of Coloured Objects. Mees, C. E. K. (Kodak, Ltd.) 2s. 6d.

Manual of Exposure and Development. Tenth Edition. Watkins. (Watkins Meter Co., Hereford.) 1s. 3d.

Manual of Process Work. Clerc, L. P. (Ilford, Ltd.) 7s. 6d.

Photo-Engraving in Relief. Smith, Turner & Hallam. (Pitman.) Second Edition. 21s.

Practical Photo-Lithography. Second Edition. Mason Willy, C. (Pitman.) 10s. 6d.

Photogravure. Cartwright, H. Mills. (Hunter-Penrose & Co.) 19s. 6d.

Photo-Engraving, Electrotyping, and Stereotyping. Barber. (Pitman.) 8s. 6d.

The Art and Practice of Printing. Atkins, W., and others. (Pitman). 6 volumes, 7s. 6d. each.

BOOKS OF REFERENCE

The Theory of the Photographic Process. Mees, C. E. Kenneth. (The Macmillan Co., New York). $12.

Photography: Theory and Practice. Clerc, L. P. Edited by George E. Brown. Third Edition. (Pitman.) 35s.

Colour Photography in Practice. Spencer, D. A. (Pitman: Greenwood.) Second Edition. 35s.

Process and Practice of Photo-Engraving. Groesbeck, H. (Doubleday, Page & Co., New York.) $7.50.

REFERENCES

Certain subjects of special interest to students of photomechanical processes are considered in the articles mentioned below.

COLOUR PROCESSES

"Accuracy Obtainable in Straightforward Colour Reproduction," Bull, A. J., Oliver, L. W., and Spencer, D. A., *Photographic Journal*, Vol. LVII, 1933, pp. 358–364.

"Making Three-colour Separation Negatives," Coppin, F. W., *Photographic Journal*, Vol. LVII, 1933, pp. 402–408.

"Reproducing Screen Plates," Spencer, D. A., *Photographic Journal*, Vol. LVII, 1933, pp. 19–22.

"Kodachrome: A New Colour Process," *British Journal of Photography*, Vol. LXXXII, 1935, p. 275.

"The Kodachrome Process," Davis, E. R., *Photographic Journal*, Vol. LXXVI, 1936, pp. 248–253.

"The Vivex System of Colour Photography" (Colour Photographs, Ltd.,) *British Journal of Photography*, Colour Supplement, Vol. XXXVIII, 7th September, 1934.

A more complete account of the Vivex Process is given in "Basic Features of the Vivex Process," *Photographic Journal*, Vol. LXXXIX*B*, 1948, pp. 78–83.

"The New Agfacolor Process," *British Journal of Photography*, Vol. LXXXIII, 1936, p. 709.

"The Dufaycolor Process," Renwick, F. F., *Photographic Journal*, Vol. LXXV, 1935, pp. 28–35.

"Overall Tints in Dufaycolor Transparencies and Their Correction," Murray, H. D., and Spencer, D. A., *British Journal of Photography*, Vol. LXXXIV, 1937, p. 5.

"Colour Photogravure," Cartwright, H. Mills and others, *Photographic Journal*, Vol. LXXVI, 1936, pp. 558–572.

PHOTOMETRIC MEASUREMENT

"A Comparator for Screen and Tone Negatives," Cartwright, H. Mills, *Photographic Journal*, Vol. LVII, 1933, pp. 59–68.

ZINC

"Allotropy of Zinc," Haughton, J. L., *Penrose Annual*, Vol. XXXVIII, 1936, pp. 129–131.

"Sheet Zinc for Photo Engravers," Finkelday, W. H., *Penrose Annual*, Vol. XL, 1938, pp. 132–134.

Negative Making

"A Description of the Ilford Screen Direction Indicator," Tritton, F. J., and Wilson, E. T., *Photographic Journal*, Vol. LXXVIII, 1938, pp. 15–18.

"Testing Half-tone Screens for the Angle Condition," Bull, A. J., *Photographic Journal*, Vol. LXXVIII, 1938, pp. 130–132.

The industry which deals with photo-mechanical processes is very complicated. The student should make himself, as far as possible, acquainted with trade practices, both in technique and in business procedure, prices, methods of ordering, terms, and so forth, matters which are outside the scope of the teaching textbook.

The practice of studying current technical literature should also be followed. He will in this way keep up with the advances made from time to time. Only experience and good judgment will enable him to discriminate between that which is probable and valuable and that which is improbable and misleading. Much valuable information may be obtained by the study of the catalogues issued by the leading supply houses, and these should be studied whenever the opportunity to do so occurs.

INDEX

PHOTOGRAVURE MACHINE PRINTING

By H. Biskeborn

This working manual covers machine-room practices, methods of correction, ink and paper problems, modern photo-gravure printing machines. It is an indispensable guide for the potential pressman and a valuable reference book for the more experienced journeyman printer. The supplementary processes involved in making the printing surface are also described. The book is printed throughout in photogravure. **17s. 6d.** net.

PICTORIAL PRINTING PROCESSES

By Kenneth Ullyett, F.R.Met.S.

An introduction to the modern technique of producing printed pictures, written expressly for students of printing and commercial art and for editorial and advertising staffs. The book is full of information of the greatest service to all concerned with picture reproduction in books, newspapers, and periodicals, and every type of advertising literature. **15s.** net.

PHOTO-ENGRAVING IN RELIEF

By W. J. Smith, F.R.P.S., E. L. Turner, F.R.P.S., and C. D. Hallam

A modern textbook for students, apprentices, and others interested in the technique of photo-engraving. The work of every department of the process engraver's establishment is discussed, with descriptions of the tools, materials, and methods employed. **21s.** net.

PRACTICAL PHOTO-LITHOGRAPHY

By C. Mason Willy

This practical book describes the methods of offset plate-making, and fully explains the necessary working formulae. It is of great value to offset printers and to those contemplating the installation of an offset department. The whole process of plate-making is described. Illustrated. **25s.** net.

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