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BRITISH WAR PRODUCTION

1939-1945

MR. CHURCHILL AT BRADFORD

The photograph shows him being welcomed by workers on one of his many visits to war factories in different parts of the country.

BRITISH WAR PRODUCTION

1939–1945

A RECORD

19073

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THE TIMES

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PREFACE

THIS Record of the productive effort of British Industry during the war is a reprint in book form of "*The Times* Record of British War Production, 1939-1945," published at the end of the war for circulation abroad. It has been compiled from articles contributed by Staff Correspondents of *The Times* or by other writers each of whom had an intimate knowledge of the branch of industry or Government Department concerned.

No account of so vast an achievement can be entirely complete, nor can it deal individually with all the industries which contributed to the final victory; but the survey to be found in the ensuing pages shows how British Industry responded to the demands made upon it in war-time and proves its power to adapt itself to the scarcely less exacting demands of the future.

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FOREWORD

by the Rt. Hon. OLIVER LYTTELTON, D.S.O., M.C., M.P.

MINISTER OF PRODUCTION FROM MARCH, 1942, TO JULY, 1945

VICTORY in the War of 1939-45 was won not only on the battle-field, on the sea and in the air, but in the workshops and factories of the Allied Nations.

In this Record there is collected together, for the first time in one document, a comprehensive summary of the many and varied aspects of Britain's achievement in war production. And a truly remarkable achievement it was.

Of all the munitions used by the Armed Forces of the British Commonwealth and Empire ($8\frac{3}{4}$ million men in all) since the beginning of the war, no less than 70 per cent. was produced in the United Kingdom itself. The rest came from the United States of America, from Canada and from the other nations of the Commonwealth. The First Lord of the Admiralty, the Minister of Supply and the Minister of Aircraft Production can testify with me, who was responsible for the overall coordination of this vast and complex system of supply, that, notwithstanding our own high rate of production, this aid from oversea was indispensable.

In addition to what we produced for our own Forces and those of the Commonwealth and Empire, we made and sent substantial supplies to our other Allies—the United States Forces in Britain, the U.S.S.R., China and others of the United Nations.

All this we had to do under conditions of almost unbelievable difficulty. We were bombed from the air ; against this we had to disperse our production, to black-out our cities, our railways, our roads, our

factories. U-boats sank our ships bringing in our life-blood, food and raw materials. Yet, with our imports of raw materials cut by 50 per cent., we achieved the highest industrial output ever attained in the history of our country.

Such a prodigious effort was made possible only by the great labours and heavy sacrifices of the British people. All men up to age 64 and all women to age 59 were mobilized; food, clothes, petrol were severely rationed; and supplies of other everyday things drastically limited. Our export trade too had to be deliberately curtailed, so that in 1943 and 1944 it was less than one-third in volume of the 1938 level. This meant hardships for our oversea customers but it released over 1,000,000 men and women hitherto engaged in making exports for direct war work.

During all this great outpouring of effort the quality and ingenuity of British production have been more than maintained. We were the pioneers of Radar and Jet Propulsion; it was a British scientist who discovered Penicillin, a British engineer who invented and designed the Bailey Bridge; we designed and built the Mulberry harbours, the prefabricated portable harbours which made the invasion of France possible; British aircraft have proved themselves second to none in the world; and British scientists collaborated with American and Canadian scientists to develop and produce the Atomic Bomb.

The inventiveness and ingenuity of British scientists and engineers, and the high standard of quality in our production, point the way to the future and show that we shall conquer too the problems which peace is bringing.

I. THE STORY OF A GREAT ACHIEVEMENT

IN the early summer of 1940, as the little ships plying between the Kent and Essex harbours and the beaches of Dunkirk strove to save the seeds of eventual victory out of a calamitous defeat, British industry stood confronted by a challenge still more dreadful than that which it had faced in September, 1939. Most of Britain's small and painfully built up stocks of military equipment lay burnt or captured in Belgium; and Britain's people, almost unarmed, isolated by the collapse of her Continental allies, still with an economy which was not really geared for war, threatened with the cutting of her sea life-lines, stood alone against a fully mobilized Germany.

It was a challenge which, under Mr. Churchill's leadership, was accepted regardless of the cost by industry as it was by the people in every walk of the national life. In 1938 only 6 per cent. of the national income was devoted to " defence " expenditure; in 1939 only about 14 per cent.; and in the early summer of 1940 the nation's economy was still only about 20 per cent. mobilized for war. Four years later, when a magnificently equipped force recrossed the Channel, 55 per cent. of a greatly increased national income—increased in large measure by greater numbers of workers and longer hours of work—was applied directly to the war effort. During those four fateful years British industry and the British people, through deprivations voluntary and forced, through compulsion and direction cheerfully and willingly borne, and through unprecedented hours and intensity of toil, became totally harnessed to the service of total war.

This is no abstract form of words. There was no individual of either sex of working age—and few of those beyond normal working age—whose work was not consciously sanctioned or directed as his or her most valuable contribution to the nation at war. Consumption was limited to the level of necessities. And a vast increase in war output, much beyond the most sanguine forecasts, was achieved in circumstances which often involved the most difficult personal conditions—family separations and bereavements, enemy air attacks, the physically and mentally enervating effects of black-outs, fire-watching and fire-fighting, bomb-damaged homes and factories, and incessant shortages of private amenities from beer and tobacco to bicycles and railway seats. It is claimed for the British people, after the most careful examination of the facts in all countries, that it was more fully deprived of its peace-time comforts and more fully mobilized for war than the people of any other country—not excluding Germany.

To those who saw the tired and empty-handed armies returning from Dunkirk and who patrolled the Channel cliffs with nothing but make-shift firearms and a few minutes' ammunition in their hands, watching for the expected invasion in 1940, and who four years later watched the Liberation Army sail down the Solent for the beaches of Normandy, armed with everything that human ingenuity could provide and with vast reserves of equipment and of war factories behind them, the change was a saga almost too great to be credible. All this had been prepared while great victories had been won in Alamein and Tunis, in Italy and Abyssinia, in Burma and the Eastern seas, in the Atlantic, and in the skies over Britain and Germany. And those who gratefully watched the American forces sailing to the same beaches from Plymouth or Weymouth were perhaps further

encouraged, as they reflected on those four years, by the thought that at any rate Britain had failed nobody, and that these allies of the same blood, whom England had greeted with relief, watched with interest and curiosity in the streets of English towns and villages, and finally taken to her heart, were at least helping those who had helped themselves. There were not many who at that time had any very coherent idea of all that had been done in Government office and staff headquarters, in workshop and drawing office, in the business board room, and in the burning streets of London, to make that transformation possible. And it is the purpose of this record to tell the story in enough connected detail for its pattern to be understood.

Since European history began, Britain, faced by the substantial populations and conscript land armies of the Continent, has found her greatest strategical problem in man-power. And it is not surprising that throughout the war years man-power was the dominating shortage which conditioned the programme. There were times when shipping seemed perilously light and when even the exhaustion of certain materials was forecast; but in the end the human "bottleneck" was the only one which really determined the limits of output. There was never anything which was urgently wanted but which remained unmade so long as there was a man or woman to make it. The transference of man-power to war work from peaceful industry, from the home, from the office, and from idleness, was thus at once the corner-stone and perhaps the most striking illustration of the whole process of conversion to war.

In the first place there was a huge transference from the home and from both involuntary and voluntary unemployment to industrial and war work of some kind. The total number of men aged 14-64 and of women aged 14-59 either in the services or in industrial employment increased from 18,500,000 in mid-1939 to 22,000,000 in mid-1944 (counting two part-time workers as the equivalent of one full-time). Not only was the number of hands working largely increased, however, but the time worked by each individual was greatly lengthened also. For example, the average hours of work for men in the munitions industries rose from 48 hours a week immediately before the war to 54 hours in early 1944—a far cry from the 40-hour week which was a widely recognized social objective in peace-time.

In all, therefore, we may reckon that there was an increase of about one-third in the total man-hours (including woman-hours) worked in the services and industry—that is without attempting the impossible task of evaluating the increase in the intensity of the work of those in the services themselves. Within this global total, there was a huge shift from peaceful to warlike production and from civilian life to the services.

To illustrate this we may make use of the official division of industries into three groups—Group 1 comprising the engineering and allied (munitions) industries, Group 2 comprising the basic essentials, such as public utilities, transport, shipping, and food, and Group 3 comprising the civilian industries proper, that is to say, building, textiles, clothing, distribution, professional services, &c. The number of men and women employed in the forces, whole-time Civil Defence, and the Women's Auxiliary Services rose from 550,000 in 1939 to 5,250,000 in 1944. The number employed in Group 1 industries rose from 3,100,000 in 1939 to 5,200,000 in 1944; the total in Group 2 remained about the same; while the total in Group 3, primarily civilian industries, fell from 9,300,000 to 6,000,000. It should be added that a vast amount of the output of those remaining in Group 3 industries was in fact going to the various services. As an illustrative footnote, it may be added that in the middle of 1944 no less than 76 per cent. of those engaged in manufacturing industry were employed on Government work, and that 57 per cent. of men between 18 and 40 had been or were serving in the armed forces. The total number of those employed directly on munitions work rose from 1,150,000 in 1939 to 4,300,000 in 1944.

Most of Britain's national leaders have at one time or another paid tribute to the great contribution of women to the war effort. And it is certain that the mobilization of women went much farther in Britain than in any other country. The number of women working in the home fell by over 20 per cent. between 1939 and 1944, and of those remaining over 10 per cent. were doing part-time industrial work. The number of women in the services and in direct munitions industries alone increased from 500,000 to 2,460,000, and in the Group 2 industries from 850,000 to 1,600,000. Of women aged between 18 and 40, 90 per cent. of the unmarried and 80 per cent. of the childless married were in industry or the services.

Those were the over-all results. But naturally they were not reached by any smooth route. The changing phases of the war necessitated very large movements of men and women from one industry to another and between industry

and the services. The earlier stages of the build-up in 1941 and 1942—stretching into 1943 in some cases—saw the big accumulation of reserves of ammunition and standard army equipment. Labour was attracted and directed in large quantities into production of guns, shells, grenades, machine-guns, and mortars ; building workers in the early stages were busy in the erection of new shell-filling factories and the like. By 1943 these reserves were becoming sufficient. And the year 1943 and early 1944, with the great offensive in prospect and strategic bombing increasing all the while, saw a big movement into the heavy bomber factories, into the making of light naval craft, bridging, and communications stores, not forgetting " Mulberry " and " Pluto," while building activity transferred itself largely to airfields for the huge and growing American and British bomber forces and to camps for the large and growing United States forces in the United Kingdom. In smaller ways there were constant changes in emphasis throughout the years of expansion. And it must not be forgotten that as a result of these changes the task of training " green " labour, though not on so vast a scale later as it had been in the earlier stages, remained formidable right up to the end of the preparations for D Day.

It need hardly be said that a transference of man-power to war purposes on this gigantic scale involved an immense reduction in the amount of goods for civilian consumption and could not have taken place without a drastic

The stepping-up of British industry to meet the needs of total war resulted in output which exceeded the most sanguine forecasts. This photograph was taken in one of the many British aircraft factories and shows Typhoons being assembled.

curtailment—by rationing, high taxation, and other means—of the civilian's entitlement to consume. Again, it is doubtful whether any other belligerent reduced her ordinary consumption quite to the same extent. All luxuries disappeared; cars and motor-cycles, radio sets, refrigerators, silk stockings, rubber boots, table silver, vacuum cleaners, furs, pianos, tennis balls and golf clubs, watches, even armchairs and carpets—all these things were simply not to be had and were not made. But even the ordinary equipment of life was heavily curtailed. By how much, the following figures for civilian consumption in 1935 and 1943 respectively show in cold facts, though they may not fully demonstrate the human discomfort which they entailed :—

CIVILIAN CONSUMPTION

—	1935	1943
	(millions)	
Boots and shoes (pairs)	161	90
Stockings and socks (pairs)	390	240
Armchairs and settees	2.7	0.1
Woollen blankets	6.5	2.2
Brushes and brooms	60	25
Carpets and rugs (sq. yds.)	34	1.5
	(thousands)	
Cars	280	Nil
Bicycles	1,600	540
Wireless sets	1,900	50
Gramophone records	20,000	11,000
	(millions)	
Trunks and cases	8.5.	1.0
Fountain pens	9	2
Ladies' handbags	10	1

Food itself suffered along with the rest. All luxury foods went out of circulation. Chocolates and sweets were severely rationed, and ice-cream ceased to exist for several years; fruit was occasional (it is six years since the writer of this article saw a banana). But rationing saw to it that many of the more ordinary foods were eaten only in a strictly necessary and austere measure. The following figures show that there was no war-time belt-stretching in the United Kingdom :—

CIVILIAN CONSUMPTION PER HEAD PER WEEK

—	1934-38 average	1943
Butter (oz.)	7.63	2.34
Fresh eggs	3.26	1.45
Fresh meat (oz.)	30.4	22.18
Bacon and ham (oz.)	8.4	5.78
Fresh fish (oz.)	6.52	4.56
Sugar (oz.)	30.58	20.00
Fresh fruit (oz.)	27.17	12.06

There were some slight changes in 1944 and 1945, but in general the comparison with pre-war days remains the same.

The cut-back in consumption is hard to measure overall, but some guide to the consumption of miscellaneous articles is the official calculation that personal expenditure on miscellaneous goods other than food, clothing, fuel and light, furniture and domestic equipment, and cars and bicycles dropped to half the pre-war level at pre-war prices. In fact, John Bull has ended the war with his clothes very few and very threadbare; his house (if bombs have left him with one) is unpainted, with dirty and torn wallpaper and worn out carpets and chair-covers, and his cupboard is remarkably empty of crockery, glass, linen, furniture, and stores. Mrs. Bull (despite use of Mr. Bull's clothes coupons) is in not much better plight; and, unable to emulate Mr. Bull's "austerity" habit of wearing socks half the usual length, has taken to going without stockings even in January; six-year-old Master Bull has ¾lb. of sweets and two eggs a month, no metal toys (and few toys, anyway), and may have had to do without a pram in his babyhood; but he can still look forward to eating the first banana (perhaps, if he's lucky, with the first cream) of his life. The older members of the family would be prepared to assert that, if they have been able to buy half of what they did in peace-time, they haven't been doing too badly. Above all it must be remembered that these deprivations, tolerable enough if continued only for a year or two, have gone on for six long years. In the five years to mid-1944 the population had only three years' normal supply of clothing and two years' supply of household goods.

But a population cannot stint itself beyond a certain point if it is to keep body and soul together and if it is to go on fighting a war and producing goods at all. Imports were cut as far as they could be—they were cut from 55,000,000 tons per annum before the war to as little as 23,000,000 tons in 1942. Food and animal feeding meals were cut to half the pre-war level—a cut of over 10,000,000 tons. Iron ore was cut, through use of home sources, by over 3,000,000 tons; timber and wood-pulp by over 9,000,000 tons. But there is a limit. Weapons, before the heaven-sent relief of lend-lease came, had to be bought from the United States; wars cannot be fought without machine tools, oil, aluminium, copper, rubber, and wool; Britain wanted more steel than she could produce herself. So imports had to continue and had to be paid for. But exports, from a country which was equipping her fighting forces

almost from scratch, could not be maintained. So the nation had to live partly on its fat. Old oversea assets were sold and new oversea debts were contracted to the tune of some £4,000,000,000. Bombed houses went unreplaced and even unrepaired; industrial equipment was not renewed or fully repaired unless essential for war; private domestic equipment wore itself out without replacement, and the normal dilapidation of buildings just accumulated. This was the price of victory, willingly accepted. It can be repaid and repaired by the work of peace, where the price of defeat could never have been redeemed. But it is no light matter.

It is time to record what industry did with the millions of eager hands which by these various methods were put at the disposal of the war effort. The bare figures for the increases in output of various war weapons and materials are in a sense too astronomical to convey very much. But a few figures for some of the biggest items may be desirable just to give a general picture. Here we compare the annual rate of production during the last quarter of 1939 (the "phoney war" period) with the peak rate subsequently reached:—

—	Production per annum	
	Last Qtr. 1939	War Peak
Machine-guns	29,200	104,800
Sub-machine guns	Nil	1,572,000
Tanks	1,200	8,600
Tanks (weight in tons)	8,844	208,140
Carriers and armoured cars	2,500	24,400
Shells (millions)	7.8	59.4
Small-arms ammunition (millions)	45	3,046
Army wireless stations (thousands)	12	193
Major war vessels (tons)	89,000	346,000
Mosquito and other naval craft (tons)	11,300	235,000
Naval guns	1,760	20,970
Aircraft, all kinds (structure weight in millions of lbs.)	45	223
Bombs (thousand tons)	18	458
Aero engines	18,100	63,300
Aero engines repaired	—*	45,400

* Negligible.

Those peaks were not, however, reached simultaneously; nor was there at any time any question of a single set programme expanding steadily on a broad front.

In fact, priority needs were constantly altering and programmes were altering with them. The changing phases of the war, the transformation of the supply problem by lend-lease and later by the entry of the United States into the war, the switch from one campaign to another, an unexpected quick ending to some major operation, a change in the enemy's strategy or in his weapons—all were necessarily reflected in changed plans and production programmes. And with that went some fresh migration of labour, more re-training, more new production equipment, changes of lay-out, and the rest. Thus we find that in 1941 and 1942 certain aims were predominant: the building up of reserves of army equipment for the eventual great battles and the building up of the navy and mercantile marine in face of the U-boat campaign were major aims; so was the equipment of A.A. defences in face of the *Luftwaffe* onslaught and the expansion of the heavy bomber force (which for several years was a major call on production). Production of field and anti-aircraft guns, of shells and small-arms ammunition, all reached a peak in 1942; so did that of mosquito craft, until warship output actually reached an interim peak in 1941. Thereafter, with good reserves accumulated, production could safely be diminished somewhat in order to provide elbow-room for increased supplies of other more urgently needed materials; and, for example, the rate of shell production in the first half of 1944 was only about 37 per cent. of the 1942 figure, that of sub-machine guns only about 60 per cent., that of heavy A.A. equipments only one-third, and that of anti-tank mines about one-half.

The elbow-room thus provided was filled in 1943 and early 1944 in part by the production of equipment specifically intended for the D Day operation and in part by that of bombers and other aircraft required for replacement and in a lesser degree for further expansion as a result of the mounting scale of the air offensive on the Continent. Thus the rate of output of miscellaneous vessels, including landing craft, was doubled in 1943 and increased again in the first half of 1944; output of Bailey bridges was increased threefold, and a weight of effort impossible to measure in precise terms went into "Mulberry" (the synthetic Normandy harbours), "Pluto" (the cross-channel pipeline), and other specialities; heavy bomber production was tripled in comparison with 1942, and bomb output approximately doubled. Indeed, it is also worth noticing that in pursuit of the grand plan the total number of those engaged in all

industry reached a peak before D Day, so that the maximum number could play their part actually in the armed services when the great moment came.

Here, perhaps, is the place to consider some of the expedients by which these huge expansions and wide changes in the production programmes were achieved. The quantity of production reached has been indicated; and the technical achievements of British industry are reasonably well known—"Mulberry" and "Pluto," the Lancaster and the Spitfire, Radar and the 25-pounder speak well enough for themselves. What is perhaps not so well known is the organizational obstacles which were surmounted and the feats of opportunist administration which were achieved. These things were implicit in the necessity, which Britain could not avoid, for making the best of what she had.

In 1940 and 1941 time was too pressing and resources too small to wait to build great new war plants. It had to be done so far as possible with what existed already. And done it was. The private car manufacturers stripped their assembly lines, dumped their special tools in the yard, ripped out the spraying booths, put all the unwanted machines anywhere they could, and so contrived it that within a remarkably short space of time Spitfires were going out of the factory through the same door which a few months previously had seen a procession of family saloons. Chairs gave way to aircraft fuselages, refrigerators to armoured carriers, knitting machinery to machine-guns, and printing presses to gun mountings and control gear. And it was for the most part all done with the same factory floor space, the same staff and labour, and a large proportion of the same equipment and tools as had served for civilian goods before. It was in the fullest sense a "conversion" of industry.

Britain had no breathing space in which to launch out into the "Willow Run" type of undertaking. Such reserve capacity as she had available had necessarily to be used for essential extension of facilities which civil factories could not provide, and for the new building involved by "dispersion"—the scattering of vital works which was made necessary by the heavy German air attacks of 1940 and 1941. A good many new shell-filling factories were built and also a large number of small works for the manufacture of aircraft components and for aircraft assembly; a number of small dispersed alloy steel works were built owing to the danger implicit in the great concentration of the existing industry at Sheffield. But in the main, conversion of existing works and facilities was the order of the day.

The necessity for conversion of existing works and organizations, and for dispersal of works and sometimes of administrative organizations too, added not a little, as may be imagined, to the complications of planning and executing the required war output. In view of the intensity of air attacks it became a matter of policy not to concentrate the production of any war product or component thereof or key material at one place. In every case the orders were distributed between a number of different works. The result was that any single factory—more particularly any single engineering factory—was at all times working on a considerable range of different components or assemblies. Some engineering works had indeed thousands of different components on the production lines simultaneously. Another complication was the development (resulting from the necessity for bringing all workshops, however small, into the orbit of war production) of the system of using thousands of very small firms as sub-contractors to the larger firms which were the direct contractors to the service departments. The circle of firms working for the service departments, including the sub-contractors, became enormous. Even the smallest works, including the vast number of peace-time garages, were pressed into service, and it was quite usual to find the village garage working on the production of small aircraft parts or service truck repairs with the official notices of the Essential Work Order decorating its walls. Even some of the women's groups and societies in the villages, which had never previously met for anything sterner than knitting, found themselves transformed into miniature engineering workshops. And many was the volunteer spare-time work party composed of people of both sexes, of ages ranging from 8 to 80, which assembled engineering components in the local mill or blacksmith's shop.

Another difficulty which had to be overcome was the production of a much larger weight of goods with a far smaller volume of imported materials. The weight of imports was cut down—and had to be cut down—to only 40 per cent. of the pre-war figure. A substantial part of this economy was obtained by savings in food and civil consumption goods. But much of it had to be obtained through generally curtailed use of certain materials which could not be imported in sufficient quantity, much the most important of which was timber, and by increased pro-

duction of raw materials at home. The biggest development of home production was in iron ore and the light metals and timber. Production of iron ore rose from a pre-war average of 12,400,000 tons to a war peak of 19,500,000 tons; of timber from 450,000 tons to 3,800,000 tons; of aluminium from 18,000 to 56,000 tons ; and magnesium from 2,000 to 23,000 tons. In the case of timber this did not anything like compensate for the cut in imports. And there was a number of materials which frequently promised to run perilously short, although the worst fears were never actually realized. There was at all times none the less great pressure for economy in and recovery of all scarce materials. Designs of products and production equipment, including

The Queen accompanied the King on many of his tours of war-production factories. Their Majesties are seen acknowledging the cheers of workers when arriving to inspect an aero-engine factory in the Midlands.

tools, had always to take account of the need for economizing in scarce materials to the utmost. Salvage drives both in industrial works and among the general public were pushed to great lengths with some spectacular results. And the recovery of materials from scrap was also carried out on a scale which could hardly have been imagined by peace-time standards.

How, finally, does British industry stand at the end of it all? There has for years been so little time for anybody to take his eyes off the immediate job in hand, so little opportunity or inducement to think ahead beyond the defeat of Germany and Japan, that very little thought has until recently been given to the future outlook. Now industrialists are beginning to get their breath back, and more thought is therefore being given to the post-war prospect.

In fact, Britain is now taking stock, and the accumulated credits and debits of the war are beginning to be assessed. Most people, however, are quickly coming to feel that it is beyond the wit of man to strike any real balance. It is admitted that there are plenty of debits. We end the war a net debtor for nearly £3,000,000,000 to the world oversea, where we began it as a net creditor for a like or even larger amount; much industrial machinery has been overworked for several years with inadequate repairs and almost no replacements; research and experience in the field of civilian products and methods of producing them have to a large extent been in a state of suspense; the housing situation as a result of bomb destruction, unrepaired dilapidations, and absence of new building, is calamitous; stocks of goods in the hands of both consumers, producers, and distributors are at a very low level, and the private stock of furniture and domestic equipment is almost on a par with the housing situation; skilled labour has been absent for years from many of the higher-quality processes (woodworking, high-finish metal painting, as used, for example, for motor-coach work, and fancy weaving are examples which spring to mind), and the amount of skilled labour employed in most civilian lines has been small for a long time past. Last, but far from least, the sacrifice of export trade and thus of important oversea connexions and goodwill represents an intangible but possibly a major setback.

However, other countries, albeit for the most part in a lesser degree, suffer from most or many of these troubles. And there are some substantial credits to be put to the other side. There is probably a greater total skilled labour force in existence than ever before, and in this we must include the large and varied technical experience gained by large numbers of men in the forces; there has been great expansion and progress in mechanical and electrical engineering; the pressure of war needs has led to numerous and far-reaching scientific discoveries, especially in the fields of radio (particularly radar and all the very high frequency work related thereto), explosives and chemicals generally, fertilizers, medicine, and marine and aeronautical engineering; there are a number of excellent new factories laid down for munitions purposes to set against the general depreciation of industrial machinery; and the country as a whole has become attuned to smaller consumption and harder living, which may stand it in good stead in the transition period.

In all, Britain is well aware that it finishes the war a great deal poorer than it started it—poorer in its financial position *vis-à-vis* foreign countries, poorer in its stocks of goods in its houses, in its industrial equipment and in many other things. But none the less the balance between the debits and credits is difficult to assess and the average Briton does not really try to assess it. What the industrialist is most aware of is a sense of achievement, and he believes that in the course of this war achievement he has learned something of permanent value that he will not forget. The great efforts which have been made and the long hours worked in difficult tasks of organization and administration, in research, and in coping with ever-changing needs and an ever-changing background, have constituted a liberal education. And he is confident that with this experience behind him he can tackle anything which may arise in the future.

With the problems of the future as uncertain as they are, perhaps this acquired experience is the greatest asset. Certainly British industry faces a colossal task in reconverting itself to peace-time requirements. But it is confident of its ability to surmount these difficulties. It is even uncertain what the commercial needs of the post-war world will be; but industry, after its experience of coping with the unpredictable needs of war, has good reason to believe that it is sufficiently adaptable and versatile to cope with anything. Nobody knows precisely who or what countries during the next few years will be large buyers of goods, or just what goods will be wanted by those who are; but whatever goods are in demand and wherever they are wanted, British industry is certain that—given time—it will be able to deliver them.

II. ORGANIZING THE WAR EFFORT

1

THE GOVERNMENT MACHINERY

THE Government machinery of war production could be neither logical nor symmetrical, for the simple reason that it was never conceived in a single piece. The economic policies it pursued were sometimes drastic to the point of being revolutionary, but its administrative structure had grown piecemeal with the least possible disturbance to pre-existing organizations and to the established methods. It is profitless to speculate on what might have been done had the organization been different; the material fact is that the organization brought forth a harvest of shells, guns, aeroplanes, and other war stores, such as few had ever thought possible before the war came upon us.

In the first place the British Government never succeeded, perhaps never desired, to establish a single supply organization. Just as the three services preserved their independent organizations throughout the rearmament and the war, so were also the supply of weapons for the three arms separately and differently organized. The Ministry of Supply took charge of the weapons and stores for the Army; since May, 1940, the Ministry of Aircraft Production did the same for the R.A.F., and throughout the rearmament and the war the provision of ships and naval stores remained the responsibility of the two Controllers in the Admiralty; the one of the Navy and the other of merchant shipbuilding. When public opinion in the country and in Parliament pressed Mr. Chamberlain's Government to establish a Ministry of Supply, what they probably had in mind was a single department even more comprehensive than the Ministry of Munitions had been in the last war, and this may also have been the original intention of the Government itself. But it was not thought expedient to take away from the Admiralty the direct control of the design and production of naval vessels, and for the same reason the design and production of aeroplanes were left to the Air Ministry to pass later into the hands of a specialized production ministry.

Needless to say, this distribution of functions was not as simple or as rigid as the lines of demarcation between the services might suggest. In practice the Ministry of Supply from its very beginning acquired the control of certain common factors. In addition, each of the three departments had to take charge of military stores outside the narrow field of the service for which it catered. Thus the Ministry of Supply filled shells and ammunition for the Navy and the R.A.F., and the Ministry of Aircraft Production for a time managed the production of radio valves for all the three services. In the course of time the departments, and especially the Ministry of Supply found themselves controlling the production of common stores serving civilian needs as well, such as steel helmets, ropes, or drugs. But, allowing for these overlaps and mutual services, the functions of the three supply departments were clearly specialized.

Specialized, but not isolated. On the contrary, the very reason why the three supply departments were able to maintain throughout

the war their separate existence was that common factors of production were always administered by single agencies and *en bloc* ; and that a special inter - departmental and super - departmental machinery grew up to deal with common policies and over-riding priorities.

In the first place there was labour, which not only was a common factor of production but, as time went on, became the final limiting factor of the entire British war effort. As everybody knows, a single department—the Ministry of Labour—looked after the supply of industrial labour, and to some extent supervised its utilization. The same is also true of the raw materials and the machine tools. A single department—the Raw Materials Division of the Ministry of Supply—controlled the procurement, production, importation, and distribution of all the critical raw materials, which in the end came to mean most raw materials. In the same way machine tools, their production, distribution, and imports, were supervised by the Machine Tool Control of the Ministry of Supply (later by the Machine Tool Division of the Ministry of Production working through the Machine Tool Department of the Ministry of Supply). In fact, the Ministry of Supply, though restricted in the field of weapon production to the needs of the Army, became in other fields something in the nature of a Ministry of common factors.

The unity of war production did not end with a centralized administration of labour, materials, and tools. What needed centralizing was not only administration, but also policy. Above all, the conflicting claims of the supply departments had to be regularly, almost daily, settled in the light of the general strategy of the war and of the economic policy of the Cabinet. This function could not be performed by the Raw Materials Division of the Ministry of Supply or by the Ministry of Labour in the course of their normal departmental duties. When it was not done by the Prime Minister or by the War Cabinet acting on their own initiative, it had to be done by various inter-departmental bodies. In practice, as well as in theory, the supreme coordinating agency was the Minister of Defence and the Defence Committee of the Cabinet, whose business it was to define the tasks of the Production Ministries in relation to the broad lines of war strategy. On the lower, day-to-day plane the programmes and needs of individual supply departments were sorted out by various coordinating committees, which before 1941 rose and fell with the circumstances which prompted them.

By the turn of 1941 and 1942 most of this work of coordination was absorbed by the newly established Ministry of Production, and in the course of the subsequent three years the Ministry, by a process of organic accretion, acquired a number of other coordinating functions. Thus it coordinated our negotiations with the United States over supplies and exercised a general control over the various oversea supply centres. It provided itself with a Planning Department capable of translating the general strategic directives of the Minister of Defence and of the Chiefs of Staff into economic and industrial terms. It also took over the machine tool policy and brought together the various regional organizations. Even in the field of labour it won for itself a footing, albeit a modest one. Yet, however much did its functions grow, they could not raise it into the position of a true supply department. It never administered the actual production and distribution of either raw materials or machine tools. It never placed orders for weapons, and except for its regional organization it was not in direct contact with industry.

The production of weapons remained the task of the separate supply departments. It was they who turned the general armament programmes into detailed plans of procurement; it was they who found, and often created, the necessary productive capacity. And, in so far as production had to be progressed—*i.e.*, assisted over bottlenecks and fed with an uninterrupted supply of components—that work was also done by the separate departments. Moreover, each department organized production in its field by methods peculiar to itself, for the planning of output and its relations with industry differed from Ministry to Ministry, and sometimes even from weapon to weapon.

The policy of the Ministry of Supply, like that of the Director-General of Munitions Production in the War Office, who preceded it, was eclectic by tradition as well as by necessity. It had always been the policy of the War Office to divide its orders between private industry and Government factories. From the very outset of the rearmament the War Office tried to bring in the widest possible range of firms normally engaged in civilian production, most of them firms in the engineering and chemical industries.

To a country which has just emerged from a total economic mobilization, this procedure may appear obvious. It was not obvious in 1936, when the alternative plan of working entirely through the few existing armament firms clearly presented itself. Some stores, however, were so far removed from the peace-time products of British industry and offered so few prospects of peace-time employment that they were, from the very beginning, entrusted to Royal Ordnance factories. Thus the filling of ammunition was planned as an " R.O.F. job," and so was, to a large extent, the making of small arms ammunition and of explosives.

In the field of engineering products, or weapons in the narrower sense of the word, Royal Ordnance factories were called upon to undertake experimental jobs, to start production while engineering firms were getting into their stride, and, generally speaking, to fill gaps where these could not be filled by private contractors. In this way the Ministry of Supply, to borrow a scientific term, " polarized " its relations with industry. On the one hand it dealt with Government factories which it could control more or less at will; on the other hand it dealt with a vast body of private contractors, whom it at times financed, advised, and even nursed, but with whose management and methods it could not much concern itself.

In the Air Ministry, and later in the Ministry of Aircraft Production, a different and, in a certain sense, an intermediate system prevailed. Since the closing of the Royal Aircraft Factory in 1924 there were no Government aircraft factories in peace-time, and the Air Ministry had no intention of embarking upon them when rearmament began. The policy was to keep in being a group of specialized private firms whose relations with the Air Ministry would be sufficiently intimate to enable it to guide and control design and production of aeroplanes. Hence the so-called " family " of aircraft firms—about 16 in all—which took shape in the early twenties and thirties and through which the Air Ministry carried out most of its rearmament plans. Needless to say, a vast number of firms not previously engaged in aircraft production had to be drawn on as programmes grew, and in the end the various branches of aircraft production came to absorb very nearly a third of Britain's industrial resources. Yet, even at its peak, the output of airframes and engines was very largely canalized through the principal " family " firms, whose ranks had by now been swollen by about half a dozen firms previously engaged in the motor-car and electrical industries.

As a result of the " family " system production was almost entirely in the hands of private contractors. But the corollary of the system was that the privacy of the contractors was not as complete as it might appear on the surface. The bulk of the capital with which they operated, perhaps as much as three-quarters, was supplied by the State. The " shadow factories," which played an important part in the pre-war plans of war potential, were built entirely at Government expense. Countless other additions to the aircraft industry, and often entire factories, were financed by various Government schemes of " capital assistance." Nor were firms otherwise left to their own resources. Their supply of labour and the manner in which they utilized it were closely watched; their troubles, their bottlenecks, their difficulties with sub-contractors and workpeople, seldom escaped the notice of the Ministry; and now and again the Ministry stepped in to force a reorganization of management or an improvement of methods, or even a change of ownership.

Somewhat different again was the system at the Admiralty. Traditionally the policy of the Admiralty, like that of the War Office, was to divide its contracts between Government yards and private shipbuilders. However, the volume of naval construction during the war and the limited capacity of the dockyards meant that nearly all orders for new construction went to private builders. On the other hand, naval construction was so specialized that direct contracts could not be broadcast over the entire field of shipbuilding. The firms engaged on that work stood in somewhat the same relation to the Admiralty as the " family " firms did to the Air Ministry, and it was with those firms that the bulk of the naval orders were placed. The net was, however, cast much wider in the later stages of the war when the accent shifted to smaller craft, and especially to escort vessels and landing craft, for which a much wider range of contractors could be employed.

These distinctions, however, may appear clearer on paper than they turned out to be in life. They mostly affected the relations between the Government and the main contractors. But the extent to which the Government actually involved themselves in production also depended on sub-contracting. From the very beginning of

rearmament it was clear that the industrial capacity of the country could not be absorbed into war production without a very extensive system of sub-contracting or, to quote a contemporary phrase, without "bringing work to the labour." To begin with, the firms were encouraged to make their own arrangements and to place sub-contracts with whom they wished. But as time went on, free and unregulated sub-contracts were bound to raise difficulties. They sometimes impeded the proper distribution of work among the thousands of small firms in different parts of the country, and they often resulted in a great deal of cross-country traffic. One way of reducing separate sub-contracting by individual firms was the "free issue" or the "embodiment loan," or, in other words, the taking over by the departments of the ordering and the distribution of principal components or of crucial materials. In some fields, especially in aircraft production, this was happening anyhow. In their attempts to break through or to anticipate bottlenecks, the Ministry of Aircraft Production found themselves ordering the more difficult components and issuing them to the firms. The general tendency was for the "embodiment loans" or "free issues" to grow, even though there was no question of doing away with the entire network of private sub-contracts. Firms like Vickers or Rolls-Royce could prevail upon the Government not to interfere with the complicated, but on the whole efficient, system of sub-contracts which they had themselves organized on the basis of their peace-time trade connexions.

Relations between contractors and the Government, and, still more, the relations between contractor and contractor were also influenced by the so-called "groups." Several firms engaged in the production of the same weapon were often banded together into a cooperative group for the exchange of information and drawings, for mutual assistance, and sometimes also for specialized division of production. The pioneers of the "group" system were probably the Air Ministry, and in the production of the heavy bombers the "group" system was to become universal. But the same system had also

The meeting at the Ministry of Labour on October 18, 1939, between representatives of the British Employers' Confederation (on the right) and of the T.U.C. General Council (left). There was agreement on the appointment of a joint advisory committee to advise the Government on matters affecting labour during war-time.

been in operation in the field of Army equipment long before the war broke out, and some of the most important weapons made during the war—the 2-pounder, the 6-pounder, the 25-pounder, the Bren carriers, and most of the tanks—were produced by "groups." Where those groups operated some of the lines of demarcation between the Royal Ordnance Factories and private firms were apt to grow faint. For in most "groups" both Royal Ordnance Factories and private firms cooperated, even though it often fell to the Royal Ordnance Factories to act as leaders.

Many of these problems—the search for new capacity, the placing of sub-contracts, the cooperation between firms, and the cutting out of waste in cross-country transport—could, of course, best be settled locally, and the success of the settlement very largely depended on the Government's regional organization. Before the war the only local organization concerned with industrial matters was that of the Ministry of Labour, and its functions grew in scope and importance during the war. But with the outbreak of the war the Ministry of Supply established all over the country its Area Boards, the Ministry of Aircraft Production developed its regional organization, and the Admiralty did the same in the shipbuilding areas.

The next most obvious step was to coordinate the activities of local agents of the production departments, and the need became greater as the country was approaching the point at which its resources were fully employed. This was also the period when the Ministry of Production was coming into existence, and one of the main tasks of the new department, as expounded by Mr. Lyttelton in his first appearance in Parliament as Minister of Production, was to harness the local capacity still available by means of an efficient regional organization. It will be out of place here to deal with all the difficulties which were in fact encountered in endeavours to reconcile an efficient local inter-departmental machinery with the effective departmental control over its local representatives. All that need be said here is that the regional organization, by a process of piecemeal development, succeeded in establishing a pooled record of local capacity and greatly helped in steering the new orders into the right channels. It was also called upon to play an important part in the changes of programmes, in the switches of orders and of labour which became frequent after 1942, and in preparing the road to reconversion. This, however, is part of another story.

2

COORDINATION WITH OUR ALLIES

THE combination of the British and American war economies has been less publicized than the combination of their services, but the record of its development is no less spectacular. There were four phases :—

First, cash and carry, from November, 1939, to the end of 1940.

Second, American aid to Britain, from the Lend-Lease Act to Pearl Harbour.

Third, the period of combining, from the end of 1941 to about the middle of 1943.

Last, the period of combined peak effort, when the wheels ran smoothly and the two countries were working together at any rate as easily as, say, the Ministry of Munitions and the Admiralty in the first world war.

Each of the four phases was dominated by its own kind of shortage and bottleneck, and the course of development is shown most simply in this way.

At the beginning the bottleneck was dollars. Gold and securities could be used only once; we were planning a three-year war; the Johnson Act debarred us from borrowing; the arms embargo had been repealed in November, 1939, only after hot debate, and 1940 was an election year. So at the start the dollars were husbanded carefully; the United States was treated primarily as a source of materials and machine tools, and the orders for munitions and aircraft were mainly designed as insurance against loss of United Kingdom production. But careful husbandry had to be thrown overboard after the German break-through in the west. The tiny stocks of the United States Army were combed to find rifles and artillery and ammunition to defend the beaches; in the dying moments of the French Government we took over the French contracts in the United States; the 50 over-age destroyers were exchanged for Caribbean bases; the rate of new contracting was speeded up; the first M3 tanks were ordered—the forerunners of the Shermans; the first Kaiser shipyard was begun; dollars were spent desperately to tap every source of American munitions capacity.

By the end of the year our dollar reserves were exhausted. We had spent or committed some \$3 billions. There was plenty to show for it in potential production. Including the French con-

tracts, we had ordered over 10,000 aircraft even by the end of June, 1940, compared with United States Army and Navy orders at the time of only 4,500. We had done invaluable preparatory work in building up the American aircraft, shipbuilding, tank, explosive, and machine tool industries. But our orders at that time only scratched the surface of our prospective needs for 1941 and 1942.

At this crucial stage, when major new contracting had virtually come to a standstill, the President announced Lend-Lease. After two months' debate, in which contracting was still suspended, the Act was passed and $7 billions were voted. The dollar bottleneck was broken. But it emerged again almost at once in a new form. The problem was one of fitting our requirements and those of other claimants into the appropriation. The backlog of requirements rapidly exhausted the money; by October another $6 billion appropriation was needed, and once more the requirements had to be tailored to fit. Appropriation dollars were now a serious bottleneck.

In those twilight months of 1941, however, the basic problem of combination began to appear. Britain was no longer a buyer from the store, placing contracts where she thought fit; she submitted requirements to the United States departments, and these were merged in the United States production programme as a whole. Bottlenecks began to appear in the production structure; there were shortages of raw material, and priority decisions were needed; the vast administrative apparatus of total war production began to shape itself, with awful growing pains. Conflict appeared between the relative needs of Britain, Russia, and the United States forces. In November, 1940, the President had given a rule-of-thumb decision that the United States aircraft output should be shared equally between Britain and the United States. But such a formula could not stand, and as America approached war the claims of the United States Army and Navy for the United States output became increasingly pressing. What was the right balance between the British needs of the battlefront and the training and equipment of the United States Army?

It was in this period that serious cooperation began to replace the emergency goodwill of 1940. War production statistics were exchanged—a vital step. Combined analysis was made of the scale of production needed to beat the Axis. It was impossible to secure full agreement on uniformity of types of weapons in the two armies; the calibres of the basic artillery and small arms remained different to the end. But technical interchange and standardization were developing. The cooperation was informal, and depended much upon the personal relationships between the responsible men in Washington. But in summer and autumn, 1941, the foundations of combination were laid. Up to the end of 1941 Britain received little from the American arsenal, and hardly any munitions had yet come forward on lend-lease contracts. Indeed, from March to December, five-sixths of the United States war production was retained by the United States forces. In that year of munitions drought the trickle of United States supplies to Britain was vital. But the bulk of American aid was still in raw materials, food, and machine tools.

Pearl Harbour opened the third phase—the period of combining. The establishment of the Combined Chiefs of Staff clearly implied the assignment of munitions according to operational need, so the Combined Munitions Assignment Board was set up—a board in Washington to allocate United States-produced munitions, and a board in London to allocate munitions produced in the British Empire. It may be added at this point that by this time Canadian production, developed with great energy from the start of the war especially in guns, ammunition, explosives, and wheeled vehicles, was becoming very large; it was planned, however, directly to the needs of the Ministry of Supply, and consisting almost exclusively of British types rarely required to be assigned in more than a formal sense. Special allocation machinery was also set up to deal with the outputs of Australia and India, which in certain lines were very considerable. The job of the Munitions Assignment Board was to allocate according to strategic need; this led it into comparative analysis of service requirements which resulted in considerable economies.

Physical bottlenecks now superseded financial ones. By Pearl Harbour, United States munitions output had already worked up to a level roughly equal to that of the United Kingdom, and in 1942, stimulated by the challenge of the President's Victory Programme and the drastic orders stopping production of motor-cars, refrigerators, and radio sets, it plunged ahead. America was thus faced with a critical shortage of raw materials, especially of steel, and decisions had to be taken whether material should be fed to the United Kingdom factories or should be retained in the

United States for building new plants and expanding production lines. Another set of shortages resulted from the loss of Far Eastern sources of supply. This led to the formation of the Combined Raw Materials Board. Likewise the question arose whether the total military production programmes were not far too large in relation to the productive resources of the two countries; to deal with this, the Combined Production and Resources Board was established. These two Boards were entirely centred in Washington, for the problems were in their nature mainly those of fitting the British needs from the United States into the total American supply programme. Late in 1942 Canada became a member of C.P.R.B.

Throughout 1942, and until the middle of 1943, the chief practical problem was to secure something like a common approach to the implications of shortage. There were great differences in organization and outlook on the two sides of the Atlantic; the informal contacts of 1941 were not easily transformed into the more formal arrangements of 1942. The British war economy was two years older than the American, and was thus confronted with rather different problems; American attention, for example, was focused upon raw material shortages, while the main British bottlenecks were centred on man-power and shipping. Another source of difficulty was the very different division of responsibility between the services and the civilian agencies. The international arrangements had to be imposed upon national administrative structures which were shifting all the time.

Gradually there developed a vast network of Anglo-American supply contact. As labour conditions became tighter in Britain, increasing efforts were made to place larger requirements on the United States. These were placed by each British Supply Department *via* its Mission in Washington with the United States War or Navy Department. By the end of 1942, these requirements were measured in thousands of individual items, and a vast administrative apparatus grew up to deal with them.

The flow of supplies from the United States to the British forces grew strongly throughout 1942; in some important types of equipment Britain became almost wholly dependent upon United States supplies—a complete change from the original "insurance" principle. The war threw up new requirements, to provide which no capacity existed in Britain, so these became included in the United States programme. By the middle of 1943 about one-quarter of our munitions supplies were being drawn from the United States. At the same time, a considerable part of the American forces' requirements in Europe were supplied from the United Kingdom on reverse Lend-Lease.

Alongside the administrative network of contact was contact between firms producing similar stores, interchange of technical information, interchange of productive technique. There was a constant stream of Missions both ways across the Atlantic covering an immense range of subjects. The British were able to help in the solution of the United States administrative problems; the British experience was called upon in the preparation of the Controlled Materials Plan—the system of raw materials allocation—and in the building of the United States regional organization of production. The Combined Boards with their combined Anglo-American staffs acted as a focal point for this widespread variety of contact and consultation. They never sought to act as a super-State and give instructions or orders to the various countries; their function was to decide matters of allocation, to provide a forum for discussion of common problems, and generally to foster the cross-fertilization of ideas and discussion and understanding.

By the end of 1943 this process had reached a very advanced stage. It is not to be supposed, of course, that either country was able to get all it wanted from the other; indeed, as American output approached its maximum, there was increasing difficulty in fitting additional requirements into the programme. Likewise, the tighter the British labour position became, the more difficult it was to take on additional commitments for supply of the United States forces. As the war approached Europe, attention had to be concentrated upon problems of engineering and transportation, and upon relief for liberated areas. As shortage of consumer goods became more critical their supply and allocation became subject to very detailed and comprehensive combined planning.

But the real point is that in spite of many failures and frustrations it was possible to develop a community of approach and understanding which provided a background in which these

problems could be tackled rationally. As the end of the European war approached, post-war considerations began to become superimposed upon the war-time habits of thought. The Anglo-American apparatus could provide its best results only when conditions of acute physical shortage dictated the need for practical and common-sense solutions, in the interests of the common effort. This meant that modification was inevitable during the Japanese war. But it is indisputable that there will be acute physical shortages for some time to come, and that these will call for the war-time techniques of Anglo-American combination. And in the longer view, while there is manifestly no place for the complex war-time network of Anglo-American contact and negotiations, it would be a sorry thing if all the lessons were forgotten and if Anglo-American economic relationships were allowed to relapse into their pre-war grooves. The problems change, but there is surely every need to maintain the war-time practice of frank interchange of information, technique, and ideas, and open discussion of matters of mutual concern.

MUTUAL AID TO ALLIES

The estimated value of goods, services, and capital facilities provided by his Majesty's Government in the United Kingdom to our Allies up to March 31, 1945, exceeded £1,400,000,000. This Mutual Aid was continued after that date, without payment, in furtherance of the principle that the resources of the United Nations should be pooled for the common War effort. The records are, however, not yet complete.

The following table shows the amounts of Mutual Aid to all countries on the basis of the latest recorded figures. Except as shown otherwise, the figures are cumulative to June 30, 1944.

		£
I	U.S.A.	942,155,000 (a)
II	U.S.S.R.	269,457,000
III	China	9,050,000
	France	13,600,000 (b)
	Poland	120,000,000 (c)
	Greece	12,368,000
	Czechoslovakia	18,629,000
IV	Portugal	11,133,000
	Turkey	20,681,000

(a) up to March 31, 1945 ; (b) up to June 30, 1943 ; (c) provisionally.

3

INDUSTRIAL MAN-POWER MOBILIZED

TOTAL war required total mobilization of industrial as well as military resources. Industry had to arm and equip the three fighting forces and to maintain the essential supplies and services of the whole community. There was, of necessity, a relation between the man-power employed in industry and the man-power directed into the forces. It was not a fixed relation, but varied with the expansion of the country's armed strength and with the increasing efficiency of industry, the improvement of its mechanical equipment and the growing experience and deftness of millions of new industrial recruits.

No other nation has been so completely mobilized as our own. Nowhere else have women had so large a share in the war effort. The climax was reached on D Day in June, 1944, almost five years after the declaration of war, when already the peak of the industrial mobilization had been passed and men were going from industry into the forces, although industrial man-power had begun to run down.

The comprehensive purpose of the industrial mobilization was the utmost production of strictly essential things in the way most economical of man-power which the conditions of war allowed. The use of man-power and the planning of production were always conditioned in part by enemy action. For example the bombing of factories dictated a dispersal of production that made larger demands on man-power than concentration would have done. Even during the last months of the war in Europe the Government were building reserve factories to replace anticipated losses from V-bomb attacks which were frustrated only by the speed of the invasion of the Continent. The enemy struck at our sea lines of communication and at our ports, at major centres of production and at our inland transport. The theoretical economy in man-power had often to yield to the practical in matters of detail, but there was an over-all economy governed by increasing stringency.

The manning of vital industry was as essential as the manning of the armed forces. At the height of the national mobilization there were 4,500,000 men in the fighting services and 467,000

women in the auxiliary services. These figures do not include the casualties in prisoners and missing, which then totalled 193,000. It had been possible by this time to reduce the numbers of men and women in whole-time civil defence, but still the service retained 225,000 men and 56,000 women. There were thus in the fighting services or prisoners or missing and in civil defence 4,918,000 men and 523,000 women.

The forces and industry had, of course, to draw on the same general pool of man-power. In industry there were 16,760,000 men and women, youths and girls down to 14 years of age, not counting the men over 65 nor the women over 60. So large a number of workers in industry and the essential transport and distribution services was far above all precedent. The number of men in the armed forces was almost the same as in the last year of the first world war, and there were more women in the auxiliary services and more men and women in civil defence.

At the outbreak of war the number of workers in Great Britain in insured employment, including agriculture, was 15,548,000. Outside the insurable field were the higher-paid workers in clerical and commercial occupations and private domestic servants, mainly women, numbering perhaps 1,100,000. In addition were all those who would not normally enter the field of employment. From these sources was built up the augmented labour force of the country even while industry was parting with millions of men and women for the fighting and auxiliary forces.

The total in the forces and in industry in the middle of 1944 exceeded 22,000,000. As many as a million men and women of pensionable age

The manning of vital industry was one of the great essentials of the war effort and employed over 16 million workers, including men, women, youths, and girls. The above picture shows a group of workers listening to a concert in a factory canteen.

Machining web equipment.

were still working. Over 2,000,000 women not formerly in employment were mobilized for some part in the war effort. It was indeed the magnificent way in which women responded to the call for their help that made the completion of the production programme possible. Nine hundred thousand women with domestic responsibilities spent half the day in their homes and half in the factory. As many as 350,000 did part-time civil defence work. From the male population, which was 100,000 smaller in 1944 than in 1939, an additional 280,000 were brought into the services or into industry, while at the same time approximately a million unemployed men in 1939 were given service or employment. There was a large net decrease in the number of men in industry, whereas the armed forces grew in the five years from 477,000 to 4,502,000, and civil defence (on the male side) from 80,000 to 225,000 (having receded in 1944 from a peak of 324,000 in 1941).

Altogether the number of men and youths in industry fell from 13,086,000 to 10,169,000. The number of women under 60 in industry, the distributive trades, and the various civilian services in 1939 was 4,837,000 and in addition 302,000 were unemployed. In 1944 the employment total was 6,597,000 and the number of the unemployed was 31,000.

The whole pattern of industry was changed by the demands for munitions, the consequential restriction of civilian goods, and alterations in the processes of manufacture to facilitate mass production and enable women to supersede men on a large scale in many occupations. General engineering had been a man's industry. It became to a great extent a woman's industry. Machines were tooled for simple repetition jobs that could be quickly mastered by a novice, and women were given this simple routine work. More intricate and heavy work was usually retained by men, but the breaking down of processes to simple individual operations enabled women new to industry to take a large part in the manufacture of aeroplanes and many other weapons of war.

The munitions industries collectively—iron and steel, non-ferrous metals, ship building and repairing, engineering, aircraft and vehicle manufacture, chemicals and explosives—took in 1,422,000 women and 705,000 men in the first four years of the war, so that women provided at one time 36 per cent. of the labour force in the munitions industries as a whole. As very few women were employed in the heavy trades, like iron and steel making and shipbuilding, it follows that the proportion of women in the lighter trades must have been far higher than 36 per cent.

It was the policy of the Government to conserve man-power by compulsory contraction of some industries and limitation of the number of their workpeople. Restrictions on imported materials themselves limited employment. Contraction was in some industries accompanied by concentration in order that premises and possibly also machinery might be set free as well as workpeople. The double procedure was applied over a wide field and notably in all branches of the textile trades, in clothing and boot and shoe manufacture, in furniture making, and pottery. All trades supplying the civilian market were drastically curtailed.

These groups of industries contributed greatly to the switchover of man-power Retail distribution was a particularly rich field for the

supply of young men and also of mobile young women—young women, that is to say, without ties binding them to home and free to be moved from one part of the country to another. Many hundreds of young women were transferred from Scotland to the Midlands of England and from one part of England to another. Hostels were built to augment the lodging accommodation of the congested industrial areas and at the instance of the Ministry of Labour a public utility corporation was formed to manage them. The National Service Hostels Corporation had 59 industrial hostels under its control in addition to 60 for " Bevin boys " drafted to the mines. They could house 70,000 persons.

Notwithstanding the large amount of constructional work for ordnance, aircraft, and various other factories as well as for military camps and airfields the building and civil engineering industries parted with more than half their man-power. An unknown proportion of the 640,000 who left transferred themselves to munitions work, and one of the first moves in the after-war redistribution of labour has been to trace these men so that as many as possible might be brought back again for the house-building programme. The textile trades lost 180,000 men, 45 per cent. of the total number, and 196,000 women, 30 per cent. of the total number. Proportionately higher were the losses of the clothing industry, which parted with 73,000 men (53 per cent.) and 165,000 women (37 per cent.). Since there was an immense demand for uniforms and other garments for the men's and women's services, the whole of the saving of labour for clothing must have been brought about by restriction of civilian supplies. Miscellaneous manufacturing trades lost 462,000 men (46 per cent.) and 26,000 women (6 per cent.).

By far the severest comb went through the distributive trades, which parted with 916,000 men (rather more than 50 per cent.) and 43,000 women out of 999,000, but this last figure gives the net effect of a large movement of mobile women out of distribution and their replacement by immobile and, in many instances, married women. Other services were deprived of 529,000 men (55 per cent.), but only 60,000 women (below 7 per cent.). Nowhere was the labour force static. It was constantly changing with the varying demand for military supplies; and at times the alterations were both large and sudden as when, with D Day approaching, a thousand firms were called on to contribute to the construction of Mulberry Harbours.

Toolmakers at work.

The control of labour became progressively more thorough. It was exercised in detail by direction of individual workpeople to particular employments and by the withdrawal and placing elsewhere of labour in excess of strict austerity standards of good workshop practice. A qualified inspectorate verified the requirements of firms as well as their efficiency in the use of labour. There were, of course, differences in practice in different factories. Many firms were doing unaccustomed work and besides, factories with similar work might be very unequally equipped for doing it. To remove some of these inequalities and to get rid of bottle-necks industry set up production exchanges and these at last were merged in the larger and later organization of

the Ministry of Production. But in the earlier days industry had to do the best it could with too few machines and a scarcity of skilled labour. One of the duties of the labour supply inspectorate was to ensure the greatest economy in the use of skill and to prevent the hoarding of reserves of skilled men. Every branch of engineering was expanding; aircraft production most rapidly of all. Competition for skilled men did not necessarily ensure their employment on the most essential work and did nothing to increase the available supply. First of all therefore the Ministry had to impose a check on the scramble and to prevent the "cornering" of skill. At the same time rapid training and "up-grading" had to be encouraged, for the dearth of skill was a serious hindrance to production.

Man-power within the age limit of military service was controlled by the National Service Act, which became law immediately war broke out. There was already in existence a Schedule of Reserved Occupations, which gave protection to workers above specified ages in a great many sections of industry. The most essential workers were fully reserved regardless of age. In the first month of the war also the Government took powers, in the Control of Employment Act, to steer labour—and skilled labour was particularly in mind—to employment of the highest importance. The Act was applied by order and, as there was need, to indicated classes of workpeople.

Shortly after the formation of the Churchill Government, preparation was made for a more drastic use of these powers. Mr. Bevin, then Minister of Labour and National Service, issued the Conditions of Employment and National Service Order, which assured the workpeople in controlled occupations of recognized terms and conditions of employment and set up a national arbitration tribunal for the hearing of all kinds of disputes and wage claims. The Order which made strikes and lock-outs illegal was a prelude to a series of essential work orders which held a man to his particular employment and forbade his leaving or dismissal (except for misconduct) without the consent of the national service officer of the area. Most important of all was an amendment of the Emergency Powers (Defence) Acts by the inclusion of Regulation 58A, which vested in the Minister of Labour control of the use of all labour. He was given comprehensive power to require any person in the United Kingdom "to perform such services as may be specified by directions issued by or on behalf of the Minister." Every one of any age was by this regulation made liable to Government direction in employment, and it applied alike to women and to men.

These powers were steadily employed in the later part of 1940 and onwards. At the end of 1941 came the next great step by the extension of the National Service Acts to women. An immediate royal proclamation under the new Act made women between 20 and 31 years of age at once liable to call-up and, as they were called up, they were given the option of serving in the auxiliary forces, in civil defence, or in a few specified occupations. Men up to 51 years of age were made liable to military service. It was also at the end of 1941 that the Minister of Labour decided to withdraw for vital war work or the women's services women between 20 and 25 years of age on the non-manual staffs of local authorities.

The armoury of control of labour was now complete. The machinery of registration gave the Minister knowledge of where the men and women of specified classes were to be found and powers of direction enabled him to send them wherever required for essential work. It came about, with changing circumstances, that in some cases men and women had to be ordered back to their original occupations. This happened to miners, textile workers, and builders.

Relaxation of the control of labour was begun at the end of May, 1945, within three weeks of VE Day. Essential work orders were not varied, but control of engagement was restricted to men under 51 and to women under 41. Younger women with domestic responsibilities could also claim release from employment. The call-up for the forces was restricted to men under 31 and it was expected that the men over 25 would not be needed. Releases from military service began in the middle of June and were expected to set free 750,000 men and 75,000 women before the end of the year; but nevertheless an acute insufficiency of labour was in prospect in consequence of industrial retirements. The Ministry of Labour therefore announced six priority groups of industries and prepared nominated worker schemes to enable the employers in those industries to recover former workpeople from the munitions industries. The return tide was set in regulated motion and was greatly quickened after VJ Day.

4

RAW MATERIALS IN WAR TIME

THE control of raw materials was vested immediately before the outbreak of war in the Ministry of Supply. Controversy had hovered for years round the birth of this Ministry, whether it should be set up in peace-time at all as well as whether each Service should be responsible for its own requirements. The resulting compromise came into being only in August, 1939, and consisted essentially of two parts. One was entrusted with procuring all Army requirements, but not those of the Air Force or Navy. The other part, the Raw Materials Department, was concerned with the provision of raw materials for all purposes, both for all three Services and for industrial and civilian needs.

To the Raw Materials Department, therefore, the rest of the Ministry of Supply represented one of various competing claimants for supplies, and it was necessary to have also an interdepartmental Materials Committee to adjudicate between its clamorous customers.

The comprehensiveness of the scope of the Raw Materials Department emerged slowly by painful process of administrative experiment and under the pressure of the exigencies of war. It was clear to everyone from the beginning that raw materials included steel, non-ferrous metals, timber, industrial alcohol, fertilizers, industrial ammonia, sulphuric acid, silk and rayon, wool, jute, flax, hemp, leather, and paper. (Cement hived off at an early stage to the Ministry of Works and the light metals—aluminium and magnesium—to the Ministry of Aircraft Production. Oil, coal, and coal-tar were under the Ministry of Fuel and Power, soap under the Ministry of Food.)

"The Controls," recruited almost entirely from the industries they were controlling, were created from the first for these materials. The Controls themselves, however, were not given the direction of policy. This was reserved to the much smaller body of Civil servants (permanent and temporary) who constituted the central policy-formulating Raw Materials Department under the direction of the Minister of Supply. But as the war continued other administrative Controls had to be set up : abrasives ; chrome ore, magnesite and wolfram ; cork ; cotton ; diamonds ; diamond dies and tools ; foundry bonding materials ; mica ; plastics ; quartz crystals ; rubber ; while coir, kapok, ramie, and tin were attached to existing controls.

In addition to these groups of materials a very varied list of commodities which could not conveniently be fitted into any one of the main controls had to be brought under some form of statutory or voluntary control. Partly by adding a Miscellaneous Chemicals Control and a Directorate of Sundry Materials, the range of the Raw Materials Department was extended to many commodities little known to the public, but of critical importance in specialized fields. Anyone who thinks of raw materials in time of war as being a matter of regulating a few basic materials should read the Index to the Raw Materials Guide published by the Stationery Office and contemplate such chemical entries as "Diethanolamine," "Diethylaniline," "Diethylamine ethanol," "Dimethoxy diphenylamine," or exotic timbers like "Idigbo" or "Morototo" or more familiar but no less surprising entries such as "Feathers," "Arsenic," and "Hoofs."

But the organization which came into being in August, 1939, was chiefly concerned with the fact that even on the principal materials existing preparation for war needs was likely to be sadly inadequate. The nuclear staffing of the future Controls had indeed been selected and thus the foundation laid for the rapid expansion of the department. Having learnt the lesson of the First World War that cross-bred wool was likely to be in short supply to cope with the combined requirements of the French and British armies, arrangements had been made to purchase the entire Australian and New Zealand wool clips for the duration of the war. The designate Controller of Non-Ferrous Metals, Mr. Lyttelton (later President of the Board of Trade and Minister of Production), made quick and effective arrangements by which the Empire's production of copper, lead, and zinc was purchased at uniform prices. American cotton was secured by a Cotton-Rubber Barter Deal with the United States in July, 1939.

Apart from these major items and a few lesser ones, little preparation had been made either for long-term purchases or for sizable stockpiles. Although a long war was anticipated, the central strategical direction of planning in 1939 still assumed that there would be no shipping shortage and that the Army's requirements would be

limited compared with the First World War. It was not until the fall of France and Western Europe that the "phoney war" ended in a nightmare and the Raw Materials Department was faced in mid 1940 with the prospect of acute shortages in nearly every field.

The loss of European sources of supply deprived the United Kingdom of 90 per cent. of its supplies of flax, 75 per cent. of softwood timber imports, 70 per cent. of paper-making materials imported, and 35 per cent. of imported iron ore. Vichy control in French North Africa deprived us of an additional 32 per cent. of our imports of iron ore, an additional 12 per cent. of our paper-making materials (esparto), and about 90 per cent. of our imports of phosphate rock for fertilizers. Thenceforward all these materials had to come from farther afield: flax from Canada, Egypt, Australia, New Zealand, and Kenya; phosphates, timber, and paper from North America; iron ore from the West Coast of Africa.

Pearl Harbour in December, 1941, led rapidly to an even more devastating loss of sources of supply. In two months the Japanese possessed themselves of 90 per cent. of the *world's* production of rubber, 100 per cent. of manila hemp, 80 per cent. of silk, and about 60 per cent. of tin.

The loss of European resources forced the United Kingdom into greater dependence on the United States and Canada, which was further increased by the considerable advantage of the relatively short Atlantic shipping routes compared with the enormous distances to East Africa or India or Australia *via* the Cape. The British Purchasing Commission in North America, founded originally to secure military supplies, produced in due course a vigorous child, the British Raw Materials Mission in Washington. Through the Lend-Lease Act of March, 1941, the United Kingdom received in the four years to the end of the European war £320,000,000 of raw materials from the United States on Lend-Lease terms, steel amounting to £120,000,000, cotton to £60,000,000, non-ferrous metals, timber, and synthetic rubber to over £20,000,000 each.

The loss of Far Eastern world resources and the stepping up of the vast American production programme produced such unprecedented problems that an entirely new type of international organization had to be improvised quickly if a disastrous competition between British and American war production was to be avoided. Hence the Combined Raw Materials Board (served by a strong Anglo-American secretariat) was set up in January, 1942, by President Roosevelt and Mr. Churchill consisting of two members, the Vice-Chairman of the American War Production Board and the Head of the British Raw Materials Mission on behalf of the British Minister of Production. The C.R.M.B. was given comprehensive responsibility for the planning of the raw materials effort of Britain and the United States, and for collaborating with the other United Nations to ensure that their resources in raw materials were most effectively deployed to assist the common cause.

One of the great uses of the C.R.M.B. was to provide a common blackboard on which all the United Nations could chalk up both their requirements of critically short materials and the supplies they were able to produce for the common cause. Once this had been done for any commodity the two sides of the account could be totalled and the seriousness of the global position assessed. Then the Board's task was to try to get supply and requirements into equilibrium. This could in part be achieved by increasing production by pressing forward with marginal development and by assisting in the supply of special equipment. Coordinated purchasing arrangements also helped to secure maximum supplies and took various forms, either leaving to one country sole responsibility for purchasing on behalf of all others or sending a joint purchasing mission. Arrangements were thus made for mica and shellac in India, for graphite and rubber in Ceylon, for sisal and pyrethrum in East Africa, for quartz crystals and mica in Brazil and Madagascar, for balsa wood (for the Mosquito) in Ecuador, and so on.

But equilibrium could not in most cases be achieved except by drastic reduction in requirements as well. Parity of standards between countries was decreed, and in the search for this there was rigorous pruning of unessential uses (such as rubber for golf balls and hot water bottles), substitution of inferior grades (*e.g.*, of mica and zinc) or alternative materials (*e.g.*, steel for brass in cartridge cases), and economy in usage (*e.g.*, in the quantity of tin in cans or of sisal in a length of binder twine). Interchange of technical information and experience, especially between the United States and United Kingdom, with constant comings and goings across the Atlantic of all involved in the common problem, did much to maximize production and minimize consumption.

Thus the loss to the enemy of the main sources of many raw materials, coupled with the vora-

cious demands of war production, led to systematic international organization. It is significant that the British Commonwealth was the main source of supply of two-thirds of the materials it was necessary to allocate.

Over and above shortage of supply at the source shortage of shipping was for months and years the dominating theme in control in Britain. Before the war imports of raw materials into Britain amounted to an average of nearly 2,500,000 tons a month. For four consecutive months during the Battle of the Atlantic—that desperately drawn out struggle between shipping losses and the expansion of American shipbuilding—raw material imports were at an average level of under 600,000 tons a month, and this at a time when British war production was reaching its crest.

Thus the British " Import Programme " was a major piece of planning and control. Shared in effect in about equal halves by the Ministry of Food and the Raw Materials Department, the programme had to take into account every strategic flow and eddy of the war and in its turn affected British policy in the use of every material. With so little coming in there was no room for anything that could conceivably be regarded as unessential for the winning of the war.

Only in a limited sphere could Britain replace imports by amplifying home resources. The production of flax and tow in the British Isles was pushed up from 5,000 tons pre-war to over 40,000 tons. The mining of home iron ore was stepped up from some 11,000,000 tons in 1938 to 19,500,000 tons in 1942, involving great changes in the internal transport and operating conditions of the entire steel industry. More desperate was the search for home-grown timber, of which production in 1943 at 3,800,000 tons was eight times larger than pre-war. The end of the second war in Europe found Britain with two-thirds of its total pre-war stand of commercial softwood felled.

Another form of home production was the intensive salvaging of commodities. It was made illegal to throw away even a bus ticket, and up to VE Day 4,200,000 tons of waste paper had been delivered to paper mills for repulping. Rubber was reclaimed from tyres, tins were pressed and detinned, iron railings were requisitioned alike from public parks and private

A grab crane handling a large consignment of waste metal at a British steel works where some of the country's huge collection of scrap was melted down and made available for use again.

frontages to the weight of 600,000 tons of badly needed iron scrap (and incidentally to the enhanced aesthetic appearance of many gardens and streets). Yet increased home production was not all gain to the raw materials programme. In order to maintain the increase in food production British farmers were supplied during the war with more than twice the quantity of fertilizers used in pre-war days, calling for over one million tons of shipping a year.

How could domestic consumption be reduced? Thinking on this problem in 1939 had made little advance since 1918. The producer wanted to know the answer to two questions about the raw materials he needed: "How much?" and "How soon?" The first is a question of quantity, which is settled by "allocation"; the second a question of time, which is settled by "priorities." But in the first year of the war the allocation system was rudimentary and unreal (statistics were non-existent for many materials) and gave little help in solving the day-to-day problems of administration.

On the other hand, the priorities system led to an avalanche of certificates, all of the highest priority, from competing departments. Perhaps the difference between allocation and priority was revealed in its acutest form in the struggle between aircraft and tanks and guns for drop forgings. While the total amount for each use over a year was relatively easy to settle, the difficulty came when Lord Beaverbrook demanded that the prior needs of aircraft for the Battle of Britain must be fulfilled before other requirements were entertained. Once the course of the war allowed this dilemma to be resolved, the system of control continually developed the system of allocation, and in 1941 raw materials were excluded from the field of priorities. With increasingly reliable figures of stocks and increasingly more detailed analysis of the end-uses for which materials were used (the result of innumerable forms, of which the purpose must often have seemed obscure or senseless to the filler-in), it became possible to determine departmental allocations on a quarterly basis

An instance of the methods employed in dealing with scrap metal for use in making armaments. A huge electromagnet is seen picking up steel scrap and pig-iron, and loading it into trucks.

for the more important materials. Allocation being determined, it became the task of each department to allot its own allocation, while in other cases the Controls used the licensing system to eliminate many types of use and to save material for more urgent requirements.

In addition to developing an unprecedented degree of detailed control of import, acquisition and use of all raw materials, the Raw Materials Department of the Ministry of Supply also became a gigantic trading department. Up to the end of the first quarter of 1945 the Raw Materials Department had procured on Government account raw materials amounting to over £2,100,000,000 in value. This development of "nationalization of the means of production" on an unforeseen scale was forced by four main factors: the convenience of bulk buying as a means of preventing runaway prices in a seller's market; the need to have the right goods at the right port at the right time for shipment on a planned minimum import programme; the difficulty of distributing lend-lease supplies (which by American legislation had to be handled governmentally) in competition with imports on private account; and the greater control of where and when and how the materials should be used that was given by public ownership.

In fact, the Supply Departments, during the European war, succeeded in using all the forces of individual units of production and distribution through the system of Controls based upon the personnel of the industries concerned, and welding them into a comprehensive system in which the criterion universally accepted was how to win the war most quickly. Under such conditions State direction was not lacking in public enterprise. There is space for only two of the lesser known illustrations out of the great number from every industry that could be cited.

In 1939 Britain imported from France and Belgium 90 per cent. of the diamond dies through which fine wire is drawn. The methods of making these dies remained the jealously guarded secret of what was almost a cottage industry. This particularly applied to the finer dies required to draw the very fine filaments of lamps and valves so urgently required for aircraft, tanks, and radio. In these dies the hole to be drilled through a diamond (and subsequently highly polished) might have to be as minute as four ten-thousandths of an inch—*i.e.*, one-sixth the diameter of a human hair. On the fall of France it was soon found that the United States would shortly be faced with the same problem as Britain. The immediate desperate stock position was saved by smuggling out of France supplies of dies. Many individuals were concerned whose names have remained anonymous, and many risks were run in acquiring vital dies from under the very noses of the Germans.

At the same time with great speed a virtually new industry was built up in Britain. Each of the two existing die-makers in England was called upon to increase his production target by five times, and eight other wire-drawing firms (as well as a Ministry of Supply new plant) were helped to produce dies for themselves especially by an intensive trainee system. Working on the basis of original research by one of the great electrical companies a fine dies-drilling machine was developed. Repolishing capacity was also developed to reduce substantially the demand for new dies. By 1944 Britain was producing sufficient dies to meet both British and Empire demands in full and had notably helped the United States to become self-sufficient too.

The other example of publicly directed private enterprise is taken from the chemical field. The onset of the Far East war revealed insecticides as a major munition of war. The United Nations lost the most important sources of natural insecticides—pyrethrum and derris—just as the need for them immensely increased. While strenuous efforts were made—in spite of chronic drought—to increase production of pyrethrum flowers in Kenya, the synthetic material which came to be known as D.D.T. was discovered almost simultaneously in the United Kingdom and the United States. The programme of intensive research undertaken had no precedent. Companies, Government departments, chemical warfare establishments, universities, hospitals, private soldiers in the army, were organized on both sides of the Atlantic in an intensive campaign to discover the potentialities of D.D.T., the best method of use, and the possible dangers to man while killing louse and mosquito. Even before the final verdict could be given on the material's safety and efficacy, the first Ministry of Supply plant was approved in 1943 to meet what was then expected to be the country's requirement of 100 tons a year. But as research progressed, this new material revolutionized ideas as to the extent to which an insecticide can reduce disease and make life bearable in equatorial and semi-tropical countries. In 1945 production in Britain is already exceeding 5,000 tons a year.

At the same time the discovery that dimethyl

phthalate (well known in the plastics industry for many years) will keep mosquitoes from biting men, has had even greater impact on everyday life. The pooled resources of Britain and the United States are still unable to meet all demands for dimethyl phthalate and the materials—especially phthalic anhydride and naphthalene—of which it is made. It is a commentary on the conditions of total war and on the complexity of raw material administration in war-time that because men are fighting in malaria-infested regions, the manufacture of the highest class of paint should be impossible in England and the English housewife should find difficulty in obtaining good quality hair combs or sufficient fire lighters or mothballs.

5

SALVAGE OF WASTE MATERIALS

DURING the period of the European war, one of the most acute and difficult of our national problems was the shortage of raw materials needed for essential supplies. Thanks to the technical research, ingenuity, and enterprise of British industry, an important contribution was made to the solution of this problem by the utilization of waste.

A special Industrial Salvage Group Scheme was inaugurated in the latter part of 1942 by the Ministry of Supply. Under this scheme, the industrial enterprises of a given area could form themselves into a group for the purpose of promoting the recovery of their waste arisings and putting them to best use.

Although under no kind of obligation to participate in the scheme, firms to the number of about 10,000 did so cooperate, and 300 groups were formed.

The members of each group pooled and interchanged their ideas and the results of their research. They made known their individual shortages, and it often happened that the waste materials of one industry provided the raw materials urgently needed by another.

If a firm has a waste material for which neither the firm nor the group knows of a suitable use, the problem is referred by the secretary of the group to the Ministry of Supply. Thereupon inquiries are made as to the probable amount of the waste material forthcoming ; such matters as the method of collection, transport, labour, and breaking down are considered ; and advice is sought of the Department of Scientific Research and of any Control that might be interested. In this way, the resources of Government Departments and of their associated organizations are mobilized ; State and industry work together for their mutual advantage.

The groups are subjected to no official control. Although the scheme is sponsored by the Ministry of Supply and receives its energetic assistance and support, the groups are self-governing. They are an activity of industry itself.

Many striking and even romantic examples of the utilization of waste can be adduced. A public utility concern had thousands of tons of coal-dust for which no use had been found. Within a month of joining the group, the concern was disposing of the coal-dust to another firm that used it for heating boilers.

Waste gelatin and damaged cereals (unfit for human or animal consumption) have been used as substitutes for dextrine and starch in the manufacture of foundry core compounds. Old railway carriage blinds, woven from linen and horsehair, were converted into engineers' dusting brushes. Residues from dry-cleaning stills have been treated and used as Diesel fuel.

The fluff-like cotton waste arising from the manufacture of khaki-web equipment is used by another firm for making upholstery in the seats of aircraft. Bean-husks that accumulate in a workers' canteen have been taken by another firm for the packing of delicate instruments.

Waste liquors from aircraft factories, instead of polluting rivers, are drawn off by a power pump into a visiting tanker, are scientifically

treated and this converted into chrome sulphate for use in the tanning of leather for boots and shoes.

Used photographic film yields important raw materials. The silver is recovered for instrument components, and the cellulose used again for making leathercloth, stiffenings for shoes, and as a substitute for rubber waterproofing.

Sawdust is now employed in the production of phenolic plastics and resin board and as a fuel, and has further potentialities in the manufacture of industrial alcohol, and of bricks and tiles.

An exhibition, demonstrating these and many other utilizations of waste, and entitled " Wealth from Waste " has been shown in London and Glasgow. At the opening of the exhibition in London, Sir George Nelson, late president of the Federation of British Industries, stated that salvage must remain an established part of Britain's industrial structure in the future.

6

CONTROL AND RATIONING

THE controls exercised during the war by the Board of Trade over production and distribution are part of a dovetailing system designed to ensure that the available resources are applied first to war and other essential needs and to secure a fair distribution of available supplies for the civil population. In conditions of scarcity it has been necessary to substitute deliberate state planning for the ordinary play of demand and supply. Resources have been diverted from peace to war purposes, through statutory control over the amount of many civilian products which can be bought or sold on the home market or exported (which severely limits output of the less essential products). This control is strengthened and supplemented by the allocation of raw materials, the control over the engagement or movement of labour (dealt

Salvage of wastepaper has done much to make up for the absence of imported wood pulp. Feeding wastepaper into a breaker-beater, the first stage of reconverting it.

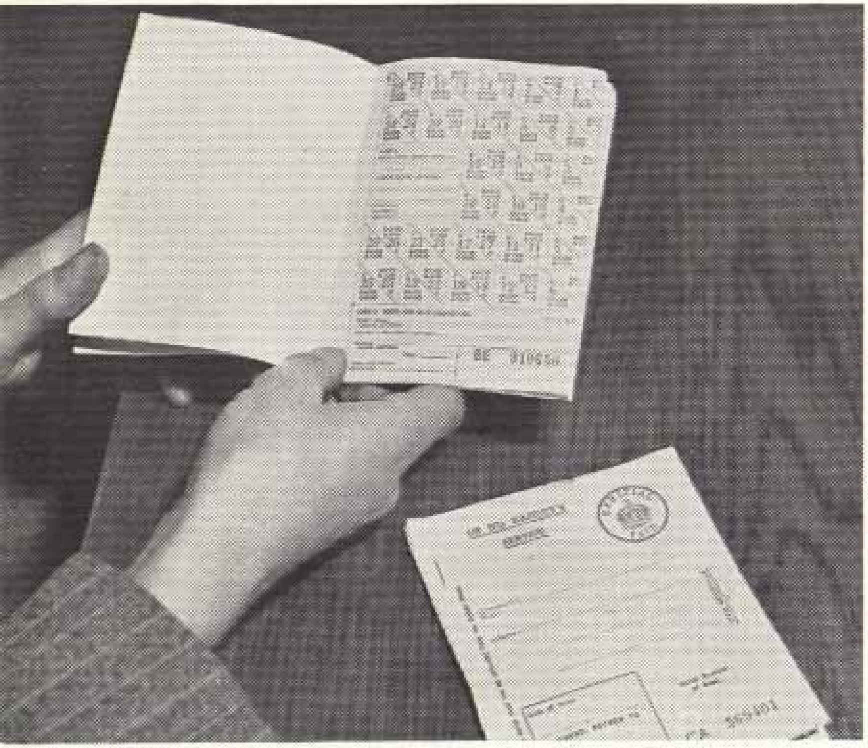
with in other articles), and the control of the use of premises.

Within the more essential civilian field production is planned and the types of goods which can be produced specified so as to permit effective price control, to ensure an adequate production of the types of goods most required and to achieve economical production. For most goods prices are controlled, so as to keep scarce goods within the reach of the general public and to prevent inflation. For clothing, as for food, fair shares to consumers are achieved through rationing; for furniture, as for motor-cars, petrol, tyres, building, and many classes of machinery, supplies are reserved for priority users by one form or another of buying permit system. For some other household goods a degree of priority in securing supplies is secured to selected buyers who most need the goods by various different administrative devices.

This degree of control, of course, developed gradually as more and more resources were needed for the war effort and as the technique of control was improved. The first positive step in the Board of Trade for controlling production was taken in April, 1940, as part of the export drive begun early in that year to help us to pay for our essential imports. Supplies of cotton, rayon, and linen goods to retailers for sale on the home market were limited by order to a quota of 75 per cent. of the quantities so supplied by any manufacturer or wholesaler in a pre-war basic period. Sales on Government contract or for export were exempt. In June, under the Limitation of Supplies Order, a lower quota of $67\frac{2}{3}$ per cent. by value of sales in the basic period was applied to a wide range of consumer goods such as cutlery, pottery, furniture, furs, and musical instruments.

By this time it was clear that restriction of civilian trade was necessary not only to force out exports but to release labour and capacity for the war effort. The machinery licensing system was therefore started. Manufacturers were prohibited from selling or buyers from acquiring machinery in 16 classes except under licence issued by the Board of Trade. This system, which set free engineering capacity for munitions production, was later extended to many further classes of machinery.

By the autumn of 1940 it was once again clear that these measures were not sufficiently drastic.



The rationing of food soon followed the outbreak of war in 1939. Here is a page of one of the first ration books showing the tickets for bacon and ham.

In September the quota for textiles was severely cut. In December the quotas for consumer goods subject to the Limitation of Supplies Order were reduced to 25 per cent. of the basic period value for luxury articles and articles using scarce raw materials, and to 33⅓ per cent. or 50 per cent. for the more essential articles.

Meanwhile more positive steps were being worked out. First, in order to make sure that the slack created by the reduction in civilian supplies was taken up for increased munition production, close contact was established between the Board of Trade, the Ministry of Labour, and the Supply Departments, so that munitions contracts could be placed so far as possible in places where labour or capacity was released. Secondly, in order to achieve more economical working of factories and to release labour and capacity where they were most needed for the war effort, the policy of concentration of production (dealt with in another article) was introduced early in 1941. Thirdly, the Control of Factory and Storage Premises was set up to receive, coordinate, and meet from existing premises the requirements of Government Departments for factory and storage premises for war purposes.

Finally, it was decided that the shortage of clothing was likely to become so acute as to necessitate the rationing of consumers in order to ensure fair shares and prevent queues. Clothing rationing began on June 1, 1941. The method chosen was one which, while limiting each buyer's effective total demand, gave him or her the maximum freedom of choice within the rationed field. Purchase or sale of rationed goods (clothing, piece-goods and footwear, but not hats) was permitted only against coupons. Consumers were given a coupon "income" which could be used for any rationed goods. For clothing and textiles the coupon value of each product was put roughly proportionate to the material required to produce it and production planned to secure the output of each product then demanded by consumers. As between footwear and clothing points were so adjusted as to try to induce consumers to buy the quantities of each which could be made available. Retailers in their turn could secure supplies of rationed goods only against coupons which were passed back from stage to stage until they reached manufacturers of cloth or footwear.

The ration for ordinary consumers was originally 66 coupons annually. Soon after the introduction of rationing, expectant mothers were given a supplement of 50, later raised to 60 coupons. Children received supplements first of 40 or 20 coupons, according to age, and subsequently of 30, 20, or 10 according to their size or age. Industrial workers were also given supplements of varying rates according to the degree of wear and tear on their clothing which their work involved.

The framework of this scheme has remained substantially unchanged, and the efforts of the Board of Trade on clothing were subsequently directed mainly to improving and perfecting the scheme and to ensuring that supplies of each rationed article were available in the quantities required to implement the ration.

First utility clothing was introduced in the autumn of 1941 in order to permit an effective control of prices as well as to save labour. Manufacturers were given separate and higher quotas for specified and price-controlled articles. Finally, the quota control of textiles and clothing was dropped in the spring of 1942. Instead, manufacturers were instructed to produce according to a pre-determined plan the required amounts of the various kinds of products. It was found otherwise that producers, faced with artificial market conditions which they could not individually assess and with the effect of demand muffled and distorted by price control, might neglect some essential goods in favour of others which were more profitable or otherwise attractive. For only the more necessary articles which could be reasonably standardized could be effectively price-controlled. As a result prices of the less essential articles increased to a greater extent and proved more profitable to manufacturers.

The control of other consumer goods was developed less rapidly. By the spring of 1942 it had, however, become apparent both that the prices of the more important of these goods needed to be effectively controlled and that supplies would have to be further reduced so as to economize labour. The production of a number of less essential goods, such as jewelry and metal toys, was prohibited; that of others, such as hollow-ware, was prohibited, except under licence, and the issue of licence was used to secure production of utility or near utility and price-controlled goods. For a few, such as photographic goods, the quota output of control was maintained.

For furniture it became necessary, as for

clothing, to develop a scheme for controlling distribution. Production was confined to utility furniture, and permits to obtain such furniture were limited to applicants in certain priority classes, such as newly-weds, bombed-out persons, parents setting up house because they were expecting children, and parents needing beds for growing children. It proved impossible to evolve a full control of distribution for other goods. For household goods, such as pots and pans, most consumers do not need a supply each year as they do of clothes. But some replacement is indispensable, as it is not for furniture. Various devices for securing priority for the more essential purchases were, however, worked out for a few products.

Throughout this period, in order to secure the maximum impact for the invasion of Europe, labour and capacity were constantly being withdrawn from civilian industry for war purposes, and many materials were getting scarce. Manpower in textiles, clothing, and boots and shoes, taken together, was reduced by 38 per cent. between mid-1939 and mid-1944, and in other manufacturing civilian industries by 33 per cent. Of the reduced total a very large percentage (49 per cent. in textiles, 39 per cent. in clothing, 20 per cent. in boots and shoes, and 79 per cent. in other manufactures in 1943) was employed on Government orders.

In spite, therefore, of a reduction in exports to one-third of the pre-war volume, supplies of civilian goods on the domestic market fell very drastically indeed. The basic clothing ration has been reduced from 66 coupons annually to an annual rate of 48 for the first half of the ration year 1944-45, and (for adults) to 41 for the second half. The 48-coupon clothing ration provides adults with only about half their pre-war consumption reckoned by quantity. Purchases for children have been reduced only by a small percentage and total supplies are perhaps 60 per cent. pre-war. Supplies of furniture and furnishings were only about one-fifth of the pre-war volume in 1944, and of hardware about one-third.

These figures indicate the discomforts consumers have had to endure in this country. Without the arrangements to secure priority for the more essential products, price control, and fair shares, the hardships would have been much greater and it would have been impossible to release so much labour, materials, and capacity for war purposes.

7

CONCENTRATION OF PRODUCTION

THE policy for the concentration of production was the logical consequence of the reduction in output imposed on certain consumer goods industries by the Limitation of Supplies Orders and on other industries by restrictions on the supplies of raw materials.

The reduction in the output of an industry without any corresponding decline in the number of producing establishments necessarily involved a wasteful use of resources, except where firms could occupy their surplus capacity in the manufacture of goods required by the Government. This waste of resources was particularly evident in industries which met the fall in their output by putting their workers on short time, or where indirect labour or other fixed costs formed a high proportion of total costs. To have allowed the civilian industries to continue to operate uneconomically would have been inconsistent with the policy of bringing about a complete mobilization of resources for war and would also have meant a steep rise in their costs of production and so of prices.

By the early months of 1941, moreover, labour was becoming scarce, especially in some areas, and an urgent demand had appeared for factory space for war production and storage. In March of that year, therefore, the Government decided to supplement the policy of reducing the production of civilian goods by a policy of concentrating the production of each of the contracted industries on a proportion of the establishments, so that every establishment might be able to work as nearly as possible to its capacity.

In the Explanatory Memorandum on the Concentration of Production (Cmd. 6258) the Government described its general objectives and indicated the means by which concentration should be carried out. The industries selected for concentration were those in which, it was thought, a substantial amount of surplus capacity existed, and the process by which concentration was achieved provides an illuminating example of the fruitful cooperation between industry and the State that has been a feature of this war. The Government decided on the degree of concentration in each industry and determined

the conditions which a successful scheme should satisfy; but the achievement of the desired result depended very largely on the initiative of the firms themselves.

The White Paper envisaged a form of concentration by which an individual firm would arrange to transfer to itself a sufficient amount of production from other firms to enable it to approach a condition of "full running." The arrangement had to provide for the complete closing of the establishment, or establishments, from which production was transferred, the maintenance intact of the plant of the closed firm (unless the premises should be requisitioned), and compensation for the "closer."

A continuing firm which satisfied the conditions laid down for its industry was officially recognized as a "nucleus firm" and, as such, it was entitled to certain benefits which were withheld from others. The benefits included certain safeguards for its labour and raw material supplies and a qualified promise of protection against its factory's being requisitioned. Promises were also given that closed firms would be helped to restart after the war. The withholding of these benefits from firms which refused to participate in concentration arrangements constituted the main sanction behind the policy.

Although the Board of Trade was the department mainly responsible for the administration of this policy (except in the food industries), many other departments were affected and had to be consulted. The Ministry of Labour, in particular, was much concerned with the question of the location of the continuing production and with the problem of transferring workers. Thus, so far

Representatives of workers and employers sitting side by side at a meeting of a production committee of a large ordnance factory in the south of England. Such conferences proved to be of great use in helping to direct production in factories and shipyards.

as possible, firms were required to work out their arrangements so that production was concentrated in areas where labour was relatively plentiful, and, as a condition of recognition as "nucleus firms," they had to agree to release their younger and more mobile workers for the services or for employment on munitions, and to replace them by older workers from the closed establishments.

The tasks of examining the labour force of the group of firms participating in a concentration arrangement and of selecting workers for transference to other industries, or from the closed firms to the "nucleus firms," naturally presented difficulties; in some industries local panels representative of the Government, the workers, and the employers were set up to assist in these tasks. At the centre the Board of Trade was helped by the business members of the Industrial and Export Council who had the important function of enlisting the cooperation of the several industries in the pursuance of the policy.

In all industries a period was allowed during which these voluntary individual proposals for concentration could be put forward, and in many trades a high proportion of the firms was covered in this way. In some industries, when this period had expired, the Government itself nominated nucleus firms from those which remained unconcentrated and required them to conclude arrangements with the "non-nucleus." The main departure, however, from the type of arrangement described in the White Paper occurred in such industries as cotton spinning, where schemes for a whole industry were drawn up. These provided for the selection of the "runners" and "closers" by the representatives of the interested Government departments and the establishment of a compensation scheme for the trade as a whole. In a few industries the trade association, or representative body, advised the Government about the selection of firms under this type of arrangement and operated a compensation scheme that had received Governmental approval.

It might have been expected that the compensation arrangements would have been the source of major difficulties in the administration of the policy. In fact, however, this was not so. In industries where concentration took place by individual arrangements the Government was not directly concerned with compensation, except in so far as payments made between the firms involved questions of their treatment for purposes of price control. In many cases the nucleus firm merely contracted to produce a certain quantity of goods on behalf of its closed "partner" which acquired them at cost and sold them through its continuing selling organization. Where, however, a compensation scheme for a whole industry was drawn up under which the "runners" paid into a pool sums which the "closers" drew out for care and maintenance, the scheme had to be presented for official approval. The treatment of these payments for taxation purposes, and the continuance of wear-and-tear allowances on the plant of the closed firms were dealt with in the Finance Act of 1941.

The Government had wisely confined itself in its White Paper to a statement of general principles. It was therefore possible for concentration to take many forms appropriate to the diverse conditions in the industries covered by the policy. As time went on, moreover, it became necessary to revise existing schemes in the light of the changed needs of the war and sometimes to provide for a further contraction of production.

From the beginning the Government made it clear that nothing in the nature of a permanent rationalization scheme for any industry was intended. Concentration was a temporary expedient designed to adapt the structure of the different industries to war-time needs in the interests of the manufacturers, the consumers, and the nation. The insistence that the care and maintenance of the closed plant should be an obligation of the "nucleus" firm, and that the cost of care and maintenance should be a first charge on any compensation fund, indicates that the future operation of these industries and, in particular, of the closed firms was borne in mind. This is seen, too, in the statement in paragraph 3 of the White Paper that "the closed factories should be kept ready to start up again as soon as possible after the war," in the promise that "the Departments concerned will then take all measures open to them to assist their speedy reopening," and in the encouragement given to arrangements by which the firm whose plant was closed retained a skeleton selling organization.

Some 70 industries or branches of industry were covered by this policy as administered by the Board of Trade. They ranged from large trades, such as cotton spinning, weaving and finishing, boots and shoes, pottery, hosiery, and furniture, to small industries, such as toilet preparations and pencils. In addition, concentration was applied by the Ministry of Food to certain branches of the food and drink trades and by the Ministry of Works to the brick industry. The process had been largely completed by the

spring of 1942, and by July of the following year, when very little remained to be done except in the clothing industry, about 6,200 nucleus certificates had been issued by the Board of Trade, and some 3,500 establishments had been closed.

It is difficult to measure the quantity of resources released by concentration, since other forces were operating on the industries at the same time as those arising out of this policy. In the figures published in July, 1943, by the Board of Trade, the gross factory space released as a direct result of concentration is given as about 70,000,000 square feet, and the net labour release as about 260,000. This latter figure, however, hardly gives an adequate guide to what was achieved, since even in industries in which the net release was small, a considerable alteration in the composition of the labour force had been brought about by the transference of mobile workers to munitions and their replacement by older or part-time workers. Concentration provided not merely for the release of a substantial quantity of resources which would not otherwise have been available for the war effort, but also for their orderly release in places where they were most needed.

8

PRICE CONTROL AND POLICY

WARFARE on the modern totalitarian scale almost inevitably implies inflation, in the sense that the monetary demand for goods of nearly all kinds will exceed the value of the supply, unless prices rise far above the level of costs. The choice is not between inflation and no inflation, but between controlled inflation and uncontrolled inflation. A nation which tried to conduct the war without provoking inflation could not develop its maximum war effort.

To ensure that the necessary evil of inflation has the minimum of undesirable consequences requires a simultaneous attack from many directions. Direct control of prices needs to be coupled with intensive action to reduce demand ; taxation should be the most drastic that can be imposed without unduly stifling the incentive to all-out production or creating intolerable hardship in individual cases ; saving should be encouraged to the utmost ; and rationing or buying permits should be applied over as wide a field as is administratively possible. Vastly more has been done along these lines to reduce the upward pull of excessive demand on prices than was accomplished in the last war and the task of the price-controllers has been correspondingly lightened.

The methods of price control employed fall into three broad classes. Under the first, actual maxima, in terms of £ s. d., have been laid down for the various articles ; consequently an infringement could be detected by inspecting the goods themselves, without reference to any records. Under the second, the maximum is related in some way to the price charged by that particular seller for the same article, or a comparable one, at an earlier date ; enforcement requires evidence of past prices, and is particularly difficult to secure where the nature of the goods has not remained absolutely constant. Under the third, the maximum is related in some way to the seller's costs ; this is not too difficult to check in the case of distributors, who are simply allowed to add a certain " margin " to the amount paid by them, but with manufacturers a cost accountant's investigation is needed, and even then the problems are formidable.

As might be expected, the tendency has been to use the method of " cash maxima " over an ever-widening field. The trouble is, of course, that it can be applied only to goods which are reasonably standardized and can be identified from the description in the Order. It was applied very early in the war to many foodstuffs and basic materials, because fairly definite standards of quality existed or could be established ; even in these cases, however, compulsory standardization was often necessary.

Over the wide field of manufactured consumption goods the difficulty of fixing actual prices was far greater ; there are innumerable

different articles, each made in a multiplicity of styles and qualities, and with hardly any definite standards. The method first employed, under the Prices of Goods Act, was therefore to lay down the general rule that no seller might raise his price above the pre-war level by more than his costs had increased. Action to enforce this rule depended essentially on complaints from buyers to the Local Price Regulation Committees.

It is hardly surprising that this Act soon ceased to have much more than a moral effect. For enforcement purposes it combines the difficulties of both the second and third methods, since evidence is required not only of past prices, but also of past and present costs. Its function was essentially to impose some restraint on major abuses at a time when prices were moving rapidly.

As P.O.G.A. became more and more ineffective, systems of direct price-fixing have been progressively evolved. These mostly have the common feature that some sort of mark has to be applied to each article by the manufacturer to enable it to be identified for price control purposes. Thus utility clothing bears the general utility mark and a specification number; pottery and enamel hollow-ware are stamped with code letters; chocolate and sweets have a product group number. These "codes" on the article may not in fact connote any precise quality standard—the so-called "specifications" for utility wool cloth are a case in point—and they seldom if ever imply that the article has been inspected by the Government; but they provide the indispensable means of linking the prices laid down in an Order to particular articles.

In these fields the cash maximum (or "ceiling") price has often been coupled with a provision that a manufacturer's price must also not exceed his cost of production *plus* a certain percentage; distributors are compelled to pass on the advantage of these lower prices, because their margin is fixed. There are two main reasons for this provision. First, the absence of precise specification means that articles of varying quality in fact have the same ceiling; this is particularly important with women's dresses. Secondly, some manufacturers are more efficient than others and can easily sell below a ceiling fixed to cover the costs of the less efficient.

This raises an interesting point, which also arose in the field of basic materials and foodstuffs. The output of the higher-cost producers is needed, so that their receipts must cover their costs, and yet the low-cost ones are not to be allowed excessive profits. With some materials, such as steel, a single price schedule was fixed for all producers on the basis of average costs, and a pooling system adopted to divert the excess profits of the efficient to make up the losses of the less efficient; the fact that all users of steel paid the same price made price-fixing for their products much easier. In agriculture such a pooling system was impossible, but again uniform selling prices were fixed for the more or less standardized goods produced; devices such as acreage payments and ploughing-up grants were adopted to give special help to high-cost producers. With manufactured goods, however, the general principle has been, in effect, to fix different selling prices for high- and low-cost producers, with no system for deciding which buyers should pay the higher price. This apparently anomalous procedure has worked surprisingly well, partly because many buyers have not known whether the price differences with which they were confronted reflected quality differences or not, and partly because the money involved was not sufficient to induce people to hunt for the cheaper sorts in an ill-stocked market.

One thing which is apparent from a study of price control as applied to manufactured goods is the immense amount of work involved. The full schedule of utility clothing prices, for example, contains well over 10,000 different entries. Such a system would be bound to break down if there were frequent changes in raw material prices or wage-rates, such as would require complete revision of the schedule. This provides one powerful reason for the Government's policy of selling most imported materials at fixed prices, even if this involved a fluctuating subsidy because of changing prices paid to the oversea producer. Incidentally, it is a remarkable testimony to the Treasury's abhorrence of a coal subsidy that increased coal prices have not been "off-set" in this way, since they affect so many industries' costs, and must have caused a vast amount of consequential administrative work.

Subsidies (and taxes) in one form or another have been a most important feature of the Government's price policy. The general objective has been to keep down the price of most constituents of a "minimum budget," and to tax non-essentials very heavily. The subsidies have

in practice been concentrated very largely on essential foodstuffs; the total of these has been announced from time to time as over £200,000,000 per annum, but a substantial part of this might more reasonably be regarded as the cost of encouraging the maximum output of home agriculture, rather than as a subsidy to keep down the cost of living. With a few exceptions, such as bread and potatoes, the articles subsidized have also been rationed, so that the low prices did not stimulate demand.

The Budget White Paper enables one to see the importance of taxes and subsidies in the field of personal expenditure on consumption. Before the war, £546,000,000 was collected in indirect taxes (less subsidies), and this added about 15 per cent. to the cost of the goods and services. In 1944, these figures had risen to £1,033,000,000 and 25 per cent. The increased taxation of drink and tobacco, together with less important items such as the purchase tax, far outweighed the cost of the subsidies and left a very substantial amount to help pay for the war. In food alone, however, taxes exceeded subsidies by £67,000,000 in 1938, but subsidies exceeded taxes by £56,000,000 in 1944.

The White Paper figures also enable one to see the effect of the Government's policy of keeping down the cost of a minimum budget, both by subsidies and by vigorous price control, while taxing non-essentials. The cost of living index, which roughly measures the former, showed a rise of about 30 per cent. between 1938 and 1944; over the whole field of consumption, however, including luxury items, the White Paper figures show an average rise of about 57 per cent., or about 44 per cent. if the effects of taxes and subsidies are eliminated. Price policy has indeed discouraged non-essential consumption, while ensuring that the minimum budget did not become unduly expensive.

A comparison of price-movements in this war and the last shows broadly the same sort of results for the first two years, both for the cost of living and for the wholesale prices of food and basic materials. After that, however, this war's indices became almost stationary (albeit with a slight upward trend), whereas last time the rapid rise continued, and the peak was not reached until 1920. It is to be hoped that the methods which have secured relative stability for four years will also be used to avert a catastrophic post-war rise, such as occurred in 1919-1920.

Making a 17-pounder anti-tank gun.

CENTRAL ARCHAEOLOGICAL LIBRARY

9

THE REGIONAL BOARDS

DECENTRALIZATION is a phase in the growth of an organization. If it is suppressed or too long deferred, the centralized control becomes clogged with detail, which forces it to work by rigid rules which can rarely be tempered for the special case. But decentralization, when it has to come, is never easy to organize. Like everything else, it can be overdone. It involves nice questions of combining central direction of policy with regional or local discretion; the promotion or appointment of new staffs; publicity to explain and "sell" the new arrangements and introduce the new men to all concerned; to say nothing of the difficulty of withdrawing from staff at the centre those functions which it has been decided to decentralize.

For many years the Ministry of Labour had adopted extensive decentralization, because their administration of the Unemployment Insurance

Acts, involving contact with the public throughout the country, could clearly not be handled in any other way, and it was not long after the Supply Departments were created that they too began to find the need to locate some of their staff in out-stations, where they could more readily deal with labour requirements, progressing, the search for spare capacity, passive air defence, and other problems of a mainly local character.

But these activities of different Government Departments were in reality different sides of the same organization—the organization of British war production—and it gradually became apparent that the decentralized units could not be fully effective without coordination, any more than could the headquarters departments themselves.

From the start all the departments concerned had adopted similar boundaries for the regions into which they dispersed, and the first attempt to provide for regional coordination was by establishing in 1940 boards (first known as Area Boards) in each of the 11 regions into which the country had been divided. After a period of working with separate advisory committees, the boards were in July, 1940, reconstituted as Regional Boards to include representatives of both employers and workpeople as well as the senior regional representatives of the Government Departments involved in war production, and one of the former was appointed as a part-time chairman. Much useful work was done by these boards, but they were undoubtedly handicapped by the fact that the chairmen were not full-time officers, and there was no one department at headquarters to which they could specially look to dispose of their difficulties. As a result of the report in May, 1942 (Cmd. 6360), of a committee appointed by the Minister of Production under the chairmanship of Sir Walter Citrine, the Regional Boards were again reconstituted, with the Regional Controllers of the Ministry of Production as full-time chairmen. These chairmen are men chosen for their standing in the industrial life of their regions. Since they have had little executive authority, and their job is one of coordination, their personal qualities and background have been among the main factors in the success of the boards.

There are three representatives of employers and three of workpeople, drawn mainly from the engineering industry, appointed by the Minister on the recommendation of the employers' associations and the Trades Union Congress; each side provides one of the two vice-chairmen. In addition to the chairman, the official members of the boards are the senior regional representatives of the Admiralty, Ministry of Supply, Ministry of Aircraft Production, Ministry of Labour, and the Board of Trade, and of the Machine Tool Control; but there is close collaboration by other departments whose representatives attend meetings as may be necessary. Each board is served by a local secretariat provided by the Ministry of Production, the whole being administered by a headquarters regional division of the Ministry, responsible for corresponding coordination at the centre.

It was early recognized that to secure close collaboration the regional staffs of all departments concerned had to be located together, and with one or two special exceptions this was arranged and brought with it the expected result that a great deal of inter-departmental business soon began to be arranged between the departmental officers concerned without depending upon meetings of the Regional Boards. Nevertheless, the boards normally meet once a month, but executive committees consisting of the chairmen, vice-chairmen, and official members meet weekly, thus providing an essential basis for regular collaboration. There are in different regions various sub-committees which relieve the executive committee of a certain amount of work. In particular there are now Distribution of Industry Committees sitting under Board of Trade chairmanship. The Ministry of Production also established 65 district offices, and associated with them advisory district committees, consisting of three representatives each of workpeople and employers to deal with more localized business.

These measures to secure coordination of local action were not at once completely effective. In the nature of things Ministries and officials who were responsible for the production of munitions were reluctant to admit the interposition of some authority away from the centre which might, through excessive regard to local circumstances, interfere with matters on which full information was not available locally. One of the first tasks, therefore, was to allay their fears, and at the same time to ensure that the local staffs were kept much more fully informed of the national picture. An inter-departmental committee which was established at headquarters was found invaluable in this connexion. The committee provided agreed instructions to all regional staffs and

arranged that departments would keep Regional Boards informed as fully as possible of their various plans and activities. The instructions which were issued, moreover, made clear the field in which the regional organization would operate, and reassured departments that it would not interfere in production details which were outside its scope.

It soon became apparent that the organization, which had been established for this purpose of coordinating executive action, had two other major contributions to make. In the first place, departments were able to obtain from it much more comprehensive and reliable information about local circumstances and the potentialities of local industry. It is the very divergence in the point of view of the different regions which gives to the regional structure its great significance. Secondly, central government must frequently deal in broad policies which apply with different degrees of precision in different places and at different times. The regional organization has been successfully used to enable these policies to be applied with flexibility so as to meet local conditions and local needs. It was found that when the local representatives of departments were agreed on a course of action, they were able to cooperate in carrying it out to an extent which would have been impossible if they had been entirely bound by separate instructions from each of their headquarters.

The organization was developed too late in the war to be all-embracing, and it was not felt wise to bring under its control certain activities which, although they were in the nature of common services, were being adequately covered by existing organizations.

There is not space to describe in detail the functions of the Regional Boards, which have varied in character and importance to keep pace with the changing war situation, but a few general remarks will show how they have contributed to the full and efficient use of production resources during the war, which was their main purpose.

(1) They have provided a means of employing the experience and advice of both sides of industry, not in matters of general policy, as can be done at headquarters, but in the execution of policies in the individual district or factory. This has been a two-way link between Government and industry and has led on each side to better understanding and more constructive action.

(2) They have provided a means of coordinating the activities of the various departments in the regions.

(3) One of the most successful features of the boards has been the way in which they have dealt with all manner of emergencies which could not have been foreseen and for which no regular instructions could have been devised. They have kept the wheels oiled and prevented many difficulties developing into major issues.

(4) The work of the boards has naturally been very largely, though by no means entirely, concerned with the use of capacity and man-power and the attempt to balance the needs of the various departments for local facilities. In recent months they have had a large part to play in dealing with the consequences of reductions in programmes and in seeing that proper explanations are made of the changes.

(5) Under the general supervision of the boards the Ministry of Production has operated regional and district capacity offices which, although established too late to be employed on the great expansion of war production, have rendered valuable assistance in placing sub-contracts, and in helping to bring into use marginal capacity, including small units in country districts ("outworking depôts") which otherwise would have been difficult to mobilize.

Women at work on the assembly of Westinghouse metal rectifiers in a temporary workshop.

(6) It has been a function of the boards to provide in each region a focus for difficulties or complaints, either on the part of firms or workpeople, which have frequently responded more easily to local consideration than they would to discussion in Whitehall.

The boards could hardly have succeeded had they not been the direct responsibility of a single War Cabinet Minister—the Minister of Production. He has been powerfully supported by the inter-departmental committee mentioned earlier, and by the National Production Advisory Council, which consists of six nominees of the national employers' organizations and six nominees of the T.U.C., together with 11 vice-chairmen of Regional Boards.

10

THE GROUP SYSTEM

IT has been said that if at Dunkirk the positions of Britain and America had been reversed the war might very well have been lost by the allies. For the United States with its Willow Runs and West Coast shipyards planned in the grand style needed many months in which to get tooled up for production. Britain's long experience as the workshop of the world stood her in better stead and made rapid improvisation easier. A great part of our industrial potential could be switched almost overnight from peace to war work. It was improvise or capitulate ; and by our good fortune improvisation is to the British factory man as compromise is to the British politician.

Nothing in the story of the war is more fascinating than the account of the manner in which this conversion was achieved. In Britain there are some 230,000 workshops and factories. A few are enormous, in the American tradition. Eighty per cent. employ only a handful of men apiece. These took their share of the heavy load imposed by the disasters of 1940. This spread of industry, and its flexibility, proved a lifesaver in making dispersal a practical policy as well as a desirable objective when the German bombers got busy. The system worked.

It was not only shipping space that kept chocolate from the shops, and not only labour shortage that made it difficult for a man to get shaved. The sweet people were busy making breech mechanisms and respirators, and from the razor-blade factories Oerlikon shells and tools and gauges were pouring.

Factories that had made almost priceless carpets turned to producing very modest-priced camouflage netting. The football-pool promoters used their huge premises to pack parachute containers and build storm-boats. Flares came in uniform Government cardboard boxes from works which formerly sent out exotic perfumes in elaborate packings. Stocking manufacturers made Bofors gun parts. And if the playroom went short of toys it was because a doll factory was busily producing thousands of a device which saved the lives of merchant seamen, and a toy manufacturer was making Stens instead of pop-guns. Even Londoners grumbled less about their travel difficulties when they knew that London Transport had been making bombers.

Nor was all this a matter of accidental re-arrangement. To the toy-maker the Sten gun was an ideal job—small parts, neat assembly. The manufacturer of dog powders took as naturally to the production of water-sterilizing outfits. Rover may have had some off-colour days, but later on Rome avoided an epidemic.

No less ingenious was the use of Britain's very limited available space. Prisons were converted into workshops—from one former condemned cell came vital parts for aircraft that saved many a pilot's life. We burrowed underground into the rock and slate and stone of ancient Britain to find protection from Luftwaffe bombs for the making of key instruments for our own Lancasters. A cellar of the Houses of Parliament was transformed into a well-organized factory. Thousands of tiny garages became the workshops of a small army of sub-contractors, many of them in the south carrying on under attack from piloted plane, long-range shellfire, flying bomb and rocket. One man set up a machine under the front stairs of his home and then worked to one-thousandth of an inch. Another enthusiast produced small parts in a corridor adjoining a projection room at a cinema and worked a shift between the shows. For one important job a henhouse became a small factory, and shell caps

instead of shell eggs were turned out, with an unaccustomed regularity and speed.

Some 20,000 women became " out-workers " —using the front parlour table as an assembly line and calling in the neighbours as extra hands. It seemed a little thing, but it added thousands of man hours to the total industrial output of the nation.

Not least important in the operation of the ploughshares-into-swords policy was the development of the group system. It was worked from very early days in industries which already had some arrangement of this kind, as in motor-car manufacture. But it grew to significant proportions where often no active groups had previously existed.

Most striking example is in the well-told story of the " Mulberry " achievement, where the leading firms in civil engineering were mobilized to form a team which—with departmental direction and assistance in the provision of labour, transport, and materials—used all its technical experience and weather wisdom to beat " impossible " conditions, including even time and tide, whose uncooperative tendencies are notorious.

In almost every field of production newly associated firms, joined together by the parent Ministry for the more rapid production of a weapon or store, helped each other to tackle common problems. Often they threw everything they had into the joint pool ; necessity banished selfishness. Groups could draw on the research experience of any unit, borrowing from the special knowledge of one to break the bottleneck of another.

When necessary they lent each other machinery, materials, and even men. The single test was—would it speed the job and help to win the war ?

Encouraged by lively individuals in industry and backed later on by organized departmental help—as in the Mutual Aid Groups sponsored by the Ministry of Production and the technical panels of the Machine Tool Control—the group idea has proved a war-time development which might usefully be adapted to the no less urgent needs of peace production. In some areas—notably on Tyneside—self-organization is to be continued to help increase the total volume of employment in the region's engineering shops. Elsewhere group training schemes for apprentices or equally important foremen's panels, where psychology is a subject along with technical development, are to be carried over after the war.

From modest, but spontaneous, beginnings, the group idea has grown into a part of the nation's industrial set-up which many feel should not disintegrate. Often the groups have no fixed terms of reference. Many depend for their success on the enterprise of enthusiasts. All of them demonstrate once more that the adaptability of British industry which has made possible war-time achievement can help to ease adjustment to post-war problems.

11

FINANCE OF INDUSTRY

THE work of the Finance branches of the Ministry of Supply has been concerned with three main aspects of the problem of facilitating the fullest use of British industry in the war effort, with as little detriment as possible to its permanent structure and financial resources. First came the conversion and expansion of industry for munitions production ; secondly, the provision of working capital on a sufficiently liberal scale to enable manufacturers to meet their commitments in wages, materials, and overheads ; and, thirdly, the assistance of manufacturers in exceptional financial difficulties so that full war production was maintained.

Of these problems the conversion of industry to munitions production and the large-scale expansion of individual firms came first, alike in importance and point of time. Industry itself ordinarily provides the capital assets it requires to meet expanding demands, but the abnormal nature of the expenditure made it inevitable that the Government should provide the means of expansion. Capital assistance—as this provision has come to be known—has been the principal Government instrument by which industry has been expanded and remodelled for war production. In some cases complete factories, and in others extensions and adaptations of buildings, have been provided for contractors' use at Government expense, together with all

equipment, plant, and machinery necessary for their operation.

In general, the Government's policy has been to retain full rights of ownership over these assets. But where a contractor wished to own the assets himself, because he could foresee a post-war use for them, or where, owing to their nature, it was impracticable for the Government to retain ownership in them, as, for example, in the case of building alterations, it was agreed that they should be his. This was subject to his agreeing to make a satisfactory contribution towards the capital cost, either at the outset or at the termination of the scheme when the enduring benefit to the contractor from the Government's expenditure could be more fairly assessed.

The capacity created was worked to the limit. Multiple shift working of the vast and newly recruited labour force meant that manufacturers had to meet financial commitments on an altogether exceptional scale. Management and labour were inexperienced in armaments production and methods of manufacture were more uncertain than in the case of peace-time products. Designs were subject to frequent modification and service requirements fluctuated with the varying fortunes of the war. Clearly these hazards called for the utmost flexibility in finance.

Two main steps were taken. First, the size of the problem was reduced by the Government's policy of bulk purchase of many materials and components and their issue to contractors, without charge, for processing and assembly. Secondly, a system of "progress payments," or advances on Government war contracts, was introduced. The essence of the latter arrangement was that, within the contract price, contractors could claim monthly payments up to 90 per cent. of their expenditure, certified as having been properly incurred on the contract. Ownership in materials bought in connexion with the contract was vested in the Government and work in progress was subject to examination by the Government's technical officers—arrangements which went far to ensure that moneys advanced in progress payments were properly secured.

The progress payment system has proved, and still proves, a most effective way of assisting industry in the day-to-day financing of its war production. In cases where normal progress payments were insufficient, it was usually enough to arrange for an increase in their scale and frequency. There has been continuous and close liaison with the banks, whose functions have not been abrogated by these arrangements.

It has inevitably happened on occasion that a firm's difficulties were too deeply seated to be cured by expedients of this kind. Officers with special qualifications and experience in the field of industrial finance were, therefore, appointed and given wide powers of action. Sometimes loans have been arranged. Where necessary, managements have been strengthened by the appointment of a Government nominee. In extreme cases the Ministry, acting under Defence Regulations, has assumed complete control by installing an authorized controller charged with full responsibilities of management. It is a tribute to the adaptability of British industry that very few such cases have arisen. Where unfettered control was found to be necessary the Government has acquired a company's share capital.

The guiding principle throughout the war has been that financial considerations should not impede the fullest production of war materials, and the Ministry has aimed at securing this end with a proper regard for the public purse.

12

BANKING IN BATTLE ORDER

THE most important function of the banks, judged by the work involved, is the provision of cash whenever and wherever it is needed and of a safe, swift and reliable means of remitting funds throughout the country. It was obvious that this vital service might be impaired in time of war by enemy action involving directly or indirectly the head office or branches of any bank, and accordingly precautions were taken well in advance of the outbreak of hostilities. Principal among them was the system of what may be called "shadow branches." Under this plan, duplicate signatures of customers at any one branch were recorded at its "shadow branch" and the fluctuations in customers' balances were notified to it each day. The "shadow branch" was chosen so as to be not too far away for con-

venience but far enough to avoid the likelihood of simultaneous dismemberment.

By these arrangements, which also included records of securities and other crucial items, it was possible to "reconstruct" promptly and accurately the accounts of any branch which might be put out of action, and to conduct normal banking business by resort to the duplicate signature records. At the actual scene of disaster local initiative, sometimes in cooperation with other banks and with public authorities, was thus able to maintain essential facilities, and customers suffered virtually no interruption in the availability of their money or discontinuity in transacting their business. The system was tested early, though on only a small scale, by invasion, when it proved possible for Channel Islanders reaching England to draw in the mainland on their balances with branches of the banks cut off by enemy occupation.

Far more exacting tests, however, were imposed by recurrent air raids, and the smoothness with which the emergency arrangements worked must have surprised not only very many of the banks' customers, but the artificers of the system as well. Several hundreds of bank branches were put out of action, temporarily or permanently, in air raids on London and many other places. Thus, one bank lost no fewer than five branches in Liverpool in one night. In Sheffield, after a violent raid on the centre of the city, five branches of one bank and branches from two others besides all reopened for business in the ball-room at the Cutlers' Hall. One way or another, business was resumed almost immediately, without the confusion and uncertainty that would undoubtedly have arisen but for the foresight of officials working with little more than imagination to guide them.

It is a tribute to British safe-makers that strongrooms withstood so well both high explosive and incendiary bombs, imposing strains and stresses far surpassing those they were constructed to combat. "Incidents" are on record in which, by reason of débris and intensity of heat, a strongroom could not be approached for a fortnight or even more; yet the contents were ultimately found to be intact, though sometimes scorched, or damaged by water, and the locks moving "sweetly" as before. Here too the efficacy of the provisions was all the more fully tested because of the greater quantity of securities and valuables entrusted to the banks by customers contemplating war hazards. Where securities were not available for some days, most business requirements could be met by use of the duplicate records at the shadow branch; and to guard against the risks of invasion negotiable securities at branches on the east and south coast fringes were physically removed inland. Again, after enemy action many thousands of customers had reason to be thankful for the safeguards provided by the "night safe" facilities installed at many branches in the years preceding the war.

An indispensable part of a smoothly working cheque transmission system is a centre at which debits and credits arising from the transactions of distant payers and recipients can be exchanged between the banks. Ordinarily the bulk of this work is carried out at the London Bankers' Clearing House, but the vulnerability of the capital and the seriousness of the consequences of any interruption of the service made it advisable to shift the centre of the machinery. It has, in fact, been established near Stoke-on-Trent since September, 1939, and has operated satisfactorily, handling about 1,000,000 cheques a day, in spite of some delay in the time taken to clear cheques. Similarly, several banks felt it advisable to move sections of their head offices to provincial centres, thus partially dispersing the personnel and records of control.

Decentralization was also necessary in respect of currency reserves, and the enlarged quantities of cash held at selected centres in the provinces have ensured that currency has always been available without fail (though on occasion local shortages have occurred in coins of particular denominations) for wage payments and other business and private purposes. The increased use of currency under conditions of full employment, high wages, and big movements of forces and civilian population has put a heavy strain on the banking system, which nevertheless has been smoothly and regularly met.

At the earlier stages, when rapidly expanding war production was outrunning the ordinary facilities for finance, the enlarged flow of wages and other outgoings from factories, shipyards and other establishments often required more liberal accommodation from the banks than might have been justified by normal tests of the proper limits to a bank advance. Later, as the system of progress payments by Government departments came into operation more widely and promptly, less exceptional facilities were needed from the banks.

It seems to have been thought, at the outset, that the aggregate lending power of the banks might have been strained by the demands of

war industry, and they were officially asked to confine their lending to vital national purposes. As things have turned out, Government financial provision for current and capital needs of undertakings on war production, the bulk purchase of numerous foodstuffs and raw materials, the "concentration" of industries not of first priority, the running down of stocks of goods in traders' hands and other factors have brought about a diminution in the demand for bank advances.

Closely related with the financing of industry at war is the financing of industry emerging from war; and at this stage of changing conditions the Treasury has issued a fresh statement to guide the banks in their lending operations. Meanwhile, in preparation for re-expansion of peace-time industry and trade, various banks have proclaimed their readiness to finance reconversion of industry, resettlement in trade and new business enterprise within rather more elastic definitions than were formerly observed of a "proper banking risk"; and two new corporations are being set up, with banking support, to finance industrial reorganization and the launching or expansion of smaller undertakings.

Some entirely fresh functions have fallen to the banks under pressure of war finance. The operation of a meticulous system of exchange control was an innovation calling for the rapid exercise of technical ingenuity to improvise methods of carrying out responsibilities delegated through the Bank of England. The complex requirements were all the more difficult to embody in a smoothly working system by reason of frequent revisions of the official regulations rendered necessary by changes in the war situation and as observation revealed openings for leakage.

A spectacular task was the mobilization, under Government orders, of hundreds of millions of pounds' worth of customers' foreign-currency stocks and shares and their transmission bodily to Montreal when the threat of invasion became imminent. No less ingenious was the utilization of the banks' internal machinery of collection and payments for carrying through all transactions in clothing coupons beyond the retail stage. Day by day millions of coupons pass among retailers, wholesalers, and manufacturers through the banks, at which all but the very smallest traders maintain "coupon accounts."

One way and another, then, the volume of work to be handled has certainly not diminished. Each bank, however, has been required to reduce its total staff to a figure not exceeding 85 per cent. of the pre-war number. Within this reduced personnel the proportion of women has greatly increased, while temporary staff, the very young and the old have helped to fill the gap created by withdrawal of men into the Forces. To cite one bank's experience as an example, every other member of the pre-war male staff has joined some branch of the Forces; well over one-half the total present staff is on a "temporary" basis; and nearly one-half of the personnel now consists of women, as against less than one-fifth at the beginning.

The stringency has been particularly acute in the category of men competent to fill positions of some responsibility requiring considerable technical knowledge and experience. The result of the general pressure is to be seen in longer working hours and shortened holidays, as well as in deferred retirements. Bank staffs, like every one else, have borne and are bearing the heat and burden of the day in maintaining a vital service, without which ordinary day-to-day business in every part of the country would be infinitely more cumbersome and fraught with far greater risks.

13

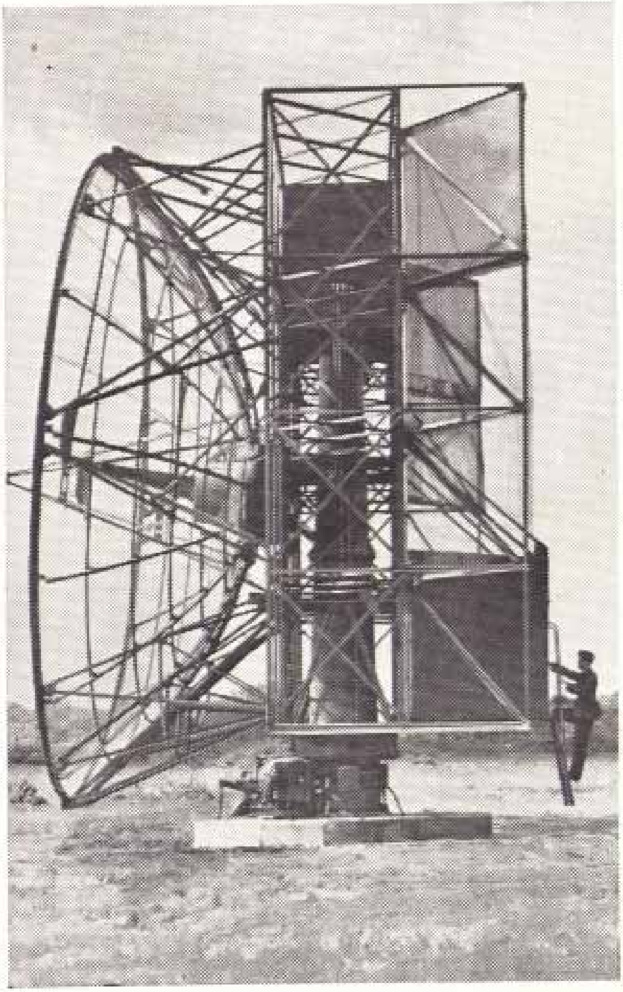
SCIENTIFIC RESEARCH

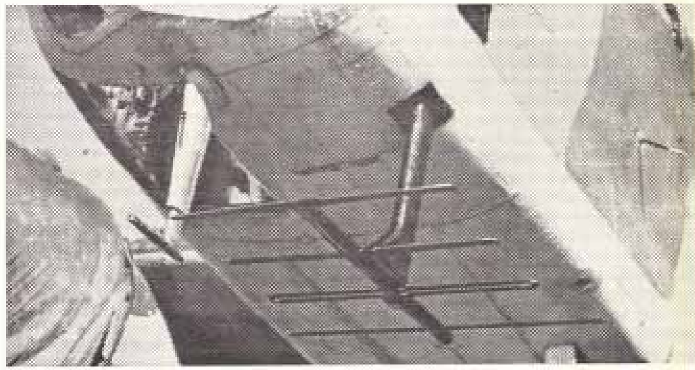
THERE is no aspect of the war upon which scientific research has not been brought to bear with fruitful results. In Navy, Army, and Air Force, in respect of offence, defence, and communications; in the workshop and in the fields; in the mill and in the hospital fundamental changes have taken place as the result of the systematic enlistment of the nation's scientific workers in the service of the total war machine.

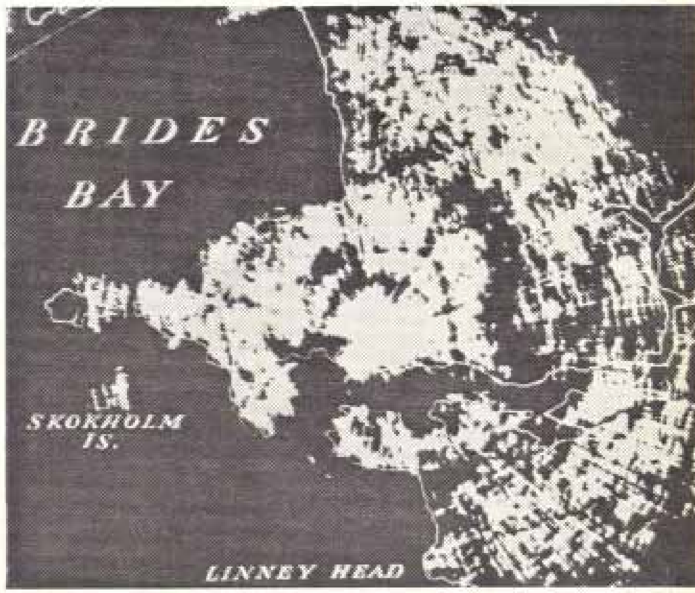
Some of the advances have been made along more or less expected lines, as in the case of the brilliant metallurgical work of Sykes which has led to great improvements in our armour-piercing shell: that a proved metallurgist should better the performance of steels under peculiar conditions is not astonishing. Other of the advances will come as a surprise, in their nature, to many, as, for instance, the way in which the systematic application of statistical theory has vastly simplified and cheapened that inspection which plays so vital a part in modern workshop practice. The work of the experimental psychologists on industrial fatigue, on the reactions of airmen,

and kindred subjects also lies a little away from the more conventional examples of applied research. From the whole vast field which includes, then, metallurgy, mathematics and psychology, physical, biological, and mental science, it is possible here only to select a few examples, nor must the most important be omitted because attention has often been drawn to them.

Radar, the application of the technique of wireless waves to the location of aeroplanes, claims pride of place, however often it has been acclaimed, since without it our limited air force could scarcely have held the Hun in check in the battle of the skies of 1940. It may be worth while, with an eye on those who decry the pursuit of pure science for its own sake, to point out that this technique grew out of the chain of researches pursued by Faraday, Clerk Maxwell, Hertz, Lodge, Marconi, and Appleton, of whom only Marconi was working for practical ends. Sir Edward Appleton had worked out special methods of emitting and receiving wireless pulses. in connexion with his work on locating the ionosphere, that is, the electrified layers of the upper atmosphere. Later, largely by the efforts of Sir Robert Watson Watt, it was found that the reflection of a wireless pulse from an aircraft







Three photographs illustrating the development of radio-location, which British scientists had in readiness at the outbreak of war. Left: The fighter direction aerial system. Top right: Radar equipment fitted beneath the nose of a R.A.F. Beaufort. Lower right: A Radar view of the south-west tip of Wales as shown on the cathode-ray tube of the apparatus carried in R.A.F. aircraft.

could be detected even when the aircraft was a hundred miles away.

How the Radar methods have been developed by the use of very short waves, which allows the use of directed beams, is a familiar tale. These methods have been applied to the laying of guns and the direction of searchlights. They have obvious possibilities after the war as aids to aerial and marine navigation. What is not always pointed out, however, is that much of the theory used in this wireless work is merely adaptations of the wave theory of light devised and worked out to explain curious laboratory experiments in optics. Another aspect of research in wireless optics is the instrument used for blind bombing: short wireless waves which penetrate cloud are made to furnish a kind of image of the ground target. Wireless technique and wireless components have been employed in the development of portable apparatus for detecting buried land mines, although wireless waves, in the ordinary sense, are not involved.

The study of the ionosphere, originally undertaken for the pure joy of investigation, has during the war led to another striking development. The electrification of the layers of the ionosphere is controlled by radiations from the sun; it builds up during the daytime and falls during the night. As a result of the scientific analysis of this effect and its variation from month to month, it has been possible to forecast some months ahead the most suitable wave-length for radio communication over a given distance for any time of the day or night and for any part of the world.

Wireless waves are merely a kind of light waves; another kind of invisible light that has been the subject of research for war purposes is the infra-red. This has been applied for night driving, where it enables drivers to keep in touch without any visible light that might betray their presence to the enemy, and for secret signalling and marking. As regards ordinary light a great amount of specialized research has been directed to the various problems of photography that are involved in taking successful photographs from the air. The camera mounting, the film, and the development of the film have all been the subject of most interesting developments, based on systematic laboratory work. It may be mentioned that photography from the air of the water surface near beaches was made to give very valuable information as to the depth of water by the application of the science of hydrodynamics.

Turning from light to sound, the most sensational war researches here have been the acoustic methods for locating submarines. The method called Asdic is, in a way, similar to Radar: once more a spurt signal is sent out, only here it is the sound wave from a sharp " ping," and its reflection from the hostile craft, in this case a submarine, is received. The interval between the emission and reception of the signal gives the distance.

Another aspect of the menace from the sea, and the part played by science in its elimination, is the magnetic mine, overcome by the " degaussing " of ships and the sweeping with an invisible electric current between two ships, instead of a cable. The apparatus here was relatively simple, but the manufacture of that for wireless and sound was a great war undertaking which likewise entailed much research, followed by development and planned manufacture on a great scale. The sea reminds us of quite another aspect of war research, that on the utilization of seaweed, which is so plentiful round our coast, for food and textiles. It is said, for instance, that excellent custard powder has already been produced. We are in a fair way to have shortly rayons, or artificial silks, made from seaweed, but this is not, perhaps, mainly a war interest.

As regards more conventional food production, researches carried out at Rothamsted and elsewhere on artificial fertilizers, control of insects, constitution of the soil and on plant diseases have been of great benefit to our agriculture. Here again statistical work, mainly due to Professor R. A. Fisher, directed to the design of experiments calculated to give the greatest precise information with the least experimental effort, has been fundamental. Research on soil microbes has led to a new process for preparing manure.

Another aspect of the influence of research on our diet is the work carried out by the Ministry of Food in close collaboration with the Department of Scientific and Industrial Research and the Medical Research Council. Nutritional science has provided the basis for planning our war-time feeding. One example of the work is dehydration, or the removal of replaceable water from foods such as eggs, meat, and certain vegetables to save shipping space. Laboratory work has been carried out at the Low Temperature Research Station of the D.S.I.R., the main end in view being to maintain the nutritional content while preserving a product that can ultimately be made to resemble more or less closely the natural food.

During the whole course of the war intensive research has been carried out on the composition of our bread, from the point of view of vitamin content, baking quality, and keeping. One outstanding result of the work carried out in the Cereals Research Station is that we now know where the nutrients are concentrated in the wheat grain and can anticipate the results of any milling policy from the point of view of food value. Again, the insect problem has been successfully attacked by the entomologists. In the last war large stores of grain were destroyed by insect pests, but, as a result of research, in this war such losses have been negligible.

The applications of chemical research to explosives, artificial rubber, and artificial resins, such as the transparent plastic used to make windscreens in aeroplanes, are well known—at least, the fact that chemistry has been so applied is well known. Owing to the circumstance that gas warfare never broke out, little has been heard of the vast amount of research that has been done on war gases and on counter-measures against war gases, such as ointments, special gas-masks, and so on.

There seems little doubt, however, that it was our state of preparedness, which was well known to the Germans, that saved us from gas attacks, while at the same time the enemy was led to expend man-power and treasure on preparations for such attack. We owe much, then, to the researches of our chemists and physiologists in this field. Our meteorologists also played their part here, as they have in calculations relative to fog clearance from aerodromes by lanes of burning petrol, which have been described in the Press. Small-scale experiments by Professor Rankine were also fundamental for this striking operation.

Research on explosives has led not only to various new explosives, but also to investigation of the remarkable effects that can be produced by giving destructive charges special forms, about the effects of which very little was known before the war. Charges hollowed out in certain ways produce much more powerful directed local blast than the same weight of explosive in ordinary block form. Such shaped charges, as they are called, have been extensively used for demolition and for airborne bombs designed for piercing armour or concrete.

In the field of medical research much has been done in devising an improved system of vaccination against typhoid and paratyphoid fevers, cholera, and other endemic diseases, but the most striking achievement has been penicillin. The original observation and the preliminary development of this powerful agent against the staphylococcus and other disease-producing organisms was made by Sir Alexander Fleming, after which Sir Howard Florey and Dr. Chain produced the substance in a purified form. Active research was then carried out by the organic chemists, in particular Sir Robert Robinson at Oxford and Professor Heilbron in London. Finally came the question of production in quantity, which was taken up on a big scale by English manufacturers and on an even larger scale in America. This is a sketch of the kind of chain that leads from a discovery in a laboratory devoted to pure research to production in quantities that put the result at the service of all who need it.

At the National Physical Laboratory, besides the usual work on, for instance, the testing of ship models and of aircraft models in experimental tanks and wind tunnels, which goes on week after week, a great variety of special research jobs have been undertaken. For instance, in connexion with Pluto, the pipe-line which conveyed oil from England to France, a great deal of skilled experiment had to be done on the coiling of steel pipes on drums before it was possible to lay the line successfully. Another odd job carried out at the laboratory was the design of special machinery to wash the explosives out of unexploded German bombs found in inhabited areas.

For every example of our war-time research that has been given here another one that he may think just as important will occur to the reader who has been in touch with the scientific side of the war effort. What about jet propulsion in the rocket and in the jet-propelled plane? What about the modern aeroplane compass? What about the metallurgical research that lies behind the modern supersession of riveting by welding? What about the examination of structure by X rays—non-destructive testing, as it is called—which has been so successfully developed by Dr. Pullin for the Ministry of Aircraft Production? These and a dozen other examples deserve all the good words that their advocates could demand. No research, however, has found a radically new way of making paper economically from home-produced material, and in the end it is paper shortage that confines such surveys as this to a brief compass.

14

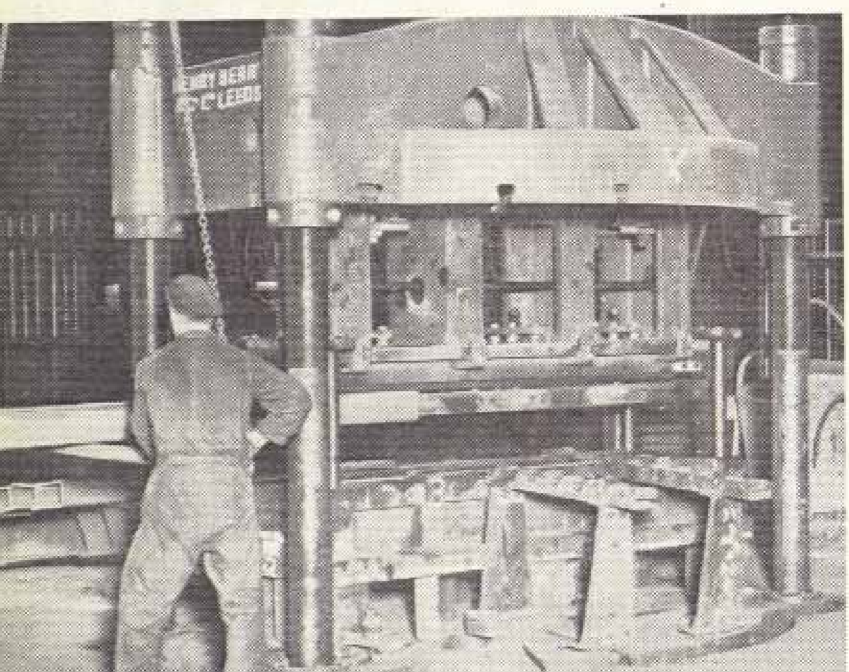
FUEL AND POWER

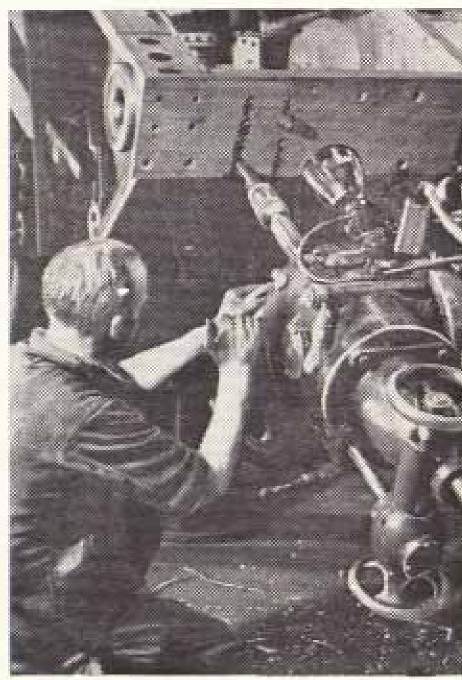
COAL mining has been a problem industry during five years of the war. All was well for the first few months. There was no sign in public policy or in the relation of output and demand to indicate more complex difficulties ahead than those to be expected in the working up of output to meet the increasing needs of the war industries here and in France, for power, heat, and light. Many young miners were embodied with the Territorial Army and the Reserves, but this removal of man-power was not particularly disquieting because the empty places were taken by men who had been unemployed. There was, in fact, an increase of individual annual output. Though the strength of the labour force of the mines declined in 1939 the annual output of the individual worker increased and the total output of the industry increased also.

In the spring of 1940 output was raised to nearly 5,000,000 tons a week. France had added to her demands, and with growing needs for larger supplies the industry raised its employed man-power above the level at which it stood immediately before the outbreak of war. This increase was made possible by relying more on elderly workers and even by calling back men who had retired. It was the time of the German onslaught on Belgium and France. In June came the collapse of France, the entrance of Italy into the war, the cutting off of the continental demand and sudden cessation of exports for which there could be no immediate compensating demand at home.

Exports had amounted to 47,000,000 tons in 1939; they required 27,000,000 tons in 1940 (mainly in the first five months), and collapsed to 9,000,000 tons in 1941. There was at once a migration of surplus miners from the exporting coalfields into other industries, chiefly munitions, and a certain number—many fewer than has been commonly supposed—were called up for military service. What was even more serious was the failure of the industry to recruit a sufficient complement of young workers to ensure the future strength of the labour force.

Output has fallen seriously and consistently; man-power has declined, and a diminution of individual production has still further decreased the supplies of fuel. Whereas 230,000,000 tons of coal were mined in 1939 the quantity in 1944 was only 184,000,000 tons. The annual output of each





A 520-ton hydraulic flanging press required for the manufacture of gun-cradles which was produced at an urgent call from the Ministry of Supply. It was installed and ready for use in 49 working days—200 days ahead of schedule.
Right: Holes being drilled in the hull of a Crusader tank with a portable electric drill.

worker was almost 302 tons in 1939 and only a little more than 259 tons in 1944. In the latter year fortunately opencast working came to the aid of the country with a production of 8,600,000 tons.

For all that the munitions industries and the public utility undertakings have not been without coal, nor has industry generally except in isolated cases, while householders who have failed to receive the full amount of their severely limited allowances have had more reason to put the blame for the deficiency on transport and hard weather.

At times the margin of supplies, including stocks hoarded in the summer, has been narrow, but the Ministry of Fuel's control of distribution, combined with its regulation of industrial supplies according to an official measurement of essential wants and its practical instruction in economy, prevented disaster. The "programming" of supplies was most successful. There was besides a fuel efficiency service, organized by Dr. E. S. Grumell. A staff of 83 full-time fuel efficiency engineers and 642 part-time voluntary engineers visited nearly 24,000 factories and made 15,000 "follow-up" visits in the two years 1943-44, with notably good results.

In June, 1942, the Government assumed full operational control of the mines and announced the intention to organize the industry on the basis of national service, "private interests being subordinated to the overriding needs of increased production." Hitherto the Government's control over production either in coal mining or in any other industry had not extended to the exercise of day-to-day responsibility for the processes of production. The Mines Department of the Board of Trade was exalted into an independent Ministry and provided with elaborate headquarters and regional staffs. At headquarters the Minister was assisted by a production director, a labour director, a services director (responsible for distribution and allocation of coal), and a finance director.

A national coal board, linking headquarters and the districts, was entrusted with advisory duties on the general planning of production efficiency, the maintenance of man-power, welfare, health, and safety. In each coal-producing region a controller was appointed to exercise the powers of the Minister "to assume control of colliery undertakings and to give directions to the managements regarding the carrying on of the undertakings." But the Government did not supersede the colliery managers or subordinate them to any external control in the detailed working of the pits. Day-to-day management was left "in the hands of the managers, who will continue to be the servants of the owners, though subject to removal at the instance of the controller should he deem that course necessary." There was therefore the "dual control," which was to be consistently criticized by the mineworkers' leaders as a limitation of the Government's power to override private interests. For no more than a short time did Government control quieten the campaign of the miners for complete nationalization.

In the finance of the industry Government control had far-reaching effects. The wage awards of the Greene and the Porter tribunals made additions to the earnings of the miners, which bore hardly on the undertakings and coalfields with a low man-shift output and therefore a high cost-of-production rate. A method of equalizing the added burden was found in the Coal Charges Account. The account is a financial pool. With a levy of 12s. a ton on all output, the account was not balanced last March, and there was £11,500,000 of indebtedness to the Treasury, to be recovered later from higher prices of coal. Eight coal mining districts contributed more to the account than they drew out of it; 11 drew out more than they paid in; and one had an almost level balance. Some large net amounts were drawn from the account last year—£3,941,000 by Durham; £7,508,000 by South Wales; £1,607,000 by Lancashire and Cheshire; £886,000 by Yorkshire; and £465,000 by Cumberland. All coalfields receiving from the account more than they pay into it are not self-sustaining at the present level of costs of production and prices. Mr. Harold Wilson, who was at the time Director of Economics and Statistics at the Ministry of Fuel, has written that "by the end of 1944 economic laws had ceased to apply to the industry."

For the secondary sources of fuel and power, excluding liquid fuels, the mining industry last year supplied 20,700,000 tons of coal to the gas industry, and the gas undertakings produced 330,000,000,000 cubic feet of gas and 7,600,000 tons of coke for general consumption.

For the production of electricity the mining industry supplied 24,000,000 tons of coal, and the electricity and railway and transport undertakings produced 32,800,000,000 units of electricity. The coal carbonized in coke ovens was 20,100,000 tons, which yielded 14,100,000 tons of coke and 95,000,000,000 cubic feet of gas.

15

THE BATTLE OF THE FACTORIES

THE toll taken of British industry under the three phases of enemy bombing might have been more serious if it had not been for the intensive work of the Emergency Services Organization.

Throughout the country there were 12,000 cases of damage to war production factories arising from enemy action. Roughly half this number were in the London region, where after D Day there were 2,500 incidents resulting from flying bombs and about 1,000 from rockets. Many factories were hit on more than one occasion, and one factory, that of Messrs. Siemens and Co. of Woolwich, was damaged on 27 separate occasions during the first stage of the war. In July, 1944, flying bombs damaged 1,200 London factories, and on some days during that peak month as many as 100 factories a day were damaged by direct hit, near miss, or blast. Morale was sternly tested, but work stopped only for employees to seek shelter under benches and machines when the flying bombs were nearly overhead on the direct line of approach.

Equally severe had been the threat to war production during the "blitzes" on Liverpool, Manchester, Birmingham, Coventry, Sheffield, Bristol, Exeter, Plymouth, Cardiff, Sunderland, Bath, Barrow, Southampton, Portsmouth, and Hull. Essential services were disrupted and hundreds of factories put out of action overnight.

Effective machinery was introduced to keep the production centres running. Lord Beaverbrook, when first Minister for Aircraft Production, demanded high-speed repairs for factories when disrupted by enemy action, fire, or explosion, and "E.S.O."—the Emergency Services Organization—came into being to achieve this task, the full magnitude of which, under flying bomb and rocket attacks, could not have been foreseen.

E.S.O. was devised in detail by the Ministry of Aircraft Production, and authorized to act for all Supply departments, including the Admiralty, Ministry of Supply, and of course the M.A.P. itself, and the watchword of E.S.O. was "Help Industry to Help Itself." The bulk of the rescue and reconstruction work obviously had to be done by industry itself, since the man-power position made it impossible to keep a standing army of reconstruction experts. But Sir Peter Bennett, who devised the E.S.O. plan, knew that the job could be done. He was assisted by Mr. F. J. E. Brake of the M.A.P. in the early negotiations with the Engineering Employers' Federation, and by Captain Spencer Freeman, the Regional Controllers of the Ministry of Aircraft Production, and Mr. W. Strath in converting the scheme to a working reality.

Central and regional arrangements with the Engineering Employers' Federation led, in July, 1940, to the formation of reconstruction panels in 128 industrial centres throughout the country. Every member of these panels was a voluntary worker—civil engineers, industrialists, production and engineering executives, builders and administrators.

The Ministry of Works delegated powers to E.S.O. for authorizing constructional works and established huge stocks of certain building materials at depôts throughout Britain. Immediate access to other controlled materials was arranged, and the Ministry of Labour also gave an overriding priority for building labour. Nearly 500,000 tarpaulins—which might be regarded as the "penicillin" of emergency repairs—were kept in store, as well as various equipment for first-aid repairs to supplies of gas, electricity, steam, compressed air, and refrigeration. Thus the machinery was all set to face enemy action; but one thing more was necessary in order that E.S.O. could act swiftly.

A nation-wide "intelligence" system was set up so that not only could the E.S.O. machinery come into action at once when an incident was reported, but Ministers and production directors could be informed immediately a factory was damaged. From that moment initiative rested with the reconstruction panels, who were guided and coordinated by the Regional Controllers at the Ministry of Aircraft Production in consultation with the Regional Controllers of the Admiralty and Ministries of Supply and Production. The "nerve centre" of this great organization, covering all 128 areas, was at the Ministry of Aircraft Production Headquarters, London, where a staff worked watches to keep a 24-hour service.

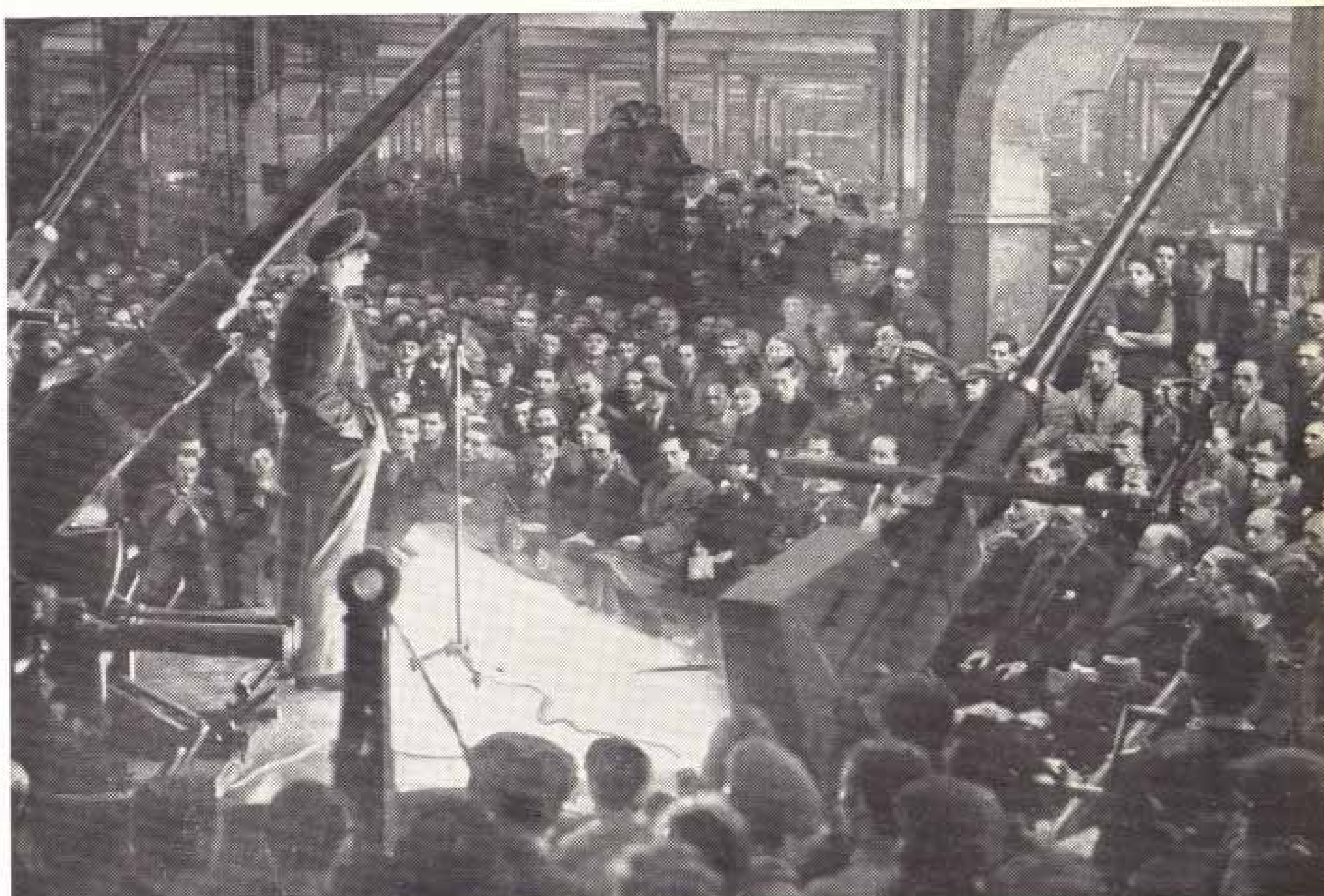
Since conditions varied in each area, panels were left to settle their own internal organization. Concentrated enemy action, as in Coventry, Birmingham, or Trafford Park, Manchester, called for different treatment from that needed for sporadic damage. Each panel, however, soon found that for the speedy restoration of production, the needs might fall under one or more of the following headings:—

Gas, electricity, water, sewage, telephones, transport, labour, bomb-disposal, temporary manufactur-

ing capacity, lifting tackle, repairs to fabric of the buildings, compressors, boilers, heating-units, heat-treatment, repairs to and replacement of machine-tools and electrical equipment.

Intensive damage in a concentrated area entailed shortages of all resources and concomitant priorities for which advance arrangements were made for appropriate emergency committees with all interests represented. Weatherproofing of plant and restoration of essential services were the first concern concurrently with any problems of emergency feeding, housing, and transport of production workers. Panel members received functional assignments; times for completion were set to conform to a planned programme of restoration. As many of the factory operatives as were useful were organized for salvage purposes. Weatherproofing was effected by rigging tarpaulins, lent by M.A.P., to roofs and places where a building was open, for covering plant and equipment and restoring black-out. Arrangements with the Machine Tool Control ensured immediate treatment of machinery with a rust-proof solution, classification and removal of machine tools for repair, and temporary replacement where necessary.

In order to keep to restoration-of-production time schedules, panels invoked mutual aid schemes, established in advance between war production factories, to supply deficient resources, such as specialist technicians, building operatives, roofers and sheeters, cranes, welding gear, and so on, either in casualty factories or to restore essential services. Repairs to factories and workers' houses in the London area were carried out largely by the casualty firms' own production



A valuable link was forged between workers who helped to make the aircraft and armaments and the men who used them in battle, by the frequent visits made by men of the services to war factories. Here an A.A. gunnery officer is seen addressing workers at a factory.

labour, owing to the pressing need for building operatives for other housing repairs. The provision by neighbouring factories of local temporary manufacturing space and equipment also figured prominently in mutual aid schemes and was frequently invoked.

For the fabric of the building the first steps were demolition, where necessary, making safe, and clearance of roadways. Next followed, after consultation with the reconstruction panel, a specification of minimum repairs necessary to restore production based on war-time standards. Approval of these proposals and replacement or repair of machinery and plant led to resumption of normal conditions. More permanent repairs were deferred until circumstances permitted; meanwhile assistance to firms in recovering costs from the War Damage Commission was rendered. In some cases, where repairs *in situ* were not practicable, dispersal premises were found and production transferred. The number of such cases was comparatively small.

In the absence of appropriate departmental machinery, the E.S.O. network of panels, with their local knowledge and contacts with all factories in their districts, was used frequently as spearheads in campaigns requiring urgent national action. The organization successfully obtained the full cooperation of Government departments when it was necessary to bypass normal administrative procedure to minimize loss of production.

Over-all control of E.S.O. was assumed by Sir Allan Gordon Smith, with Mr. Brake as deputy, in June, 1941, when the Ministry of Aircraft Production Regional Organization was formed, incorporating the Directorates of Passive Defence, Production and Capacity, and Dispersal of Factories. Captain Spencer Freeman discharged the executive responsibility for E.S.O. and devoted his full time on a voluntary basis from the day of its inception in July, 1940, until after the cessation of the heavy flying-bomb attacks in September, 1944. Mr. V. C. Hanson was Deputy Director, E.S.O., and Mr. R. Lillice served part-time at headquarters coordinating the work of the London panels.

The keynote of the Emergency Services Organization was speed of action and encouragement of local initiative; the motive power was the enthusiasm, public spirit, and devotion to duty of 3,000 unpaid industrial executives and technicians, with a very small nucleus of loyal and untiring officials at Regional and Central H.Q., who together fought and won the Battle of the Factories.

16

WORKS RELATIONS

TO men and women in industry the victory in the war has been a triumph of the mind as much as of material things. In the workshops they would not contemplate defeat. Largely this stemmed from a sense of individual responsibility greater than at any previous time in British history; and largely this has been consciously developed by individual managements and workers' representatives whose war-time experience in the building-up of factory information services provides a pattern for the future.

It became clear in the very early days of the war that people in factories wanted information and not exhortation as an incentive to great effort. When the Ministry of Labour investigated absenteeism it found that "perhaps the most significant of what may be described as psychological causes is the lack of real interest in the job and a lack of conviction of its importance and urgency, due often to ignorance." Absentee figures were low in those plants where this fact had been appreciated and combated. Official help, when it arrived, took the form of a service which drew its inspiration from the provision of facts. It became known, and continues, as "works relations."

A new figure, the "works relations officer," made his appearance in industry, first in the Royal Ordnance factories administered by the Ministry of Supply and later in privately owned factories up and down the country.

It was his job to organize a programme of factory activity which included the use of service speakers, who talked of their battle experience with the weapons their audiences made, specially designed posters, weapon demonstrations (particularly for the small component producers), factory and mobile exhibitions, film shows, production charts, wall newspapers, and so on.

In addition to playing their part in the main job of building up good internal relations, these things were used to tackle specific problems. A production chart in an iron ore mine stepped up output by 14 per cent. in a week: it simply but graphically told the mine workers that without their ore Britain would be short of steel for

The lunch-time entertainments organized in the war production factories have been greatly appreciated by the workers. Mr. Ernest Bevin, then Minister of Labour, is seen addressing the audience at a munitions works.

tanks. A poster on welding electrodes cut the waste of stub-ends in typical factories by 50 per cent. In hundreds of works where service men spoke—giving facts, not "pep talks"—production rose. An economy campaign in a factory using easily spilled components cut waste by 23 per cent. These experiences were common.

Wherever "works relations" has been used intelligently it has helped to build a "happy ship," to sustain and increase production, to reduce scrap, to cut absenteeism, to improve quality of product.

All this has, of course, been aided by the sharp focus of the war. Now when the urgency of the need for production at any cost has gone, the job becomes more difficult. But in the months ahead a sense of partnership in industry will be no less necessary than during the war years. We shall still require to stimulate the interest of all concerned in the business of production in order to achieve a maximum output under the new conditions. Many believe the war has shown the way to do it.

Relations work of this kind has impinged on that of welfare—bad name for a good service which post-war industry will certainly be required to maintain—and has sometimes been a function of the personnel manager, sometimes of the publicity manager, sometimes of the managing director himself. It must never be described as, and never is, propaganda. It accepts the definition of Mr. Samuel Courtauld :—

> . . . . the worker is the most costly, the most delicate, the most various and variable machine which industry has to employ, and he is infinitely more complex and less uniform than any raw material, or any intricate chemical compound.

And in those factories where it is practised sensibly it produces dividends for management and men alike in healthier understanding of mutual problems.

It is a good sign that we have reached the end of that period in which hours of work and wages were practically the sole topics for discussion between employers and employed. The factory information service encourages the new trend through the efforts of individuals in particular plants, through works relations groups which have been set up in various parts of the country for the fuller exchange of ideas and experience, and through the works relations centres which during stage 1 of the war have been available to all firms engaged on war production. At these centres the material available from the Ministries has been displayed along with practical information on how to make the best use of it—often in the form of examples from factories themselves.

When he opened the London Centre Mr. Oliver Lyttelton summed up their war-time value and post-war promise in this way :—

> Production is a human problem. If even an odd thousand workers suffer from a sense of frustration and although that thousand may represent a very small percentage of the whole army of workers engaged in production, the evil that is done is out of all proportion to its size. It is with the object of stifling this propaganda of frustration that this centre has been formed. The old slogan "Theirs not to reason why, Theirs but to do and die" is as out of date as the penny-farthing bicycle. It is our duty

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to see that the people of this country are as well educated as they are patriotic: as far as possible the reasons for everything should be explained to them. I do not think anyone who visits these centres can come away without some new idea. It is new ideas which will help us to shorten the war, and it is largely upon new ideas that we must regain our place in the world of peace.

17

WELFARE WORK

THE scope of the war effort of the United Nations demanded tremendous industrial power. The vital necessity for maximum production gave added urgency and importance to man-power problems.

The Minister of Labour and National Service frequently emphasized the futility of speeding the evolution of labour supply policy at the expense of understanding, acceptance, and participation of all parties in the execution of the policy.

The Essential Work Orders, which restricted drastically the employer's freedom to discharge a worker, or the worker's freedom to leave his employment, were one part of a national effort to bring income and conditions of work up to a certain standard; for when an undertaking was "scheduled" under the Orders it was required to pay employees a guaranteed minimum weekly wage; while the Minister had to be satisfied that there were adequate welfare arrangements and, where necessary, arrangements for training.

This appreciation of the State's obligation to those asked to take part in war industry was reflected in the setting up of a Welfare Department in the Ministry of Labour to act with the Factory Department (previously under the Home Office). The Factory Acts represent one of the earliest examples of national concern for workers' welfare, but they covered only conditions inside the factory. The new organization was concerned with conditions outside the place of work affecting the well-being of the workers. It dealt, in conjunction with the Ministries of Health, Transport, Works, Education, with such things as bus and railway services, recreation, billeting, hostels, day nurseries, shopping facilities, British Restaurants.

Action to improve these conditions was not a luxury which could not be afforded in war-time. It was an integral part of man-power policy.

The Government, through the Factory Inspectorate and through the Supply Departments (Ministries of Supply and Aircraft Production and the Admiralty), continuously emphasized the need for efficient personnel management in factories and for trained welfare supervisors. The Factory Inspectorate were given powers to order that doctors, nurses, and welfare workers should be available. Because of the shortage of persons trained in welfare and personnel work, the Ministry of Labour inaugurated a training course for labour management and welfare supervision, and 800 persons passed through this course.

The Ministry of Supply itself, for the factories under its direct control, set up a Labour Department staffed by experts in personnel administration and labour management, in size and scope far beyond anything that had been known. A significant fact, proved up to the hilt by official and other forms of inquiry, was that absence from work (absenteeism) was markedly less in all industries and undertakings having competent personnel departments.

Little publicity has yet been given to the work of the Supply Departments and the Ministry of Labour in establishing hostels, sometimes accommodating as many as 1,000 persons in each, to overcome the inevitable problem of housing transferred workers. Provided with a theatre, games rooms, library, reading and writing rooms, as well as canteens, these hostels were centres of considerable social activity of a kind that will have an influence on post-war life in many towns and villages.

The lack of "somewhere to go nights" when, after the 1940-41 rush, some leisure time was to be enjoyed has been an important welfare problem. It was particularly acute in remote areas where hostels and builders' camps were set up, and in towns where recreational facilities were few and already overcrowded. It was nationally recognized that the existence of suitable and adequate recreational facilities helps immeasurably in the adjustment of workers to a new environment. The machinery of existing voluntary organizations was used, but the Ministry of Labour also fostered the establishment of workers' clubs run by specially created voluntary bodies in the places concerned. The capital needed to start these clubs was found by the Treasury. The T.U.C. urged all local trade union clubs to

open their doors to transferred workers and to develop special facilities for them.

In the large hostels the recreation and entertainment programmes were elaborate, mostly organized by the residents themselves, with occasional visits from parties of professional artists under the auspices of E.N.S.A. and C.E.M.A. Both these organizations provided entertainment inside the factories also, while the laying on of wireless music during working hours received a considerable impetus when the B.B.C. included a daily and nightly programme of "Music While You Work," and encouraged talent in the factories by broadcasting "Works Wonders" and similar lunch-time entertainment.

An important power conferred upon the factory inspectorate was the authority to direct any munitions factory employing more than 250 persons to maintain a suitable canteen. Very few orders were necessary and canteens were to be found in over 10,000 factories, half of them employing fewer than 250 people each. Civil engineering and building sites and docks accounted for 900 more. In addition, industries and undertakings not covered by factory legislation—railways, omnibus services, offices—provided on a large scale for this need. A combination of the Essential Work Orders and the Welfare Department of the Ministry of Labour (backed notably by the Ministry of War Transport in the case of road and railway services) resulted in a steady improvement in conditions in those industries and services outside the scope of the Factory Acts.

Medical supervision and service in factories was extended greatly during the war years. As against 35 full-time doctors employed before 1939, the number increased to 180, with 750 doctors substantially employed part time as compared with one-tenth of that number when war began. Special arrangements were made by the Ministry of Health with the hospitals to give special care to transferred workers, even to the provision of sick bay accommodation in cases of slight illness.

The steps taken to ease the burden of mothers who wished to give their help to the war effort were comprehensive: over 2,250 day nurseries, nursery classes and nursery schools, the opening of elementary infants' schools to 100,000 children under five years of age. Daily guardians also helped to a useful but limited extent, as did play centres after school hours. The problem of shopping was always difficult, and local settlement by committees of employers, trade unions, and shopkeepers was encouraged by the Ministries of Food and Labour. Generally speaking, adequate time off for shopping was found to be the best way to deal with it, and most employers made suitable arrangements of this kind. British Restaurants, of which more than 2,000 were opened, helped to meet the needs of small factories as well as assisting married women to take up employment outside their homes.

The employment of women was a special concern of the Ministry of Labour and a pamphlet was issued early in 1941 giving guidance to employers and advising special arrangements within the factory to meet the needs of women with domestic obligations. Part-time employment was a logical development.

The steps taken to remove the general wages problem from the field of controversy provided for the continuance of collective bargaining, but also ensured that agreed rates of wages should be effectively enforced, with the reference of unsettled claims to arbitration and the prohibition of strikes and lock-outs. The Conditions of Employment and National Arbitration Order was made. This provided for the reporting of a dispute to the Minister of Labour, whose first step was to see that the existing machinery within the industry was used. A failure there meant that the trouble would go to the National Arbitration Tribunal. Any agreement, decision, or award taken under the Order was binding upon the disputing parties.

Substantial advances were made in the provision for workers to have some say in the actual running of war industry. In 1941 voluntary joint committees were established at coal mines and shipyards, and in 1942 agreements were made in the engineering industry and for the Ministry of Supply ordnance factories to encourage the creation of joint production committees and similar consultative and advisory bodies. On these representatives of management and workers met to exchange views on methods of production and to cooperate in increasing efficiency. The movement spread to many other industries.

Man-power was mobilized because there was a will to cooperate, sustained by the knowledge that the State would see that

- The rate for the job was paid;
- Conditions of work were satisfactory;
- Decent living conditions were provided;
- Feeding arrangements were adequate;
- Transport to and from work was as good as possible;
- Health was safeguarded;
- Women's domestic obligations were eased;
- Dependent children were not neglected;
- Provision for leisure time was made.

CRUISER TANKS

In the assembly department of a factory showing British Crusader tanks in course of construction. The building of tanks in Britain was undertaken in the main by the railway locomotive builders and other firms normally making very heavy machinery, and to a lesser extent by the motor industry.

III. THE SERVICES' DEMANDS

18

EQUIPMENT AND STORES

THE provision of equipment and stores and medical supplies is a varied and fascinating responsibility. This is the field of non-munition supply, less spectacular but no less necessary to the successful waging of war than the provision of weapons, ammunition, ships, aircraft, vehicles, and all the other lethal essentials of attack and defence. The scope of equipment, stores, and medical supplies is limitless, and the production is the job of a vast range of industries which in peace-time are the most numerous and important in our industrial economy.

Textiles, cotton, wool, rayon, flax, hemp, jute, and silk; clothing and hosiery; every type of medal ribbon and badge; boots and shoes and leather goods; cordage and camouflage; narrow fabrics and web equipment; kegs and drums; hand tools and cutlery; accommodation and barrack stores and field equipment; woodware of every type; pharmaceuticals, drugs, surgical instruments, hospital stores, and X-ray; hutting, floating pontoons, emergency air strips, wood chips for surfacing airfields, bomb shelters, waterproofing equipment for amphibious operations; personal equipment of all kinds from a needle to a one-man tent; obsolete and used surplus clothing and stores for reconditioning, adaptation, or breaking down—these are a few of the tens of thousands of separate items which are comprised in equipment, stores, and medical supplies.

The majority of these stores are what is known as "common user"—that is, they, or many of them, are required in similar, but not always identical, patterns for every section of the fighting forces and official war organizations. It is, therefore, proper and natural that to a very large extent the planning of their production and the responsibility for their procurement became increasingly focused in one department as labour and materials became scarcer and the advantages of coordinated planning, which would eliminate competition and prevent waste, were revealed and recognized.

It followed naturally that the department responsible for this production, the Directorate General of Equipment and Stores of the Ministry of Supply, developed and expanded continuously and logically until it eventually took charge of this type of production not just for the Army but also for the Royal Air Force, Civil Defence Services, Land Army, Ordnance factories, and indeed for every recognized official war service, except in a large number of items, frequently of a specialized character, for the Admiralty.

In war production of this kind, which at every stage affects the amount of non-food consumption goods available for the civilian population, there has had to be close and continuous collaboration between the Ministry of Supply and the Board of Trade. In certain classes of stores—*e.g.*, medical supplies—and in those items for which service and Government requirements were the major user—*e.g.*, hand tools, kegs and drums, and narrow fabrics—mutual arrangements were made between the civil departments

concerned and the Ministry of Supply which placed upon the Supply Ministry the additional responsibility, in its planning of production and allocations of materials, for ensuring an adequacy of essential supplies for the civilian population.

To ensure the best use of manufacturing capacity, labour and materials, this branch of the Ministry of Supply also undertook certain allocation duties, as distinct from production functions, as, for example, in the Directorate of Woodworking. In this way it was possible to secure that the steady flow of multifarious demands on woodworking capacity should be placed in such a manner as to spread the load equitably over the industry in conformity with national considerations and thus ensure the quickest possible execution of urgent contracts, many of which were ancillary and were not, therefore, susceptible of forward planning.

The Directorate-General of Equipment and Stores is made up of 10 production directorates located either in London or in the most convenient provincial centres of the manufacturing industries concerned. Two other directorates—one for Provision and Coordination, providing a constant link and liaison between the user service or department and the production branch or oversea procurement agency, and one for Progress and Inspection—give common service to the department. The Chief Inspectors of Stores and Clothing and the Chief Progress Officer and their staffs come under the latter directorate, and the Chief Inspector of Medical Stores under the Directorate of Medical Supplies. There is, therefore, continuous and close contact between the Chief Inspector, who designs the item in collaboration with the user and planner and provides the specification ; the Production Director, who plans the production and allocates the materials and components, and the Progress branch, which maintains touch with the contractor from the moment the order is placed by Contracts Department until the goods are delivered to the user.

The first Director-General of Equipment and Stores was Lord Woolton. He was succeeded in 1940 by Lord Catto, who was followed by the late Sir William Wilson. The present Director-General, Sir Cecil Weir, was appointed in May, 1942.

The monthly reports of the various production directorates in this branch read like veritable industrial romances with their accounts of the placing of contracts for individual items by the million and tens of millions, cloth by scores of millions of yards, cartons by the hundred million, and all kinds of commodities and products in quantities and numbers unheard of in ordinary commercial life. Over 30,000,000 battle-dress, about 50,000,000 blankets, nearly 100,000,000 pairs of standard army socks, over 25,000,000 towels nearly 40,000,000 pairs of ankle boots since 1939 ; enough bandages in a single year to encircle the world four times ; 18,000,000 packing cases in 12 months ; 8,500,000 gallons of paint and 250,000,000 boxes of matches in the same period ; several hundred thousand ambulance stretchers ; 9,000,000 sets of web equipment for all services—here are a few items selected at random to give a measure of war production carried out in the United Kingdom alone. This takes no account of large supplementary supplies of certain items provided from the United States of America, the Dominions and colonies, and other oversea sources.

The functions of the Clothing and Textiles Directorate of this department do not stop at the provision of uniforms and service garments. They take them also into the field of normal civilian manufacture—and have caused them also to enlist the much valued cooperation of the voluntary women's organizations—for the production and procurement of many millions of garments and a great deal of cloth and components for the relief, under War Office direction or Unrra arrangements, of the urgent necessities of the liberated countries of Europe and the Far East. They have placed upon them, too, the considerable and complex responsibility for the production of the civilian outfits for demobilized sailors, soldiers, and airmen, not only for planning the entire production of and materials for this high-class range of suits, raincoats, shirts, collars, ties, hats, and, in collaboration with the Controllers of Footwear and Hosiery, shoes and socks, but also for assisting the Service Departments in organizing their issue arrangements.

But clothing and textiles as a production function goes far beyond the provision of clothing, wide and varied as that responsibility is. It includes also such items as bedding, towels, bitumenized textile airfield tracks, tents and tarpaulins, and a host of technical and operational stores, both main and ancillary, which are actually inside the direct munition field. It covers the production of steel helmets, of which over 20,000,000 have been made for the services and civilians, needles, body armour, and other mainly metal items which are associated with this side of equipment either for use in its production or as a component of the store itself.

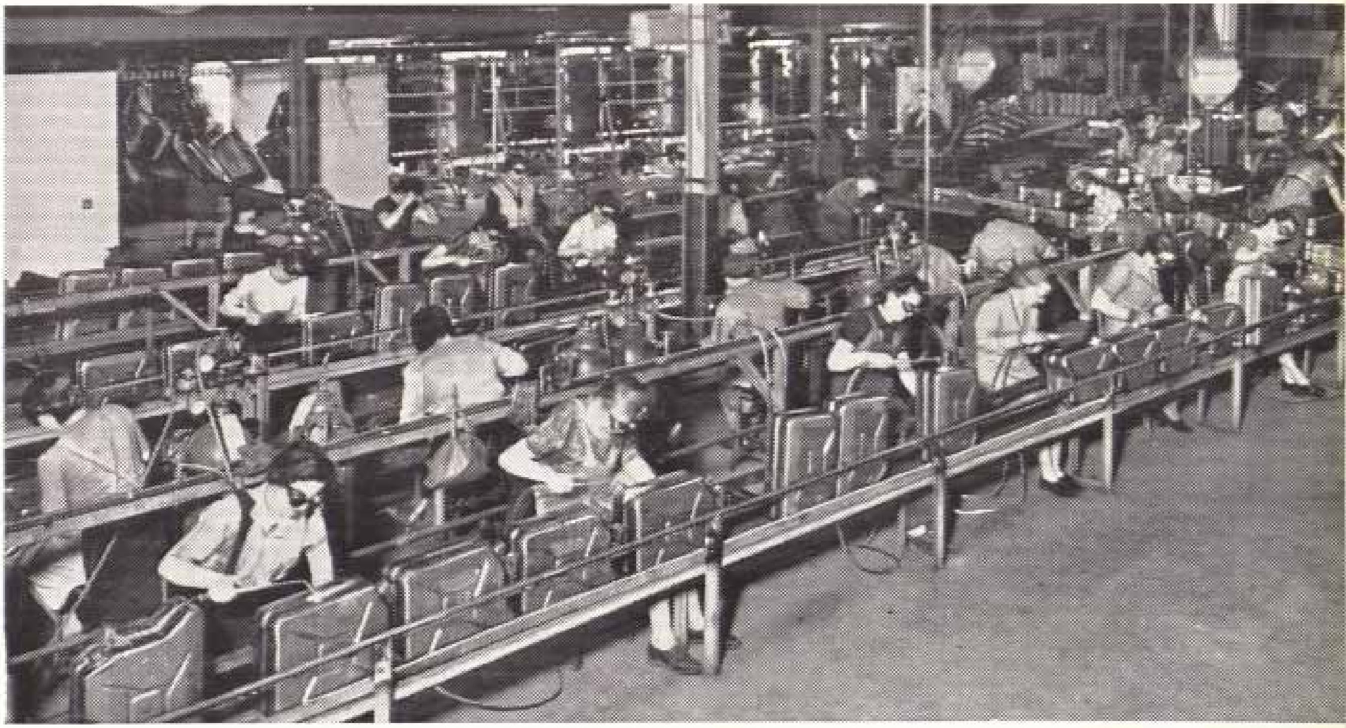
It may be asked what is meant by " produc-

tion" when applied to this supply department? It does not, of course, except in a limited number of cases, mean the actual manufacture in a Government-owned factory by Government servants of the store in question. It means, to take clothing as an illustration, determining the specification, quality or texture of every item comprised in the finished garment, ordering the cloth, the buttons, the linings, the thread, and the other components and issuing the appropriate amounts of each to the maker-up, who in his turn must manufacture to an approved specification. At each suitable stage inspection by trained viewers takes place, and throughout the period of production progress officers are available to assist the contractor to clear bottlenecks of transport, material, or labour, and to see to the expediting of urgently needed items which may either be coming along too slowly or which have to be hastened to meet a sudden or advanced operational requirement.

The production department is a supplier and a planner who uses industry as producer and frequently as adviser.

The flexibility of the consumption-goods and light engineering industries has been amply demonstrated in the war. Despite concentration and contraction of capacity in terms of space and labour, the workers, many of them either much over or much under average working age, have on the whole given a good rate of output per operative and manufacturers have proved adaptable in the difficult management problems of turning over from one type of production to another. The low labour priorities which these industries, generally speaking, have had have increased their problems, but they have been helped in getting production by the ready provision of materials from the Department's allocations, by long and regular production runs on the same or similar items and by the coordination of patterns which has been greatly developed in order to simplify manufacture and to economize in labour, materials, and production time without affecting serviceability.

A branch of production with so wide a range as equipment and stores has, of course, had its highlights, and some of these are of considerable public as well as Service interest. A war speeds up development and stimulates research, and a production department must keep in close touch with the scientists and research chemists.



Manufacturing Jerricans at a British factory. This steel four-gallon petrol container proved of great utility during military movements. Over 40 million Jerricans had been delivered by the early months of 1945.

On the medical side outstanding developments are penicillin and mepacrine. The first has saved thousands of lives and expedited the return to health and fitness of very large numbers of wounded and sick in the forces. The second has overcome the calamity which otherwise the loss of most of our quinine supplies would have entailed, and probably has opened the door to a wider attack, in the post-war era, on the evils of malaria. The development of both can be attributed in the first place to the action of the department, stimulated by war urgencies, and to the cooperative enterprise and team spirit displayed by the manufacturers and laboratory workers concerned.

Several thousand million tablets of mepacrine have been supplied since its manufacture began in 1942 after the fall of Java; from the United Kingdom alone more mepacrine for the treatment of malaria is being produced each year than the annual work output of quinine before the war. In the case of penicillin, joint American and British efforts have resulted in all Service requirements being fully met and in this wonderful drug becoming available to civilians in every necessary case within what, in other circumstances, would have been an incredibly short space of time.

But we must pass on from this fascinating branch of supply to the field of general stores and similar groups of Service supplies. Among the metal containers an outstanding item is the Jerrican. It is not too much to say that without this remarkable strong steel returnable four-gallon petrol container the rapid military advances across the Desert and the Continent could not have been made. The late President Roosevelt, in expressing appreciation of the supplies made available to the American Army under reverse Lend-Lease, put it even higher than that. This can came in to production only in the autumn of 1942, yet by magnificent team-work on the part of the manufacturers over 40,000,000 Jerricans, containing some 250,000 tons of special steel, and employing many thousands of specially trained, mainly female, workers, had been delivered to the Army, Navy, and Air Force and to our American allies by the early months of 1945, and every demand had been met on time.

Over a million Morrison shelters, enormous numbers of Nissen huts—over 100,000 of the standard living hut and over 40,000,000 sq. ft. of the larger sizes in one year alone—deceptive devices by the thousands, untold fathoms of glider towing ropes and parachute cords, tools for every conceivable type of weapon, vehicle, gun and aircraft, boots for snow and footwear for the tropics, "compo" ration packs and water-bottles, water sterilizers and disinfectants, skis and Arctic outfits, and so on and so on. The number of separate items is very large, and in each of them the requirements must necessarily be sufficient to cover first issue and maintenance for all the users. Adding to the numbers enlisted in the general fighting forces those of the Home Guard and Civil Defence services and other Government organizations, and calculating the requirement over the war period, the extent of industry's contribution in non-munition war production can be assessed.

For the present this production continues. Non-munition requirements go on after fighting ceases and until demobilization and the using up of stocks diminishes current demands. For the Far East war new equipments were devised and are still being produced. They are designed to increase comfort, safeguard health, and reduce, as far as possible, the risks to the troops using them. Lightness, coolness, resistance to tropical pests, rot, and rust—these are some of the major requirements of these new types of clothing and equipment. Again ingenuity, experience, and technical and scientific knowledge have been called into play, and again they have responded. The jungle boot is a technical triumph, and there are many others.

Finally there is the reverse of new production, which also comes within this department—the disposal of surplus and used materials, clothing, and stores. For several years back, since salvage arisings and the throwing up of obsolete stores started, nothing has been allowed either to go to waste or to be sold other than through controlled channels. Millions of battledress, for example, have been repaired, cleaned, dyed, and issued either back to the Services from which they emanated or to the civilian market for agricultural workers or to clothe enemy prisoners of war. What was unusable in this way has gone back to raw material to be rewoven. Enormous numbers of boots, no longer wearable in the field, have been rebuilt, repaired, or reconditioned either for the Services, for relief in Europe, or for prisoners of war. And so through the whole range of returned stores the system of re-use has operated to the maximum. The ultimate disposal of war surpluses in collaboration with industry has already been the subject of a White Paper and need not, therefore, be elaborated here.

19

SHOT AND SHELL IN THE MAKING

THE old adage, *experientia docet*, does not always prove to be true, but fortunately in the case of ammunition, production benefited by past experience and made provision for the supply of adequate rounds, so that this time there was no shell scandal. In fact, production was in excess of that found to be necessary, but to meet the changes that were encountered on the field of battle, new types of ammunition had to be evolved from time to time, and this frequently necessitated drastic alterations in methods of manufacture.

The production of shell is often regarded by the uninitiated as a very simple engineering proposition in that the dimensional limits allowed are on the generous side, but it is possible to comply with all such requirements and yet be faced with rejection because the article is above or below the stipulated weight. Again, the ordinary engineering machine tools are not suited to mass production of ammunition, and special single-purpose machines had to be evolved and produced in quantity sufficient to meet the anticipated requirements of total war. Fortunately this was appreciated in pre-war days, and some machines were built and tested before war was forced on the country.

The question of actual requirements was not easy to determine, being largely dependent upon experience in the field. While it was the considered opinion that trench warfare was a thing of the past, and accordingly the necessity for artillery barrage was rather remote, it was yet realized that it was essential to be prepared for any contingency that might arise.

Probably no better example of the problems connected with ammunition could be cited than that of anti-tank shell and shot, which have had to be modified to suit the increase in protective armour adopted by the enemy. The pre-war requirement was limited to the 2-pdr. shell, which in turn gave place to shot, for which Treasury sanction for an output of 1,076,000 was approved, and at that time this shot was considered superior to the German 3.7cm. shell. To be used effectively the weapon needed a degree of cover which the desert could not afford, and accordingly there was an outcry that British guns were no match for the 5.0cm. used by the Germans. This, however, was met by the 6-pdr., the use of which contributed materially to the successful campaign in North Africa. In time this was countered by the 7.8cm. and 8.8cm. weapons introduced by the Germans, but with our 17-pdr. and high velocity shot the situation turned in our favour, and the 17-pdr. Sabot proved superior to the best of the enemy's ammunition. The penetrative effect and range of shot was materially improved by capping the shot and superimposing a ballistic cap.

A photograph taken in a shell factory in the South of England showing men of the night shift at work. This factory was one of many visited by the King during the war.

Women operatives turning and finishing 25 - pounder shell cases. The 25-pounder gun was tried out with great success in Greece and was later employed on a vast scale in the North African campaign.

While it is easy to record the rapid development from one form of ammunition to another, production difficulties were encountered which at times seemed almost insuperable. Before the war the manufacture of armour-piercing ammunition was restricted to one or two armament firms and it was no easy matter to introduce into a number of ordinary engineering works the necessary technique for the machining of the special alloy steels used and the heat treatment necessary to secure the desired penetration and fragmentation. Fortunately, the steel adopted was very similar to that used for ball races, so that the method of heat treatment was not entirely new.

Perhaps the ammunition of most interest to the British public was that used for anti-aircraft purposes. The 3in. 20cwt. high-explosive shell had been evolved as the result of the experience gained during the 1914-18 war, and when war broke out in 1939 this was being produced in considerable quantities, but it was realized that it was not capable of reaching planes flying at the height which was likely to become operational, with the result that the 3.7in. weapon was evolved. The period between Munich and September, 1939, was used to increase production of this 3.7in. ammunition and contemporaneously the heavier 4.5in. shell was turned out, but this never really found favour, and the 3.7in. was the ammunition that contributed most to the success of the gunners during the extensive attacks on London in 1941.

After the successful defeat of the mass attacks on London, the enemy resorted to low flight tip-and-run raiding, which in turn was countered by the 40mm. shell. This was so effective that the attacks became too expensive for the enemy to continue. Even at the peak period of expenditure it was found possible to meet all requirements. Development of the rocket and its place in anti-aircraft work is dealt with in another article.

Let us return to field ammunition. Before 1939 a considerable amount of work had been undertaken in planning the change-over of industrial plants to mass production of the huge quantities of artillery ammunition estimated to be required in an emergency. Plant had been designed and ordered and was in many cases in the course of installation. This covered the range from light 40mm. Bofors A.A. ammunition and two-pdr. A.T. to 25-pdr. and on to 9.2in. Fortunately in the 25-pdr. we had a weapon which proved to be remarkably efficient. It can be said to have finally passed its trials in Greece with first-class honours. Later it was built in devastating numbers for the greatest barrage known in history. Perhaps the finest joint production of the gun maker and the ammunition maker was the 5.5in. howitzer, which fires an 80lb. shell with long and accurate range, and this proved a godsend to the infantryman.

At the beginning of 1943 the supply position was such that production of 25-pdr. ammunition and several other sizes was practically stopped to release labour for other urgent preparations for D Day.

With the successful landing in the summer of 1944 the demand for ammunition again increased,

plants were brought back into production and by the end of the year were again working at their 1941 level. By March, 1945, they were almost back at their peak again, ensuring that the army in the field never lacked full weight behind them.

With VE Day the demands again decreased, but stocks had to be maintained and the special requirements for war in the Far East increased in importance.

In line with the heavy demands for shell it was also necessary to provide special types of ammunition for the infantry, and apart from the numbers and variety involved the problem was complicated by the necessity of utilizing a somewhat different industrial sphere. The infantryman's friend of the last war, the Mills bomb, still had a function to fill, but changed conditions necessitated our forward troops being provided with an antidote to something more deadly than infantry charges, and hand weapons, including anti-personnel and anti-tank grenades and demolition charges, involving manufacture in iron, steel, plastic, and glass, were introduced.

The consolidation of ground won in the war required the provision of mines of many types, while the infantryman's own gun, the trench mortar. was developed in a variety of types.

In the production of these stores the small factory came into its own and, by the judicious placing of the work, garages, printers, papermakers, and a host of other trades, were soon capable of meeting the demands. Perhaps in this work more than any other the adaptability of British industry was used to the full, particularly as recognized standard materials became scarce. Steel forgings had to give way to cast-iron; aluminium—needed for aircraft—had to give place to zinc, tube to fabrication, brass to steel; but despite all these changes the rounds did not suffer, indeed their range and lethal effects were generally improved and production times reduced.

When dealing with a production rate of 1,000,000 a month, it will be appreciated that a change of process which saved 10 per cent. of the cost and a similar percentage of production time, such as was introduced at one point, was of the greatest value.

One other side should be mentioned: that of "insurance" ammunition production. It was stated by the Government that any use of gas or chemical warfare by the enemy would be countered tenfold, and this had to have foundation in fact. While fortunately neither was utilized, the "tools" necessary were delivered.

At the peak period upwards of 1,500 firms were engaged in ammunition production, these being spread strategically over the country. In order to equip them capital assistance was given to firms to obtain the necessary plant, &c., to the value of some £40,000,000. Women were largely employed on the work, and the help given by the trade unions was material.

The six-year story has been one of growth, change, decrease, and growth again made possible only by the willing and enthusiastic cooperation of all concerned both in the firms and in the Government production departments. This fact carried with it a lesson as to the importance of ensuring that the means of production are maintained and are sufficiently flexible to be able to expand and adapt to meet the changing demands of a major war.

The numbers of shells, &c., filled during the period from 1940 to June, 1945, were as follows:—

A.A. shell	51,900,000
Tank and anti-tank..	49,500,000
Field medium	68,500,000
Mortar bomb	89,800,000
Grenades, mines, &c.	100,700,000
	360,400,000

Ammunition for Small Arms

A review of the ammunition position by the Chiefs of Staffs Committee in the early days of the war disclosed a dangerous shortage of small arms ammunition, threatening both the build-up of an adequate field force on the Continent, as well as the development of the offensive and defensive power of the Royal Air Force.

At this review, potential capacity was rated at 60 million rounds a month, of which only five millions a month had been in regular commission for some years before 1939. The Chiefs of Staffs Committee estimated full war expenditure of S.A.A. at about 500 million rounds a month, including 120 millions for the R.A.F., but whereas the initial requirements of the Army and Navy were almost wholly for ball ammunition of .303in. and 7.92mm. calibres, the R.A.F. demanded quantities of special types of .303in, (armour-piercing, incendiary and ranging tracers).

which grew to predominant proportions as the strategy and tactics of the Air Arm developed.

The introduction, for example, of the self-sealing petrol tank required the use of new types of incendiary bullets for attack of enemy aircraft.

By this time, too, the 20mm. Hispano Suiza cannon was becoming of increasing importance in the armament of aircraft, and the satisfaction of demands for the large variety of types which were developed for this calibre presented a very formidable production problem, the productive effort expended on some of these types being as much as 35 times that needed to produce a round of .303in. ball.

A further complication arose from the decision to chamber the Sten gun for 9mm. ammunition, a continental calibre, so that captured enemy dumps could be utilized by our advancing forces. Difficulties were encountered owing to our lack of experience in the production of this ammunition, and some considerable time elapsed before these were overcome.

The packing of S.A.A. added a complication not present in the production of all warlike stores. To cover the use of S.A.A. in various fields of operation, packing in suitable quantities and in suitable containers had to be evolved. A packing suitable for ammunition to be used in a fighter aircraft might be entirely unsuitable for the same ammunition destined for use by an infantryman or in a tank or, again, on the high seas. Furthermore, the global character of the war, covering a very wide range of climatic conditions, called for special waterproofing of the ammunition and the hermetic sealing of the packages in which it was transported and stored.

The problem of raw materials was also, at almost all times, acute. Technical considerations

Shells stacked in a filled shell store of a Ministry of Supply filling factory, ready for fitting with fuses. From 1940 to June, 1945, over 360 million shells, grenades, and mines were filled in Great Britain.

The Cromwell tank, which, with the Sherman, composed the main strength of our armoured divisions.

involved constant modification of designs, and towards the middle of the war a threatened shortage of copper entailed the development of an entirely new technique for using steel with a 10 per cent. coating of gilding metal, instead of pure cupro-nickel or gilding metal for the production of bullet envelopes.

As against four factories before the war, there were ultimately 20 factories engaged on production of components or their filling and assembly into complete rounds. Additionally, recourse was had to a large number of trade firms for production of 20mm. components and armour-piercing steel cores. As to the equipment and manning of these establishments, it was found that, owing to the lack of orders in peace-time, there was a grave deficiency of makers of S.A.A. plant, process tools, and gauges. The extent of the personnel problem may be gauged from the fact that at the peak of production there were well over 100,000 operatives employed in S.A.A. factories 30,000 males and 70,000 females.

Between September, 1939, and VE Day the total of S.A.A. supplied from United Kingdom factories was about 12,000 million rounds, of all calibres up to and including 20mm. Production for Empire account in the Dominions and India to the end of 1944 amounted to another 7,750 million rounds, mainly .303in. and 9mm. In addition, about 7,500 million rounds were obtained from the United States, mostly .30in. and .50in., production of these American calibres being left almost wholly to the United States.

By the date of the German collapse, a total of approximately 30,000 million rounds of S.A.A. had been made available for the prosecution of the war by the forces of the British Commonwealth, allied contingents fighting alongside them, and patriot forces in countries overrun by the enemy.

20

CHANGING TANK DESIGN

WHEN the Battle of France began in 1940 Germany was able to deploy a team of four tanks suited to the needs of the *Blitzkrieg*. Those tanks had been designed and built for that purpose during the preceding six years. As the war in Europe drew to its close, Britain's team of tanks was just beginning to be deployed. Thus was driven home—if it needed to be—the lesson that it takes years to design and build a tank for whatever role it may be intended.

The German team consisted of the Panzers Marks I, II, III, and IV. The first two were considered to be light tanks, the third was a cruiser, and the fourth, although considered a heavy tank, was in reality only a heavy cruiser. Later, when the *Blitzkrieg* had spent itself, the German designers turned to defensive tanks and produced the monstrous Tiger and Royal Tiger.

At the outbreak of war the British Army had one light tank, the Mark VI, with an armour basis of half an inch, an armament of two machine-guns (.303in. calibre), and a cross-country speed of about 35 miles an hour; several cruiser tanks with thin armour and the two-pounder gun, and the Mark I Matilda, with an armour basis of 2in., one machine-gun, and a speed of six miles an hour.

The Matilda Mark II, which came into service in 1940, was probably the most powerful tank in the world at that time. It had an armour basis of 60mm., with frontal armour of 2½in., was armed with a two-pounder gun (40mm.) and a Besa machine-gun, and had a cross-country speed of about 11 miles an hour. It weighed about 28 tons. Matilda was more than a match for all the German tanks then in service, carrying more armour and a better armour-piercing gun. Then in development was the Valentine, a cruiser tank with an armour basis of 2in., a two-pounder gun and a machine-gun, and a cross-country speed of about 13 miles an hour.

All the tanks which we had in France at the time of Dunkirk were lost. We had left in Britain about 50 of all types. Perhaps the worst feature of the loss was the fact that the enemy had in his possession both of our newest types and could study them at leisure. He learned his lessons quickly, for the German Mark IV was soon fitted with a long 75mm. gun. At the outbreak of war the heaviest German armour-piercing tank gun was the 37mm., which was increased after the battle of France to the 50mm. In these circumstances it was decided to go into production with the Churchill, which, at that time, existed only on the drawing-board. It was designed as an infantry tank for the purpose of cracking a fortified line. That the tank had to overcome many troubles is common knowledge, but the astonishing fact is that it eventually proved to be our best all-purpose tank with no fundamental alteration of design.

The Churchill was originally designed with frontal armour of 4in. and side armour of 3in., with a turret of 3in. thickness. To begin with, it carried a two-pounder gun and a 3in. howitzer and two machine-guns. At first it had a speed of nine miles an hour. It was mechanically unreliable, and it was urged in its favour that if it broke down it could be used as a strong-point because of its very thick hide.

The Churchill now has much thicker armour—its frontal plate is the thickest of any tank yet in service anywhere in the world—it carries either a six-pounder (50mm.) or 75mm. gun, and in the Crocodile flame-throwing version carries a flame gun as well. It is also fitted with a 12in. mortar (A.V.R.E. assault tank), or can be fitted with three different types of bridging gear. In the ordinary tank form it now has a speed across country of 13 miles an hour, and has acquired a splendid reputation for reliability. It is an immensely strong tank, as one story shows: a Churchill was left standing on a slight slope and for some reason its brake failed. The tank ran down the slope and into a gravel pit 40ft. deep. When the crew recovered it they drove it away undamaged.

The first tank to achieve real reliability was the Valentine. It was an unspectacular vehicle which performed consistently well, particularly in the Western Desert. It was there that tanks of that type set up the astonishing record of running over 3,000 miles on their tracks without breakdown of any kind. The German tanks in the same theatre were expected to do no more than 500 miles between major overhauls, and frequently did much less. Captured German reports showed that their tanks were suffering from every conceivable sort of trouble from suspensions to turrets. It says much for their repair organization that they were able to keep so many of their tanks running.

It was quite obvious from the beginning of the war that we should sooner or later have to fight an offensive war—it was, in fact, the condition of our survival. But the tank requirements were changed with the shifting scene of war; from heavy infantry tanks to smash the Siegfried line, to cruiser tanks for the desert; and back again to infantry tanks. In the cruiser tanks speed was required, and if at first it was achieved at the expense of armour and gun power, it was later allied to those qualities. The Crusader was certainly a fast cruiser tank, but its armour was thin and it carried at first only the two-pounder, later being fitted with the six-pounder. Mechanically, too, it was not remarkable for reliability. However, it paved the way for the Cromwell, Centaur, and others. Sherman (carrying either 75mm. or the British 17-pounder gun) and Cromwell composed the main strength of our armoured divisions.

Both the Cromwell and Centaur have 3in. of frontal armour and 1¾in. on the sides. The Cromwell is fitted with the six-pounder gun or the 75mm., and the Centaur with the 95mm. howitzer, a weapon which proved invaluable in the assault on D Day. Both tanks can cross country at about 30 miles an hour with an ample reserve of power. The Challenger, which is simply a lengthened Cromwell fitted with a larger turret carries the 17-pounder gun. The Challenger

and the 17-pounder Sherman provided the heavy gun-power needed by our invading forces to combat the German Tigers and Royal Tigers. That they were able to do this was partly because of the special "Sabot" ammunition which they could use.

Following on the Cromwell came the Comet, another cruiser tank, more heavily armoured and carrying a heavier gun in the 77mm. This gun was a new departure, being a "hotted-up" 75mm. firing the same shot as the 17-pounder. In addition it is fitted with new gun-laying devices, which give greatly improved fire control. A further improvement is in the cupola, which is provided with immediate all-round vision without the necessity of swinging the periscope round.

Whatever type of tank he is aiming at the designer must always endeavour to make the best compromise between weight of armour, gun power, and speed in a vehicle which is limited in size by such factors as the load which military bridges can carry (remembering that the tank frequently has to cross the bridge while carried on its transporter vehicle), and the width and the loading gauge of British railway track. An additional complication is the paramount necessity for the tank to "float" over heavy ground. This means width of track. A further handicap was imposed on British designers by scarcity of suitable engines, either petrol or diesel. In peacetime British motor engineers produced only one or two engines of more than 100 horse-power, and so, until the Merlin aero engine was converted to tank use, there was only the Bedford engine, of 350 horse-power, and the Liberty, of 400 horse-power. The Merlin was thought to be unsuitable for the very heavy stresses of tank propulsion by reason of its delicate design and specialized nature, but it has proved to be an extraordinarily tough and reliable unit in action. It is this powerful unit that has made possible the Cromwell, the Centaur, the Comet, the Challenger, and the Centurion.

Nothing has yet been released about the Centurion except its name and its number, A.41, but it may be supposed that it is another step forward in design or it would have been unnecessary to produce it.

It remains to describe the special purpose tanks, of which there are quite a number. They consist of the various A.V.R.E. (Armoured Vehicle, Royal Engineers) Churchills, already referred to briefly, and one or two other types.

Taking off in the order in which they came into battle, first came the flail tanks for clearing minefields. The most recent of these is the Sherman Crab. There are other mine-destroying devices, but they have not yet been taken off the Secret List. It has been a cardinal principle of British tank design that wherever possible the special purpose tank shall keep its ordinary armament, so that when its special function is completed it can go on fighting. The flail tanks still carry their main armament in the turret. So does the Churchill carrying the fascine, which is used for filling in the ditches.

The A.V.R.E. Churchill (carrying the 12-inch mortar or Petard) is primarily for use against concrete fortifications. The charge thrown (called the "dust-bin") has a very potent effect upon reinforced concrete fortifications. The range of the Petard is short.

There are two types of bridgelaying tank, the Valentine and the Churchill. The Valentine normally carries the Scissors bridge, and the Churchill carries either the Scissors small box

The Churchill, which later became our best all-purpose tank. A Churchill tank is seen crossing a Scissors bridge, which can be carried by a Valentine tank.

girder or another type of bridge. In addition, there is the Churchill fitted with trackways (Twaby Ark).

Two factors which made for improvement in the performance of British tanks were the increased use of welding and the effectiveness of the methods of welding employed. It will be interesting to see whether there is any limit on the effectiveness of welded armour plate.

The construction of tanks in Britain was undertaken in the main by the railway locomotive builders and other firms normally making very heavy machinery, and to a lesser extent by the motor industry. Behind these firms stood a huge army of sub-contractors of every sort and condition.

Armoured Cars

The popularity of the armoured car with the troops in the field has waxed and waned according to the various phases of different operations. For example, they were regarded as a first priority for the campaign in the Western Desert, but in the early fighting in Normandy were used little, if at all. Later on, when the front became mobile again, the armoured cars came back to popularity. Their usefulness in Italy was always limited by the terrain.

Despite all this, some excellent examples of armoured car design have been produced and, in suitable circumstances, they have proved very effective. At the outbreak of war the Guy armoured car was being supplied in quantity. Later came the Daimler; both Daimler and Guy were remarkable for having the engine at the back. The Daimler was capable of being driven both ways, there being a separate steering wheel for the purpose.

Humber supplied large numbers of cars which were used by the Army, and Morris supplied some for the Army and the R.A.F. Regiment. A.E.C. provided a very heavy design which was able to carry the six-pounder gun, and later the Mark III of this type was built to carry a 75mm. field piece.

Daimler and Humber supplied a great number of Scout Cars. Some of the Humbers were fitted with an ingenious arrangement which enabled the gunner to fire a .303 Bren gun without exposing much more than his steel helmet above the car turret. This was a remote control handle-bar arrangement which carried the firing mechanism.

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GUNS OF TO-DAY

ALTHOUGH the Royal Regiment of Artillery laboured for long, during the war with Germany, under a quantitative disadvantage as compared with the artillery branch of the German Army, its advantage in quality kept growing steadily. Except for some few pieces brought out of store for possible use in the event of a German landing here (after the disaster of Dunkirk) a clean sweep had been made, or was being made, during the years between the wars, and new weapons were being designed and built for every branch of gunnery.

The basic weapon of British artillery is the 25-pounder gun-howitzer, which was developed from the experience gained with the 18-pounder of the last war. The 4.5/5.5in. gun-howitzer took the place of the old 60-pounder and 6in. howitzer. The Coast Defence guns have undergone a clean sweep and have almost doubled their range. There were still a few 3in. anti-aircraft guns in use, although they had been outmoded by the vastly superior 3.7in. The 3in. guns were kept as a stand-by until sufficient 3.7s had been produced. It was not generally appreciated that the 3.7 was in many respects a better gun than the German 88mm., good though this weapon undoubtedly was. The reputation of the 88 was probably due to the fact that the enemy had enormous quantities of the gun and could afford to bring them right up forward for use in the anti-tank role, as well as using large quantities of them as anti-aircraft guns and field guns farther back.

The 88 was conceived as an all-purpose gun, and this conception helped to make it easy to provide production in quantity. In addition, large numbers of them were sold to the countries bordering on Germany. Thus they formed a *cache* against the day when German forces would overrun those countries, as they did. As an anti-aircraft gun the 88 was outranged by the 3.7; as an anti-tank gun its penetration performance was not as good as that of the British 17-pounder. All the same, the 88 was a very formidable proposition to come up against in any circumstances.

It is probably true to say that the 25-pounder gun-howitzer is the finest gun of its type in the world to-day. It is relatively light, yet robust; it has a long range, yet is extremely accurate; it is simple to build and to maintain. In hard

A battery of 25-pdr. gun howitzers. Developed from the 18-pdr. of the 1914-1918 war, the 25-pdr. is described as probably the finest gun of its type in the world.

figures it throws a 25-pound projectile 13,500 yards, and can fire as a field gun or as a howitzer. Although its muzzle velocity in its normal role is only 1,700 f.s., it has performed most useful work upon occasion as an anti-tank weapon, firing a solid shot of 20 pounds at a muzzle velocity of 2,000 f.s.

The 25-pounder has been supported in the field by two guns on a common carriage, known together as the 4.5/5.5in. gun-howitzer. This extremely convenient arrangement provides the heavy mounting of both gun and howitzer fire that is needed in the field. It means also that provision of spares is considerably cut down as only one type of carriage is to be provided for. The performance of the two guns is :—

4.5 :—Range, 20,500 ; muzzle velocity, 2,250 f.s. ; weight of shell, 55lb.

5.5 :—Range, 16,000 ; muzzle velocity, 1,675 f.s. ; weight of shell, 100lb.

The 25-pounder, the 4.5, and the 5.5 have provided between them the vast preponderance of those enormous artillery barrages which have been such a potent factor in the success of our armies in the field.

It was always recognized that the 7.2 howitzer was a good gun, but the carriage with which it was provided was never particularly satisfactory, and various means had to be adopted to enable it to stand up to the tremendous recoil thrusts of the full charge when it is fired at extreme ranges. This disability has been most happily overcome by marrying the gun to the American 8in. howitzer carriage. The 7.2 has a slightly longer range than the 8in., although it fires the same weight of projectile (200 pounds).

The anti-tank regiments of the Royal Artillery began the war with the two-pounder, which was quite an effective piece for use against the armour thicknesses then prevailing in enemy tanks. It was a light gun with a rapid rate of fire and very great accuracy, although its muzzle velocity was not particularly high at that time. However, this was improved upon later and towards the end of the European war the gun was again brought back into prominence by the addition of the Littlejohn attachment, which very materially improved its armour-penetration performance. The six-pounder anti-tank gun came into use during the campaign in the Western Desert, and was at once acclaimed as a most effective weapon of its type. As compared with the enemy's 50mm. (the six-pounder has a calibre of 57mm. and is known by this name in the American Army), the six-pounder was considerably superior in performance. This weapon, too, has had its effectiveness increased by the use of special ammunition, in this case " Sabot " shot, which enables it to pierce the very heavy armour of Tiger and Panther tanks. Its muzzle velocity varies with the different types of projectile which it can use. The lightness and rapid rate of fire of this gun make it an admirable front-line weapon.

The development of the 17-pounder anti-tank gun—considered by many to be the finest anti-tank gun in the world—sounds like the spy story by Philips Oppenheim. Normally artillery is developed as the result of an intelligent appreciation of what the enemy will produce and also as the result of improvements in gun steels, propellants, and other technical items. It is true to say, however, that the 17-pounder was designed and developed to meet the Tiger, information about the development of which had reached Intelligence from various sources. It is a coincidence worthy of the rest of the story that both the 17-pounder gun and the Tiger tank should have gone into action in Tunisia within a few days of each other, and it must have been very disheartening to the Germans to discover their newest panzer had already met its master.

The 17-pounder, which is extremely light for its fire power, has a muzzle velocity of 2,900 f.s. with both armour-piercing shot and high explosive. Here again " Sabot " shot has added materially to the effectiveness of the gun, and the thickening up of armour that the Germans were

able to undertake in anticipation of D Day did not prevent their tanks from being penetrated by this remarkable gun.

The enemy air attacks on this country provided us with an excellent opportunity to watch our anti-aircraft gunners at work. It is a fact not too welcome to the onlooker that enemy aircraft can take avoiding action and that during the time it takes a shell to travel from the gun to the target the target may have travelled several miles. At present it is possible only to "predict" the probable position of the target aircraft, and the " prediction " is based on the assumption that the aircraft will continue on the course on which it was flying when the " prediction " was made. However all that may be, the fact is that the 3.7s and 4.5s did sterling work in shooting down enemy aircraft—and particularly in shooting down flying bombs—and in driving away enemy raiders from vital targets. The 3.7 is a rather delicate piece of mechanism, but extremely accurate up to its range of 39,500ft. It fires an H.E. shell of 28lb. The gun is provided either as a static weapon for fixed A.A. defences or mounted on a towing platform for use in the field.

The 4.5 is a static weapon firing a 54½lb. shell, to a range of 42,240ft. The 40mm. Bofors gun originated in Sweden and is a very useful rapid-firing gun for engagements up to 9,000ft. It is automatic and is loaded in clips of four rounds. The 20mm. guns are dealt with under small arms.

Our 9.2in. and 15in. coast defence guns came into their own a little before the final collapse of Germany when the Straits batteries sank 11 out of 18 German ships trying to make passage through the Straits from the occupied ports of France up to Germany. This was magnificent shooting at a range of 20 miles. The gunners who have used these weapons always had great faith in the 9.2 as an accurate and powerful piece of artillery, but pride of place for range and power must go to the 15in. There is one amusing story about the 15in. equipments which were situated near Dover. It is said that there was reason to suppose that a particular building near Calais was being used by the German Army in 1942 for highly suspicious purposes, and the gunners thought that they would try to put an end to the business. After three ranging shots they hit the building full in the middle. This was a matter for mutual congratulations all round, and celebrations continued for some little while after. During this pleasant interlude a message was received from the Civil Authorities in Dover pointing out that as a result of their effective firing more than 80 German shells had fallen in the " vicinity of Dover " in the course of three hours, and asking the gunners " not to be so damned accurate " in the future.

After the appalling losses of Dunkirk any and every sort of gun was pressed into service until production could make up for the losses.

A gun that played a prominent part in the North African campaign was the 5.5 gun howitzer. It throws a shell of 100lb. a distance of eight miles. A battery is shown in action, the rammer being returned after the shell had been driven home.

This is not the place to tell the story of that production effort in full, but it will not be unfitting to mention some of the magnificent work that went into gun production. Any and every sort of factory that could make guns or small pieces of guns was roped in. Groups were formed among the smaller factories, so that they could make complete sub-assemblies and, in some instances, complete assemblies.

One such group was formed in Kent, with its headquarters at Maidstone. Led by a man whose name became a by-word for improvisation, this group began by making small components for ammunition and weapons, went on to make sub-assemblies for six-pounder guns, and finished by making the complete weapon and carriage. They did tnis for four years and some of their tiny factories were under fire from bombs, shells, flying bombs, and rockets during the whole of that period, but they were never late on a contract.

The natural leaders in the drive to produce guns were the Royal Ordnance Factories. They were designed, built, and tooled for just that purpose and they did a magnificent job. In point of fact they produced rather more than half of all the guns—tank, anti-tank, field, and anti-aircraft—that were made in Britain during the war. One Ordnance Factory established a record by producing 1,000 guns in one month, and the labour force in that factory was 75 per cent. women.

The production of the prototypes of the 17-pounder gun is another example of the work of the Ordnance Factories. Two of them were asked to make one gun each as quickly as they could. In the last war 12 weeks was the fastest time in which a gun had been made. During this war, up to that time, the record was six weeks for a small gun.

Twenty-one days after the orders had been given the Director-General of Ordnance Factories called a meeting at one of the two factories of all the factory superintendents who were to go on to the 17-pounder. They were to discuss production methods and any particular difficulties that had been met with so far in production. The D.G.O.F. asked the two superintendents already on the job to say what progress they had made. Neither wanted to say, as each was afraid that the other might be ahead. Finally one rose from the table and pulled a cord which drew back the curtain at the end of the room disclosing the complete gun, finished in 21 days. The other superintendent then said that his prototype would be finished the next day.

This, it is true, was an outstanding effort. Even so it was improved upon later on when a 17-pounder gun was produced in the incredible time of 18 days. So much for British production methods!

A 9.2 coast-defence gun being fired on the south-east coast. With the 15in. gun the 9.2 shared the main duty of guarding the Channel. On one occasion these guns sank 11 out of 18 German ships at 20 miles range in the Straits of Dover.

22

INFANTRY WEAPONS

As compared with the last war the infantry battalion is now a veritable arsenal.

The infantry began the last war armed with the No. 1 (.303) rifle and sword bayonet. There were a few Vickers machine-guns, but very few. Officers were armed with the Service Pistol No. 1 (.455 inch Webley revolver). In the course of that war the infantry acquired the Mills grenade and the Stokes mortar and the Lewis and Hotchkiss machine-guns (.303 inch), together with an enormous increase in Vickers machine-guns. Nowadays the infantry have, or have had during the war, the rifle No. 1 and No. 4, the Bren light machine-gun (.303 inch), the Mills grenade, the No. 69 plastic grenade, the phosphorus smoke grenade, and the No. 74 or sticky grenade. In addition there are the Vickers medium machine-gun, the Boyes (.55 inch) anti-tank rifle, the Projector, Infantry, Anti-Tank (or P.I.A.T.), the 2-inch, 3-inch, and 4.5-inch mortars, the two-pounder anti-tank gun, and the six-pounder anti-tank gun. Apart from all these there are the sub-machine guns, chief of which is the Sten.

Moreover the Home Guard—infantry if ever there was any—were equipped with light artillery as well as most of the foregoing. They had the Northover projector, the Blacker bombard (or 29mm. Spigot mortar), and the Smith gun. Some of these weapons were also available to the R.A.F. Regiment for the defence of aerodromes, together with 40mm. and 20mm. anti-aircraft weapons.

Testing a Bren machine-gun in a factory. The Bren gun is popular with the troops, being light, reliable, simple and accurate.

At the beginning of this war the rifle was still the No. 1—commonly known as the S.M.L.E. (Short Magazine Lee Enfield)—and its bayonet. It was a thoroughly reliable weapon which had stood the test of active service in all theatres. It had the famous Lee bolt action, the best in the world for easy manipulation and, consequently, for high rate of fire, and it was extremely accurate.

Good though this rifle was, it was not suited to mass production, and it had been decided in 1926 to develop another design. This was the No. 4 rifle, and it was fitted with a short bayonet. It was put through extensive troop trials, which it passed satisfactorily. The design was then put into cold storage pending an emergency. The emergency came, and just before war broke out production of the new rifle was ordered. In 1941 it began to flow through. While production was in progress one or two further changes were made to simplify production still more. One of these was the substitution of the plain spike bayonet for the original design. The weapon has given satisfaction in service.

Since then another pattern of rifle—a light weapon—has made its appearance. This is the No. 5, which is actually a modified No. 4. The modifications—some of them very ingenious—being intended to reduce its weight for use in the Far East. The new weapon weighs 7lb. as against the 9lb. 2oz. of the No. 4. It is also considerably shorter. Its accuracy has not suffered from the changes, however, and it is generally comparable with the No. 4 rifle for service use. Two of the more interesting changes, both contingent on the shortening of the barrel, are the addition of a flash eliminator and a recoil pad on the butt to reduce the effect of the recoil. It also has a new hunting-knife type of bayonet 8in. long.

The Bren light machine-gun, so deservedly popular with troops, is a considerably modified British version of a product of the famous Czech arsenal at Brno. It is light, accurate, reliable, and simple. In fact, it has most of the qualities desirable in a weapon of this kind and has more than justified its production.

The Vickers medium machine-gun has been made the more effective by the introduction of

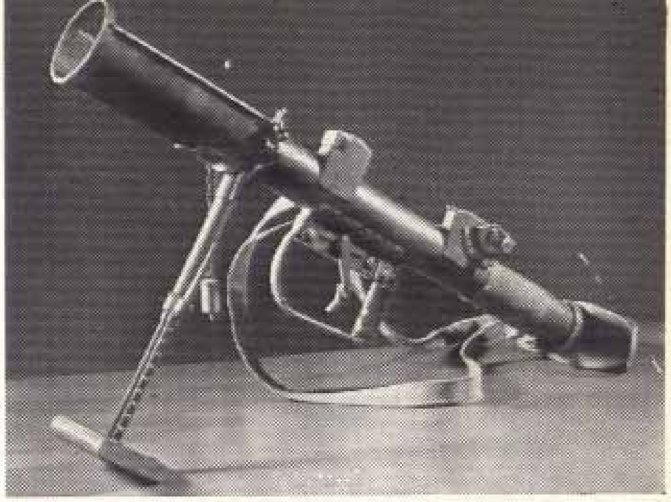
new streamlined ammunition which has considerably increased its range. Reference should be made at this point to the 7.92mm. Besa machine-gun, although this is not an infantry weapon. It is, however, fitted to most British tanks and has proved very satisfactory.

In the last war it was mainly officers who carried revolvers. This time many other ranks were so equipped, particularly the crews of tanks and armoured cars. The weapon now carried is the No. 2 pistol (.38 revolver).

The number and variety of hand grenades now issued to troops is a reflection of the difficulties with which infantry now have to contend. The Mills grenade serves purposes similar to those for which it was employed in the last war. It may be thrown by hand or projected from a rifle discharger cup. Its lethal quality compares most favourably with any other grenade in use by either side during this war. In fact, so deadly is it that it frequently constitutes a danger to the thrower.

To provide a grenade that could be used at short range the No. 69 plastic grenade was produced. It is fitted with an impact fuse and has only a limited lethal range. Even so, its blast effect is considerable, but there is little danger from flying fragments. A new and very effective dual-purpose weapon is the phosphorus smoke grenade. Its first purpose is to provide smoke cover for the movement of advancing troops; but the white phosphorus with which it is filled is a deadly composition for those who come into contact with it.

At the beginning of this war the only anti-tank weapon (apart from the two-pounder anti-tank gun) which the infantry soldier had was the Boyes .55-inch rifle. This was an accurate weapon which could penetrate about 1 inch of armour plate up to 300 yards. The Germans then increased, and continued to increase, the thickness of their tank armour. Instead of trying to improve the performance of the Boyes rifle to defeat this the grenade No. 68 was produced. This grenade was designed to be fired from the rifle discharger cup. It was interesting in that it was the first hollow-charge projectile in the world to be put into active service. Although the No. 68 was a considerable advance on the anti-tank rifle, it would perforate 2 inches of armour plate at between 60 and 90 yards, its flight was sometimes erratic and inaccurate. Another interesting anti-tank grenade is the No. 74 or sticky bomb. This consisted of a glass or plastic body with a woollen jacket steeped in a powerful adhesive. For transportation the very sticky object was put inside another container. The user threw this grenade from a distance of about 10 yards and the adhesive held the bomb on to the tank long enough for the 5sec. fuse to explode. This bomb would penetrate about an inch of armour plate. It was also a handy demolition charge.



One of the new projectors devised during the war—the P.I.A.T. It is a deadly anti-tank weapon, firing a 2½lb. projectile with accuracy.

Even when allied to patriotism these weapons were not enough against the heavy tanks our troops were meeting. The next step was the development of the P.I.A.T. This clumsy, unorthodox-looking article is in fact a very deadly anti-tank weapon. It weighs only 33lb. and fires accurately a 2½lb. projectile. It can hit a moving target at from 80 to 120 yards and a stationary target at up to 370 yards. Its hollow-charge projectile can penetrate 4in. of armour plate. In the wooded country of Normandy it dealt very successfully with Tiger and Panther tanks. The infantryman found he could successfully attack houses, machine-gun posts, emplacements in hedges, and even snipers in trees with this weapon, for the fuse was so sensitive that it would detonate on touching leaves and twigs.

There has been no striking change in mortars except the increase in their size. The normal 2in., 3in., and 4.2in. mortars have increased range, greater accuracy, and considerably more punch at the receiving end.

British troops who met German troops in the Saar zone in 1939 noticed that the Germans were armed with a machine-carbine—that is, a short, light, automatic rifle. There had been some investigation into the value of this type of weapon before the war, and as a result of the meeting at the Saar a demand arose from the

Army for similar weapons. There were some machine-carbines in this country and they were sent to units for immediate use. As a result the Thompson sub-machine gun, which was in production in America, where it was known as the "Tommy" gun, was selected as a stop-gap and supplies were obtained. The imminence of invasion in the following year, with the probability of much street fighting, brought this problem to a head, and the Sten gun was developed by British designers and put into immediate production.

The keynote of the Sten was its simplicity and suitability for mass production. It was designed to be made in millions and everything except its efficiency was sacrificed to that end. At first it was an ugly brute to look at, although most of its defects of appearance have now been remedied in the No. 5 Sten. However, at ranges up to 200 yards it fired quickly and accurately and it killed Germans.

A Home Guard firing a Sten gun from the shoulder. Simple to make, more than 3,000,000 Sten guns were produced during the war.

The Sten consists of only 51 parts in all, and most of those parts could be made in any factory in Britain. In two or three factories it was produced "on the line." There were not enough factories of that kind, however, and any factory that could do even one operation on one component of the gun was brought into a production scheme. In the London area there were scores of such factories, ranging from garages employing up to 20 people to one production unit established in a disused chicken-house where three people were employed.

The "belt" between these tiny production units was a truck which made a daily tour of all of them. It set out with a load of raw material, left it at the first factory, picked up the components which had been completed there, took them on to the next workshop where another operation was performed, collected the previous day's work from there, and so on all round Greater London.

This system was completely unorthodox, but it worked. In addition it brought into the production problems the brains of many people. Frequently the tooling at these little workshops was such that they were unable to tackle the job that they were given in the way laid down, so they suggested other ways—sometimes better ways—and wherever possible those ways were adopted. The result was that more than 3,000,000 Sten guns were produced. They were used by the Regular Armies of Britain and her Continental Allies, by the Home Guard, by the R.A.F. Regiment, by parachute troops and commandos, and they were dropped in thousands to the guerrilla and patriot forces in the occupied countries of Europe. If ever an experiment in the unorthodox justified itself, the Sten gun did.

Dive-bombing in France, and particularly in Crete, where the enemy made extensive use of air-borne troops, showed the paramount necessity for, first, effective air cover and, secondly, efficient light anti-aircraft weapons. 20mm. guns were needed to give rapid fire against low-flying aircraft. The Hispano gun was in great demand for the Air Force; it was fitted in most fighter aircraft together with the .303 Browning. The early Oerlikon gun was in equally great demand for use at sea. To meet Army requirements the very much simplified 22mm. gun Polsten was developed here and put into production. It is as efficient a weapon as either of the other two and requires only one-third of the man-hours to produce. The gun was mounted for anti-aircraft defence singly at first and later in triple mountings, but was little used in later operations because of the virtual demise of the enemy dive-bomber.

23

MILITARY BRIDGING

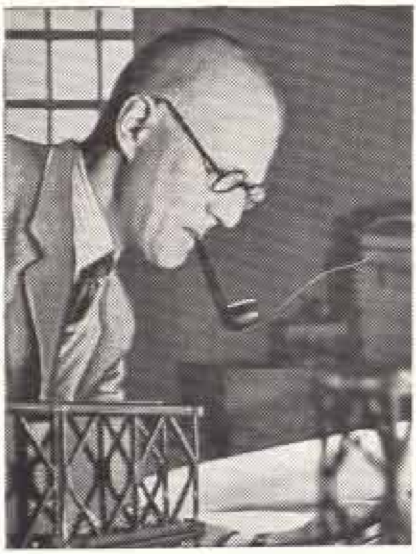
THE two years before the war saw a number of changes in the tactics of river-crossing operations. These changes were brought about by increases in the use of automatic weapons and developments in the employment of tanks and anti-tank guns. In these two years, therefore, bridging policy and equipment also underwent a number of changes.

In the first place the assault boat had replaced the Kapok footbridge, since more dispersion was required for the attacking troops to minimize casualties ; secondly, anti-tank guns were required across the river at the earliest possible moment in order to deal with the armoured counter-attack ; and thirdly, the tanks themselves were required to cross as closely as possible behind the infantry. To add to the engineering difficulties the tanks began rapidly to increase in weight and to be carried on transporters.

Until 1937 the heaviest bridge in the service was of 19 tons capacity, and it was not expected that even this would be erected within two days of the assault. In 1937 the Matilda tank was under development at 23 tons, but owing to increases in armouring during development it finally went into production weighing 26 tons. A new pontoon equipment (Mark V) of 24-ton capacity had been developed simultaneously and, although this would take 26 tons, it was stretched to the limit in doing so. It was, however, the standard floating bridge with which we went to war. Owing to a number of improvements in design it was little heavier than the old 19-ton bridge and could be assembled equally quickly ; this was essential, since tanks were now required to cross early in the battle.

Since 1929 the standard light bridge had been the Folding Boat Equipment (FBE) of five tons capacity. In 1938 the newly formed Mobile Division (now 1st Armoured) required a nine-ton bridge to take all its transport (except tanks). By the introduction of the principle of " limited articulation " and the provision of a new superstructure on the existing folding boats, the capacity of FBE was raised from five to nine tons without increase in weight. This bridge was so popular and so quick to erect that it was adopted in 1939 for use throughout the Army, and has served as the " Class 9 " bridge throughout the war.

The system of bridge and vehicle " classes " was introduced in 1938 and has greatly simplified traffic control and route marking in the field. It has also eased the problem of the ever-present competition between bridge and vehicle designers. By this system all vehicles carry a numbered sign corresponding to their weight class, and can cross any bridge which shows a similar or a greater number ; it is thus possible to tell at a glance which vehicles can safely cross which bridges The numbers are black on a yellow ground and must be familiar to many road-users in this



Mr. D. C. Bailey, chief designer at the Experimental Bridging Establishment, at work. Right : A Bailey bridge built over the River Rhine.

country, since all civilian bridges were classified under the system in 1940.

Non-floating bridges before the war existed in the form of the Small Box Girder (SBG), Large Box Girder (LBG), and Hamilton bridges. SBG would take Class 18 over 64ft. and was, together with FBE, the standard bridge carried in the division. The advent of the Matilda necessitated redesign of SBG to raise its capacity to Class 24, and this bridge superseded the Class 18 version in 1939. LBG and Hamilton were both intended for rear areas and were not designed for ultra-rapid erection. LBG, which was based on the Martel box girder designed after the last war, would take Class 30 over 130ft., and the Hamilton, which was a single or double truss Warren girder built up of angles, was of similar capacity.

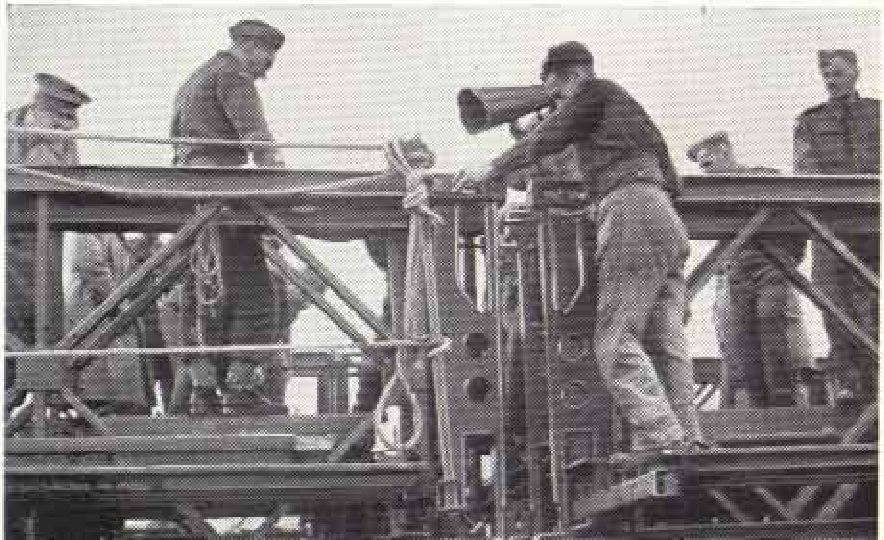
Professor C. E. Inglis, of Cambridge University, about this time produced a modernized and improved bridge built of tubes on the same principle as his famous bridge of the last war. It was a Warren girder in which it was possible to vary the number of trusses according to the strength required, a feature which had first been introduced in the Hamilton bridge and which showed great promise. The Inglis bridge was originally designed for Class 24, but was modified later to increase its capacity. It was put into production in early 1940 and was so versatile that it was introduced as the divisional bridge in substitution of the SBG.

After Dunkirk it became apparent that still heavier tanks would be required for the counter-offensive against Germany, and in 1940 the Churchill was under development at 40-45 tons. Methods were devised for strengthening the Inglis bridge, but a number of extra parts were required and the original simplicity of the design was somewhat impaired by their addition. No floating bridge to carry this load existed at all.

Mr. D. C. Bailey, chief designer at the Experimental Bridging Establishment, Christchurch, then produced an idea for a bridge the girders of which were built up of prefabricated panels. These panels could be erected in various combinations of storeys and trusses to give varying strengths of girder, and the decking could also be varied in strength. Design, manufacture and test of pilot model, and production were carried out in record time, and the first bridges were in the hands of troops 10 months after the design was first contemplated.

As will appear from above, a considerable number of types of bridge had by now crept into the service, with their attendant difficulties of manufacture and training. It soon became apparent, however, that the Bailey bridge could take the place of nearly all of them. It could be used as a heavy or light bridge, fixed or floating, and was quick to erect. Production was therefore stopped on Pontoon bridge Mark V, SBG, LBG, Inglis, and Hamilton, and was concentrated on Bailey. This production finally occupied 600 firms, who between them made over 200 miles of fixed and 40 miles of floating bridge for the use of the allied armies.

The first few months of our offensive campaign in North Africa involved no bridging problems, but the advance through Italy with its mountain gorges and swift-flowing rivers involved bridging on a scale which had never been met before. Never in history has an army carried out demolitions to the degree practised by the Germans in their three years of retreat. It has been necessary to erect over 3,000 Bailey bridges in Italy, and nearly half as many in North-west Europe, culminating in the crossing of the Rhine, over which the first 40-ton bridge was built in 30 hours. The longest Bailey so far erected is over 5,000ft.;



In the Bailey bridge the girders are built up of prefabricated panels which can be erected in various combinations to give varying strengths. The picture shows a Bailey bridge under construction.

Loading a rack of rocket projectiles on the wing of a Typhoon at a forward base. These projectiles were used most effectively in collaboration with ground forces in attacks on German strong-points.

this is a semi-permanent bridge across the Rhine, supported on piles.

It was recognized early that until a floating bridge could be built, vehicles would have to be ferried across rivers on rafts. A number of rafts were developed during the war varying in capacity from anti-tank guns to Churchill tanks, and these were used successfully on all major river-crossing operations. Out-board motors and motor-boats were also provided.

Special self-launching bridges carried on tanks were also introduced. The folding Scissors bridge on the Valentine and a 34ft. straight bridge carried on the Churchill were the two main types. These were perforce of limited span, but could be launched by the crew from within the tank without exposing themselves to fire.

Railway bridge design has also made a number of advances during the war, but has fewer unknown factors to contend with than has road bridging. Pre-drilled steel joists are provided to deal with short spans. Gaps up to 85ft. are dealt with by the Unit Construction bridge, and up to 150ft. by a lattice type " through " bridge also on the unit construction principle. More recently the Everall Sectional Truss bridge has been produced, which can be used up to spans as large as 370ft. Special forms of sectional trestling have also been evolved for railway work, but these have many other uses such as for road bridging and for jetties and harbour repairs.

This account mentions the main types of equipment only, but there have been a number of minor items which have also been developed. There are also numerous additional uses of the Bailey bridge which are still subject to censorship. There is no doubt that military engineering has made greater advances during the war than at any other time in history.

24

ROCKETS AS WEAPONS

AN important group of weapons, to the development of which the war has given impetus, has resulted from the application of the rocket principle to a variety of military purposes.

Research and development, in this country, on rockets was started some two or three years before the outbreak of war, following reports of the advances that had been made in this direction by the Germans. The long-range application of the rocket as exemplified by the German " V 2 " formed part of the programme originally proposed, but it was early decided to concentrate on those aspects of the rocket which would enable the gaps in our general armament programme to be most quickly filled.

One of these was the anti-aircraft application, and the first rocket project to be brought to fruition in this country was designed for anti-aircraft use to supplement, and in some cases replace, the anti-aircraft guns. The method of use of the weapon differed from that of the gun in that firing was normally in salvoes of about 100 rounds against a single target to produce a barrage effect, in place of attempting to hit by continuous single-round prediction. The lethal effect of each single rocket was roughly equivalent to that of a 3.7in. A.A. shell. The projector in most general use consisted of twin barrels on one mounting, though multiple projectors with a considerably larger number of barrels have also been put into service. The man-power saving was found to be considerable, and the comparative simplicity of the equipment rendered it particularly suitable for use by

relatively unskilled personnel, an important consideration at the time.

When a rocket is fired there is little or no recoil on the projector from which it is fired, which therefore can be made of very light construction. This property of the rocket renders it peculiarly suitable for crash concentration fire, which can be produced from multi-barrelled projectors which are relatively mobile, as a result of their lightness. An outstanding example of the barrage use of the rocket was the saturation weapon fired from specially converted landing craft. This weapon was used with steady success in a series of operations starting from the landing on Sicily and culminating in the invasion of D Day. The purpose of the craft was to saturate beach defences in support of landing operations during the final stages of the assault and several hundred rounds, each equivalent to a 5.5in. shell, during this final stage were fired from each craft.

Later, the land counter-part of the rocket craft was used with success in Western Europe, where a heavy concentration of fire was necessary for a short time. This weapon was a development from the original anti-aircraft rocket modified to carry a larger weight of explosive.

Another application was the aircraft weapon, again developed on the basis of the rocket motor used for the anti-aircraft weapon. This weapon has been fitted to a variety of aircraft types and has been used with conspicuous success in land operations against targets, such as tanks, strong-points, and troop concentrations. A modified form of it played an important part in the attack of U-boats, the rocket being particularly suited to this type of warfare, since its shape leads to its having a very good under-water performance.

Finally, mention should be made of the rocket-assisted bomb, which was designed for the penetration of thick concrete roofs of submarine and E-boat pens. Here the rocket action is delayed until after the bomb has dropped a considerable distance, the thrust of the rocket motors being utilized towards the end of fall to increase the terminal velocity.

The rocket played an important part in the war, but its development may be said to be still in its infancy. Higher power, greater accuracy, and increased simplicity are all objectives which must govern post-war development, and it is safe to predict that considerable improvements in all these directions are within our grasp.

Rocket guns were a potent weapon in Britain's defences against enemy aircraft. They were the result of years of experiment, and were first tested secretly in Jamaica. A multiple-barrelled A.A. rocket gun is seen in action.

IV. SHIPS, AIRCRAFT, AND LAND TRANSPORT

25

WARSHIPS AND LANDING CRAFT

THE outbreak of war found the great rearmament programme, initiated under Mr. Baldwin, far from complete in the naval sphere; and, moreover, in the previous two decades so few had been the orders for ships of war and their armaments that much of the facility for rapid naval expansion possessed by British industry for generations had been dissipated. It was still in process of being built up afresh, but throughout the early part of the war the work of shipyards suffered continuously from shortage of man-power and of the men possessing specialized experience built up by generations of shipbuilding. This very soon made it necessary for the whole of the shipbuilding of the country, naval or mercantile, to be placed under one control, so as to make the best use of available resources as required by the needs of the conduct of the war. The whole of the merchant shipbuilding was therefore placed under the Admiralty, and Sir James Lithgow was appointed Controller of Merchant Shipbuilding with a seat on the Board of Admiralty.

The building programme of warships in hand at the outbreak of war was large. There were in hand nine battleships—the five ships of the King George V class, of which only three had been launched; the Lion and the Temeraire; and the two new unnamed ships of the 1939 programme—nine cruisers of the Fiji class, of which only four had been launched; 10 of the smaller Dido class, six of which were afloat; six aircraft-carriers of the Victorious class, of which two had been launched; 24 fleet destroyers of the L., M., and N. classes; and 20 of the ships which were then called "fast escort vessels" but were afterwards more suitably named "Hunt-class destroyers." In addition to these, it had been announced in Parliament on August 2 that 56 vessels of "a whale-catcher type" were to be built for patrol and anti-submarine duties; by the time these invaluable vessels came into service they had been given the shorter and less stilted name of "corvettes."

Full details of the modifications and additions that were made to this programme are not yet available, and the progress made with it can be indicated only in very general terms. Work on the five battleships of the King George V class was continued, and they were put into commission in due course, although the interval which elapsed before the last two joined the Fleet suggests that work on them may have been suspended for a time, at the outbreak of war, in order that greater progress might be made with the production of the large number of anti-submarine craft of which the need might well have been judged to be greater. Of the other

four battleships only one, so far as is known, has yet been launched—H.M.S. Vanguard, launched by Princess Elizabeth in November, 1944—so it would seem that work on them at least must definitely have been suspended.

The cruisers were all completed as soon as might be, mostly in 1940 and 1941, though some of them were later. Two more of the Fiji class—the Newfoundland and Bermuda—were built and five more of the Dido class; there may have been more of which names and details have not yet been made public. Of the aircraft carriers the Illustrious, Victorious, Formidable, and Indomitable were all completed by 1941, but as the Indefatigable and Implacable were not completed until 1944, it would seem that work on them too must have been suspended for some time. Others have been laid down since, of a number not yet known; H.M.S. Powerful and Leviathan were both launched during 1945, but they have been described as "light carriers," which seems to indicate that they are considerably smaller than the 23,000 tons of the earlier ships.

It was on the construction of anti-submarine craft, Fleet destroyers, Hunt-class destroyers, sloops, and corvettes that efforts were chiefly concentrated in the early part of the war; and as the need was chiefly for numbers, it was mainly on the corvettes, which being the smallest could be produced most quickly. One R.N.V.R. officer, writing of his experiences when commissioning a new corvette in 1940, wrote that "indeed, it seemed as if, up and down the Clyde, anyone who had ever handled a hammer had set up a pole in his back garden and started building a corvette." By 1943 there were over a hundred of them in commission, not counting those—a substantial number—which had been lost in action.

The number of Hunt-class destroyers was not much smaller, but it was not until a later stage in the war that it became possible substantially to increase the number of the much larger and more elaborately equipped Fleet destroyers. By the end of the German war there were destroyers in commission, later than the N. class, of the O., P., Q., R., S., T., U., V., W., and even later classes, though the numbers in each cannot yet be definitely stated. Indeed, destroyer construction may have progressed even further by now.

Before leaving the subject of warships proper, mention must be made of the "frigates," which came into service in 1943. The corvettes—the "whale-catcher type of ship"—had proved remarkably good seaboats, of good endurance and capable of doing the duty for which they were designed, throughout the North Atlantic winter passage in company with a slow convoy; but they were small and uncomfortable ships—the author already quoted remarked once that "a corvette would roll on wet grass"—and they were hardly fast enough to deal adequately with the later classes of U-boats. As soon as shipbuilding resources permitted—or rather, engine-building resources, for that proved the bottleneck of production of these ships—the frigate class was introduced. These were larger, faster, and just as seaworthy in Atlantic winter conditions.

Of submarines, there were just over 60 in existence at the outbreak of war, a number which included many of the older boats, some of them veterans of the last war, which were useful only for training and experimental work. Production of new submarines in large numbers went on steadily throughout the war, though no details can yet be given. The same is true of light coastal craft, of which there were only some 20 or 30 in existence at the outbreak of war, but which were multiplied many times over after the occupation by the enemy of the whole of the Channel coast made the Narrow Seas unsuitable for the operation of larger men-of-war, and called for the employment of mosquito craft in large numbers. In all, 1,386 of them had been built up to June, 1944, the majority since 1940.

This brief survey of the developments in warship building throughout the war years brings us to the subject of landing craft, upon the building of which such a large proportion of shipbuilding resources had to be concentrated in the later years of the war.

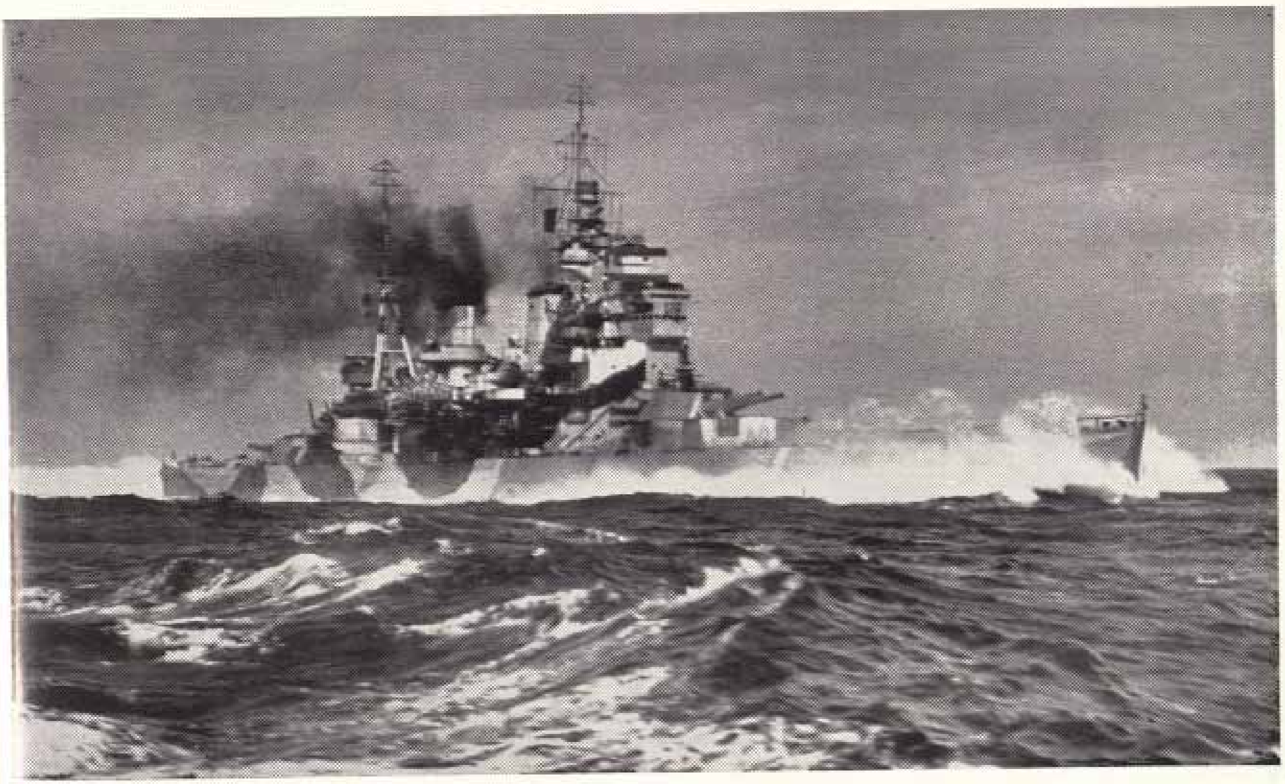
Landing craft, as we know them to-day, are to all intents and purposes a new production, dating only from the present war. Before 1914 there were in existence, indeed, a number of special boats of about the size of the battleship's launch, the largest man-of-war's boat, which were known as horse-boats, and were to be embarked if landing of troops on an open beach was in contemplation. The horse-boat was a flat-bottomed boat designed for beaching, with a square stern which let down so as to form a ramp for disembarcation of horses or

horsed vehicles when the boat was grounded on a gently shelving beach. This was a very primitive craft which had survived from the days of sailing ships, and although it was used in the 1914-18 war it was quickly found to be out of date even then. That war produced the "X-lighter," a self-propelled steel barge with a ramp at the bow. X-lighters were used at Gallipoli, but they too were a primitive production, unhandy, too large to be carried in troop ships yet too small to be seaworthy for anything but the shortest passage.

Experiments were made between 1919 and 1939 with smaller landing craft, to be carried in ships; but little money was allowed for them, and it was only in August, 1939, that the first of the landing craft known as the "L.C.A." ran its trials. It was a self-propelled, shallow-draught boat, with a landing ramp at the bows, designed to be carried in a ship and to transport a load of about 10 tons. This may be taken as the prototype of all the landing craft which were developed in great diversity after the outbreak of war.

The Norwegian campaign of 1940 demonstrated how very unprepared we were for any form of amphibious operations in modern conditions, and gave a great stimulus to study of equipment that would be needed if they were to be undertaken with any hope of success. The withdrawal from France which followed in a few months made it clear that they would have to be undertaken before the final victory could become possible, and added a still stronger stimulus in the same direction.

The L.C.A. was designed for putting ashore as rapidly as possible the first assault wave of an invading force, consisting only of troops with the minimum of weapons and equipment that they could take with them. But as soon as they were landed—or perhaps in some circumstances, even before they could actually get



A striking study of H.M.S. Anson, one of the King George V class battleships, at sea. The Anson and Howe were laid down in 1937, and are sister ships with a displacement of 35,000 tons.

The corvette has proved invaluable for patrol and anti-submarine duties.

ashore—they would need the support of tanks, guns, and armoured vehicles. From the L.C.A., therefore, was developed the L.C.M.—" Landing Craft, Mechanized "—of about the same size but designed specially for vehicles rather than men. These two types of landing craft were designed to work under the cover of gunfire from ships of war lying off the landing place; but as warships could not provide every assistance which they would need in those circumstances there was also developed the " Support Landing Craft "—L.C.S. This was another craft of about the same size fitted with a substantial armament and smoke-laying apparatus; it was not designed to be beached at all. It was much faster and handier than the actual landing craft, and its armament enabled it to engage either shore targets or attacking aircraft.

From these, it was necessary to develop something larger in order to provide an amphibious force with tanks at the earliest possible moment; so for the transport and landing of armoured formations was developed the Tank Landing Craft—L.C.T. For this purpose it was necessary to go to a length of about 200ft. and a displacement of some 350 tons, though otherwise the L.C.T. was essentially no more than an enlarged edition of the L.C.A., with a landing-ramp bow which lets down on to the beach.

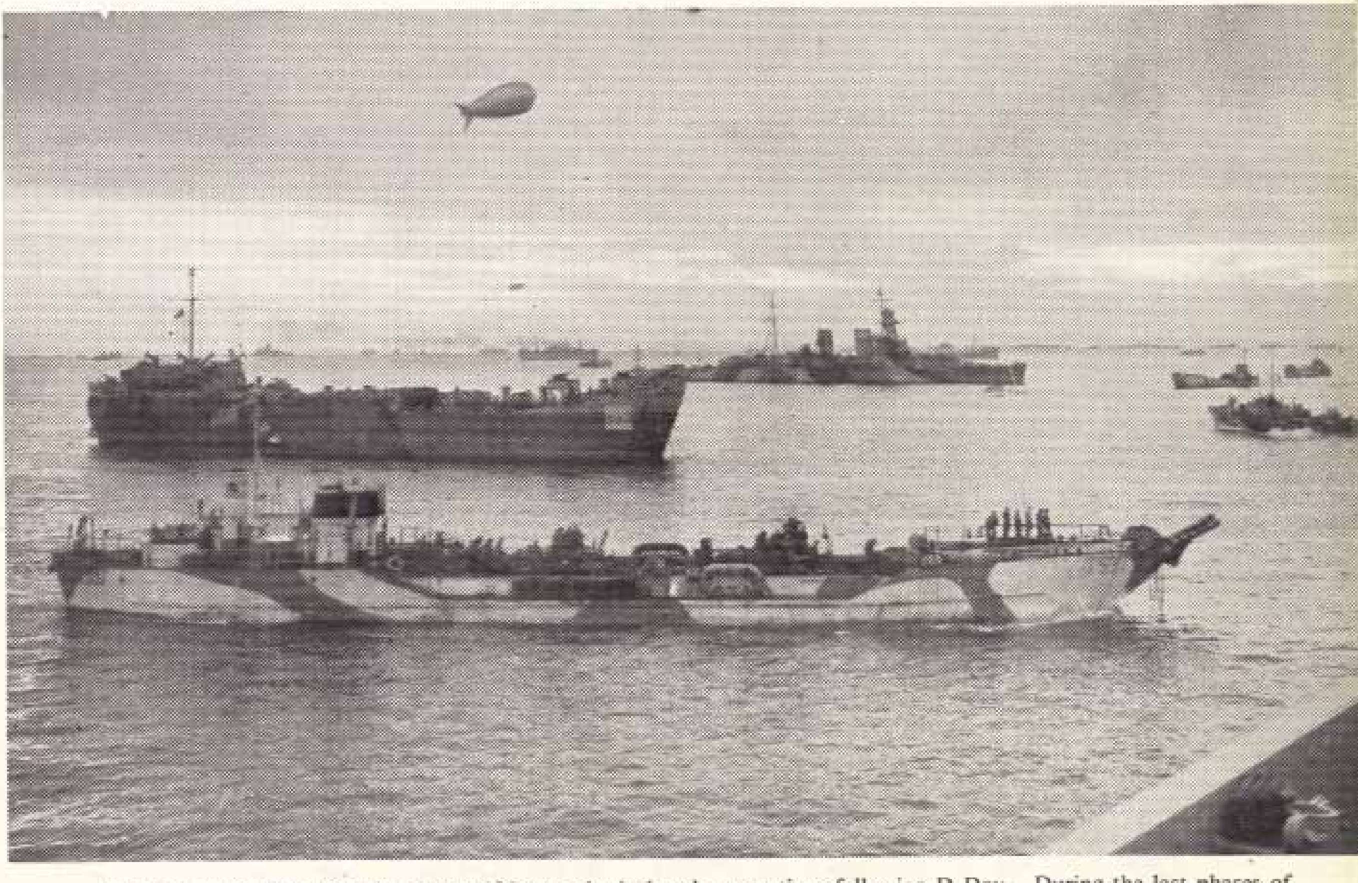
By virtue of its greater size alone the L.C.T. was able to make much longer passages than the smaller landing craft, and some of them have even crossed the Atlantic under their own power, though they presumably had to be specially battened down for that passage. Though it was designed and developed originally for the direct landing of tanks, it is, of course, available for almost any other class of military equipment or forces which need transport.

After the assault stage of an amphibious operation comes the vitally important " build-up " stage, in which, though it is probably necessary still to put forces and equipment ashore on open beaches, there should be no direct local opposition to be reckoned with. Assault craft are no longer necessary, and it becomes necessary to increase the speed and volume of disembarcation, a requirement which calls for ships even larger than the L.C.T.s. This need led to the development of the Tank Landing Ship—L.S.T.—a ship of displacement running into four figures, fully seaworthy for ocean passages yet still capable of being beached and of disembarking mechanically propelled vehicles direct. Photographs of these ships are very familiar now. When at sea they are indistinguishable from ordinary merchant ships of moderate size; for their bow ramps, which they let down when beached, just as the L.C.T.s and smaller landing craft do, are enclosed by double doors, opening sideways, which, when shut, form a bow to the ship of the ordinary form.

Besides these there are infantry landing ships—L.S.I.—also of proper ship form, but beachable and fitted with long gangways to be run out ahead on either bow; and many other landing ships and landing craft of special form and special fittings for special purposes. Some of these merit special mention, such as the landing ship dock, which is a seagoing floating dock capable of lifting smaller craft out of the water altogether, as a floating dock of standard form does in harbour, and carrying out large repairs at an advanced base; the L.S.T., fitted with railway lines in its hold, used for carrying railway rolling stock across

the Channel to Normandy and delivering it rapidly to the railways of France; and the L.C.T., similarly fitted, for the purpose of ferrying locomotives and rolling stock across rivers where the bridges had been destroyed. More than 50 different types in all were used in the various amphibious operations that formed the last phases of the war in Europe; and as many if not more are still in use in the Pacific.

No precise figures have yet been published of the total number of landing ships and landing craft built by this country, but they formed the great majority of the third category of warships mentioned in the White Paper on "The War Effort of the United Kingdom," issued last year, the first two being "major warships" and "mosquito craft." The numbers built in each war year were: 1940, 200; 1941, 314; 1942, 605; 1943, 1,601; and in the first half of 1944, 907. But though that is the latest date for which any definite information is yet available, there is no question of the production of landing craft having come to an end in June last year; on the contrary, it was then, as these figures show, at its peak, and there was no slackening in the latter half of the year, when the demands of the armies on the Continent were ever-growing. Moreover, when those demands fell off with the defeat of Germany, there was still the Pacific war to be provided for, and the part that British forces were taking in it, as well as the needs of our American allies. The amphibious attack which liberated Rangoon, and the many amphibious operations earlier in Arakan, illustrated this; but whereas in the Mediterranean and Channel landings the British-built landing craft were supplemented by a large number built in America, in the East the reverse became the case.



A landing craft leaving for the shore of Normandy during the operations following D Day. During the last phases of the war in Europe more than fifty types of landing craft were used in the various amphibious operations. Among them was the L.C.A., designed for putting ashore the first assault troops.

26

WORK IN THE SHIPYARDS

THE shipbuilding industry was not taken by surprise when war broke out and was ready to play its part immediately the urgency arose. The earlier subsidy arrangements had stimulated the placing of contracts for various classes of ships for the peaceful operations intended by shipowners, who had taken full advantage of the offers of help the Government had made to them through Parliament.

By the outbreak of war committees had already established, in collaboration with the Admiralty, the Board of Trade, and the Committee of Imperial Defence, a broad policy which would secure that the available resources could be harnessed to naval demands—including the huge drain on skilled man-power occasioned by urgent repairs at the shortest notice—and additions to cargo-ship tonnage according to the capacities and abilities of individual yards.

There was thus no attempt to establish a standard ship programme, as during the 1914-18 war, but a programme which sought to take advantage of individual organization with its consequent resilience to conflicting demands which could not be fully anticipated. In view of the many and unforeseen calls for special types of ships and often the seizure for naval and military requirements of half-built merchant ships which had hurriedly to be adapted to auxiliary aircraft-carriers and the like, the policy was sound. Moreover, sometimes because of enemy action and sometimes for other reasons, there was an incessant conflict between the hull and engine sides which called for modifications of long-term programmes to avoid such bottlenecks as might be created by an impending shortage of heavy forgings and so on.

In the earlier days there was also the inability, owing to pressing Admiralty demands, of the larger engineering firms to provide the standard simplified geared turbine sets with water-tube boilers which were needed for the 15-knot cargo liners for which there was at one time such an outcry inside and outside Parliament. An even simpler example is the fact that, in the early days, there was such a scarcity of boilers—due also to urgent Admiralty calls, particularly for corvettes and escort craft generally—that many cargo ships had to go to sea without their auxiliary boiler. While this did not affect the propulsive efficiency, it meant that a main boiler had to be used in port —a step no owner would lightly contemplate in ships of this class in normal circumstances.

The long succession of lean years, during which the industry came almost to a standstill, had left its mark in derelict shipyards and the dispersal of workers into other trades, if not, indeed, their drift into permanent unemployment. So, at the beginning of 1940, there were only 23,000 shipyard workers available for mercantile production and, although this was increased to 35,000 by June, 1941, at no time was the labour force equal to the plant and berth capacity.

The situation was aggravated by the loss of skilled workers into the Army and Naval reserves and the calling up of apprentices. The older men had been out of work so long that their physique had deteriorated and they were unable to stand up to the very strenuous exertions ordinarily demanded of them. Dilution, although practised to the utmost capacity, brought in its train special difficulties in the handling of large, heavy units of steel and for reasons of safety normal production rates were slowed down in consequence. A steel plate weighing five tons or some of the prefabricated units of 12 tons or more, which were developed as the war technique progressed, could be a serious menace when dangling from cranes in a gale of wind.

In the absence of the opportunities afforded in the lighter engineering trades, the number of women which could be introduced into the shipyards was relatively small, although they did valuable work as welders—at this task they became particularly skilled—and as painters and in the joiners' shops, on such work as polishing, and in the stores.

By 1942 the experiment was made of opening up a derelict shipyard to be run entirely with unskilled workers. A shipyard on the Tyne which had been out of production for 12 years was selected. The immediate task was to convert it from a wilderness, testing the scaffold poles for safety, seeing how much machinery had not been borrowed for use elsewhere—if, indeed, it had not been "borrowed" in another sense during the years of neglect—and so on. It was decided not to attract skilled labour from existing yards, for it could not be spared. So an attempt was made to adapt American prefabricated methods to a smaller establishment, laid out on traditionally British shipbuilding lines, where work was cramped and there was not the space and broad area essential for the big-scale operations asso-

Magnificent work has been done in our shipyards both in the building of new vessels to replace the losses of war and in repairing damaged ships. Here are workers leaving a Glasgow shipyard.

ciated with the name of Henry Kaiser and others. It was found possible to recruit a labour force of some 1,500, of which about 10 per cent. were women. Prefabricated units about 50ft. long and weighing up to 5½ tons were assembled in obscure inland factories, brought direct into the shipyard by rail and there worked into the 10,300-ton cargo ships of which five were building simultaneously.

The services of firms used to building land engines and non-marine types were not easy to enlist as they had pressing demands from other quarters. Nevertheless, steps were taken to call in their help and as time went on various small firms up and down the country, and particularly those accustomed to steel bridge work, were called upon to provide prefabricated units for tugs, small tankers, and various small craft for invasion landings. These eased the pressure on the shipyards, leaving them more free to develop their resources for the larger types. A serious strain, however, came on the labour and material supply through the exceptionally severe North Atlantic winters, just when there had to be a more northerly routing of convoys to evade submarines and for the supplies so urgently needed at Murmansk and Archangel. These gales took their toll by increasing the heavy damage repairs towards which the building resources had to be diverted.

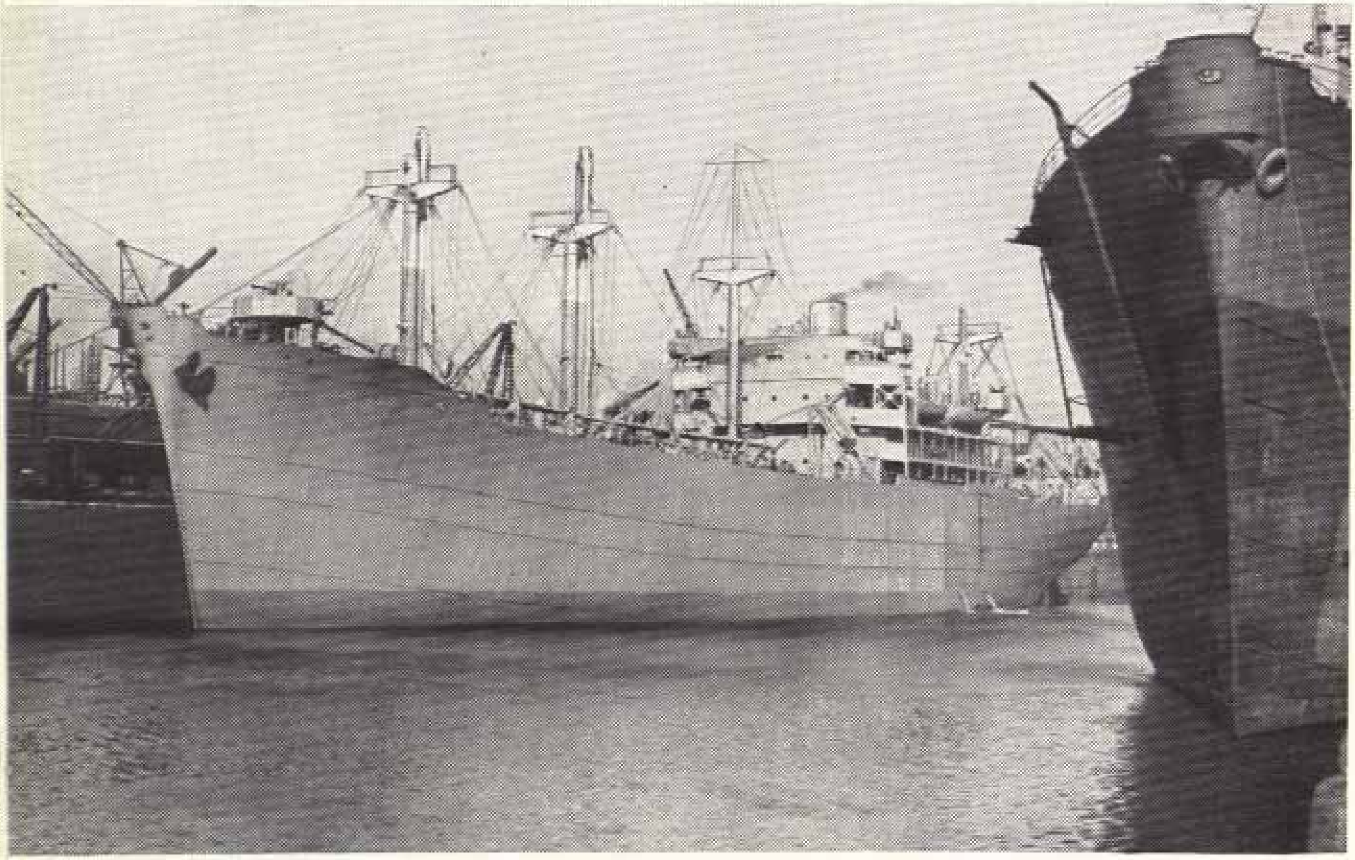
Further complications arose through increasing demands for the defensive equipment of all ships, new and old, the provision of heavy derricks up to 50 tons lifting capacity for all deep sea ships, and more accommodation for increased personnel, including gunners. Shortage of material was often severe. In the early days of the war steel had to be imported from Australia, India, and the United States. Timber supplies were always inadequate. The need for black-out precautions curtailed working hours in the winter, and at times men, and quite old men, had to work and grope about on stagings almost in darkness and in winter gales and snow under almost incredibly severe conditions. Hours were long and overtime included Sundays. To these inconveniences one might add insufficient nourishment when reckoned by what these heavy manual workers were accustomed to in normal times, and the general anxiety of the civil population. All these added their quota to fatigue and loss of efficiency.

Yet, in spite of it all, the work went forward. The measure of naval output has not been announced. More is known about the mercantile effort and many yards and districts surpassed all their previous best. This was particularly noticeable in the yards of the North-East Coast of England which is primarily a tramp ship building centre. On the River Wear most of the yards made new records. Thus, Joseph L. Thompson and Sons, Limited, whose standard ship became the prototype for all the Liberty ships, and who had established a shipbuilding peak in 1907 with 48,200 gross tons, turned out 79,650 tons in 1941, 72,000 tons in 1942, and 52,750 tons in 1943, the drop in 1943 being due to two air raids. The Clyde did not lag, although there was a greater concentration of naval activity there and because of it the labour force

available for merchant shipbuilding was also less adequate there than in other districts. Lithgows, Limited, had the highest individual output with 121,000 tons in 1941 and 102,500 tons in 1942 and contributed the handsome total of 456,000 tons towards the 1,526,000 tons of merchant ships built on the Clyde in the full five years 1940-44.

While, therefore, in the United States they were working up from almost a zero production—the total output in 1933 was only 10,770 gross tons—to an output of nearly 14,000,000 tons gross in 1943, the British shipyards were filling the gaps of war requirements of naval and mercantile urgent demands under conditions of almost incredible difficulty. This policy of letting America get on with the straight job of mass production, leaving British yards to change about as occasion demanded, was undoubtedly right, particularly as it was never sure that enemy action might not paralyse the home yards entirely. The wonder is not that the British yards seemed to do so little, but that they did so much. Centralized organization and direction were so highly developed that all the changes could be effected with the minimum disturbance of the morale of workers and managements, although they could not be taken into the confidence of those responsible for changing established organization overnight at the dictates of military expediency.

The full tale of our shipbuilding effort has yet to be told. There are many gaps in our knowledge which cannot yet be revealed, but enough is known to indicate the tremendous efforts which were put forward by the workers and the broad measure of cooperation among firms who, in peace years, regarded one another



One of a new type of fast 12,000-ton cargo ship soon after completion in a British shipyard. She is one of many constructed since war began and was designed for the special kinds of cargo which war needs brought about. The bows of another ship under construction are seen on the right.

as competitors. To this must be added the efficiency of, and confidence in, the concentrated direction, first, through the Directorate of Merchant Shipbuilding and Repairs, which was part of the Ministry of Shipping created in 1939, and then, early in 1940, through the organization centralized at the Admiralty. This had Sir James Lithgow as Controller of Merchant Shipbuilding and Repairs and a member of the Board, and, until recent months, Sir Amos L. Ayre as Deputy Controller and Director of Merchant Shipbuilding.

27

MERCHANT SHIPS MOBILIZED

ALTHOUGH sea transport was destined to play a dominant part in the African, European, and Far Eastern wars, the British mercantile marine was utterly unprepared for the outbreak of hostilities in 1939, and for the tremendous tasks which it was to be called upon to undertake. Confronted by foreign mercantile marines heavily subsidized by their governments with war purposes in view, notably the Italian and Japanese merchant navies, and having to compete also with merchant fleets whose expenses, owing to lower standards of living, were less, the British mercantile marine for years declined in numbers of vessels actually and in its proportion of the total volume of world shipping, while the shares of many other merchant fleets increased vastly.

In June, 1939, the British merchant fleet comprised 6,722 vessels of 17,891,000 tons gross, a reduction of 1,865 ships and 1,001,000 tons, being 5.3 per cent., compared with the summer of 1914, just before the outbreak of the first world war. It is true that the shipping owned in the British Dominions expanded somewhat during the 25 years, but much of this growth represented shipping wanted for local needs.

Allowing, however, for all these oversea ships, the British mercantile marine was only slightly larger in volume—by 2.3 per cent. (a negligible increase compared with the growth of other European merchant fleets)—and it numbered 1,146 fewer vessels. Remembering how important in war-time is the number of units, it is plain that the lessons of the earlier war, when the position of Great Britain became critical owing to loss of shipping, had not been learned.

The insufficiency of the British mercantile marine at the outbreak of war in 1939 would have been much more serious if, while British Governments had starved the shipyards of naval work, British shipping lines had not contracted for passenger and cargo liners of the finest types. Shipbuilding firms which had concentrated on warships had to compete for the building of merchant vessels, and some of the lines contracted for ships in advance of the actual current demand for accommodation. These ships were built solely for peaceful trading. Some of them made a very few voyages, and one or two of them none at all, before their fine accommodation had to be torn out of them and the hulls prepared for commissioning as merchant cruisers or as transports. Sooner or later all took active parts in the greatest and most beneficent uses to which sea power has ever been put.

Of the reduced amount of British merchant shipping available in September, 1939, not all could be adapted even to the transport of troops or could be employed in the carriage of essential cargoes. Owing to a great lack of cruisers, to a considerable extent the mercantile marine had to rely on its own vessels for protection, though manned partly by naval officers and ratings. Some of the finest merchant ships were directed at once to be commissioned by the Admiralty as auxiliary cruisers and to act as escorts to convoys. So there were heroic episodes like the destruction of the P. and O. liner Rawalpindi when, on patrol duty in the North, she encountered a heavily armed German warship, and the sacrifice of the Commonwealth liner Jervis Bay, which steamed to meet a battleship in the North Atlantic, her captain knowing that she was doomed but giving time for the escape of vessels in the convoy she had been guarding. Obviously neither of these ships had the slightest prospect of survival when in the course of duties for which she was quite unfitted she met an enemy warship with far superior armament. Even ships built for the carriage of bananas were fitted to act as naval auxiliaries. While merchant vessels were acting

as makeshift warships, cruisers, destroyers, corvettes, and frigates were built, and when these were completed and commissioned the auxiliary cruisers could be readapted for trooping or for other direct war purposes.

Liners designed for the carriage of passengers in comfort transported immensely increased complements of troops to Africa by the long ocean voyage by the Cape of Good Hope and so made practicable the driving back of the enemy from the approach to Egypt by the British army under General Wavell; they made possible the landing on the North African Coast which enabled the enemy to be pressed by forces from the north as well as from the south and drove him to try to escape by sea; they carried troops to Sicily and then to Italy, and they shared in the landings on the coast of Normandy in June, 1944. Particularly in the landing operations in the Mediterranean heavy toll was taken of some of the finest ships in the British merchant fleet. That was part of the price which had to be paid for the victories. Other passenger vessels, large and small, have done fine service as hospital ships.

With the experience of the earlier German war in mind the Government and the shipping industry realized that in order that ships might be directed quickly to whatever purpose was most urgent they must be brought under central control. After vessels had been withdrawn by the Admiralty from trading for direct war needs more and more ships were requisitioned for Government work. An early example of the change due to the war was the necessity of ordering cargo ships to the North Atlantic route to load grain in North America, since this was the nearest source of supply. This direction meant the employment during wintry weather of ships in trades for which in ordinary times they would not have been chartered by their owners. The decision was symptomatic of a great deal that was to follow. Ships have been engaged in trades for which they were not designed. Vessels planned to carry fruit transported cargoes of meat. For long periods liners never entered ports at which they regularly called in peacetime and they have appeared in many other parts of the world where previously they were never seen. They have acquitted themselves well in trades for which in ordinary times they would have been regarded as entirely unsuitable. Particularly hazardous duties included participation in the heroic convoys to Malta when the Mediterranean was infested with the enemy, and trying to make their way, mostly with success, in arctic conditions, exposed to fierce enemy attacks, to Northern Russia with munitions and other supplies urgently needed by our ally.

All this direction was achieved, first by the creation of a Ministry of Shipping staffed by shipping officials and Civil servants. The vessels were requisitioned, and, excepting those commissioned by the Admiralty, their management continued to rest with their owners. The latter saw that they were properly manned and victualled and the Ministry decided on the work on which the vessels should be engaged and to what ports they should proceed. The Ministry worked in conjunction with the Ministries of Food and Supply and was able to plan to fulfil programmes for months ahead, always subject to the risk of withdrawal of tonnage for other and even more urgent purposes.

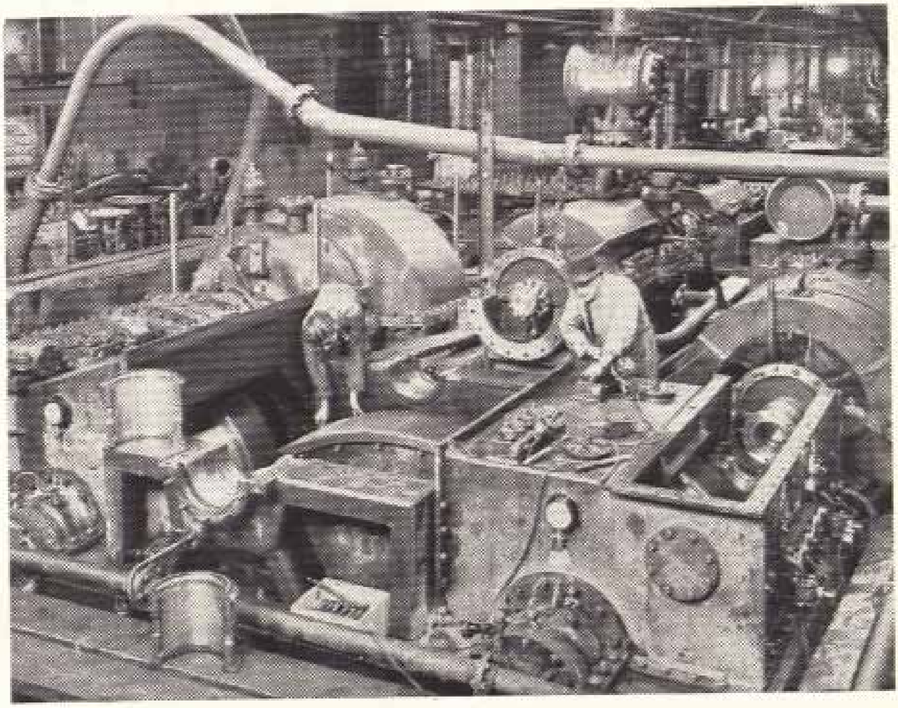
The responsibility of negotiating the terms on which the vessels should be hired to the Government rested with committees representing the Chamber of Shipping and the Liverpool Steam Ship Owners' Association. From the outset all thought of war profits was put aside. The principle of payment was that the operating expenses of the ownerships should be covered by the Government, and that in the terms of hire a proper provision for current depreciation should be included and also for a reasonable return upon capital. These latter two provisions were interpreted as being 5 per cent. for depreciation and 5 per cent. for interest on capital. The Government would not agree to include in the rates any allowance towards making good past arrears of depreciation or for building up a provision for replacement in future. At the same time the Government recognized that their predecessors in office during 1939 had found it necessary to formulate proposals for according financial assistance to British shipping which Parliament was invited to authorize by the British Shipping (Assistance) Bill, 1939. The progress of this legislation was interrupted by the outbreak of war, and the Government recorded their recognition of the need to maintain the British mercantile marine in adequate strength and in a position of full competitive efficiency.

These statements of the Government have been recorded by leaders of the shipping industry from time to time, particularly when they have been faced with the prospect of prices for replacing ships lost much in excess of the provision they have made over the years for depreciation, together with the recovery of amounts

due under war insurances for vessels lost. Meanwhile, the terms have been adjusted periodically when it was found that working costs had risen above the allowances made and the margin remaining was not sufficient to leave owners with the 10 per cent. for depreciation and interest combined which had been generally recognized as being only moderate provision.

In May, 1941, the Ministry of Shipping was merged into a Ministry of War Transport which brought within its control all forms of transport (except air) including railways, roads, and canals, as well as the ports. Lord Leathers was appointed Minister and full effect was then given to the principle that the transport of goods from the interior of one country until they were delivered where they were needed oversea was one of continuous movement. The adoption of this principle meant the exercise, for the purpose of the war, of the utmost economy in service and time. The operations covered the delivery of the goods at an oversea port, their transport in ships forming parts of convoys, their discharge at ports in Europe and their loading into railway wagons for dispatch internally by rail or into lorries for movement by road. Every phase of transport was carefully watched and supervised in order to expedite transit and avoid congestion. The work of controlling the movements of vast quantities of merchandise formed part of the fight against the enemy in his attempts to deprive the country of transport.

Other aspects of the same fight were the destruction of enemy surface vessels and submarines by the Navy and the Royal Air Force. The fight continued during the trying period of 1942, through 1943, when it began to turn in favour of the United Nations, and throughout 1944, when the United Nations had got the better of the enemy and immense numbers of vessels took part in the landings on the Continent which led directly to the collapse of Germany. In 1945 there remained the need vigorously to carry on the war with Japan and, consequently, to adapt large numbers of vessels for service in the Far East, to bring food to Europe, parts of which were on the verge of starvation, and to carry immense numbers of fighting men from the European battlefields to the Far East or to their homes.



Prefabrication contributed to the speedy building of cargo ships during the war. These men are working on an engine for one of the 10,000-ton cargo ships which were produced in considerable numbers.

The Spitfire, famous as a fighter, fighter bomber, and reconnaissance aircraft.

28

BRITISH AIRCRAFT CONSTRUCTION

FOR much of the 21 years between the wars the British aircraft industry fought a bitter struggle for existence. A sturdy infant in 1914, the first world war forced its growth to giant stature in the space of less than four years. At the Armistice of 1918 it was producing aeroplanes at the rate of 3,000 a month—and was still expanding. From its factories poured the fighters and bombers which sustained the strongest air force in the world—the Royal Air Force, which in two years after the last shots had been fired was reduced to less than a tenth of its war-time strength.

The effect on the aircraft industry of so drastic a reduction in the service was aggravated by an unwise policy of disposal of the mass of aircraft, aero engines, and of the numerous accessory articles which make up the complete aeroplane and power plant. These were permitted to get on to the market in quantities sufficient to absorb all post-war demands, and the workers and shareholders in the industry suffered accordingly. Many of the accessory articles, too, were put to uses for which they were not designed or intended, and the good will of the manufacturers suffered.

Five years after 1918, therefore, the giant had lost his fat and much of his essential muscle. He was nearly a case of malnutrition. It needed determination and faith to stay in the aircraft industry in those days, and it is to the lasting credit of the industry's pioneers that they did so. Their country was abundantly the gainer when the sterner trials of the second world war began.

For the British aircraft technicians had not been idle. Year after year they produced the world's most efficient fighters and light bombers. They continued steady development of the night bomber, which led ultimately to the great four-engined bombers of the present day, with the 12,000lb. and 22,000lb. earthquake bombs that no foreign bomber can lift. They made a great variety of landplanes and seaplanes for army cooperation, for the Fleet Air Arm, for commercial aviation—the last-mentioned group including the world's first large four-engined airliners and the first fleet of large flying-boats. They pursued research and development into armament, and many other branches of combat aeroplane development. Encouraged by a far-sighted and imaginative Air Staff, they looked ahead. Fortunately they saw more clearly and looked farther ahead than the men behind the *Luftwaffe*.

The industry went abroad for orders. For some years—until the Royal Air Force expansion programme began to absorb all their efforts—British aircraft and associated manufacturers led the world's air export trade. Much of the profits of that hardly won trade was ploughed back in the form of new research equipment at the factories, and new plant, thereby accelerating the advance of the art and bringing rich technical harvest when the need was greatest.

The upward trend to meet the resurgent demands of the growing Royal Air Force began, though but slowly, in 1935. It is one measure of the immensity of the industry's effort that in the ensuing eight years the labour force employed by British aircraft firms grew by more than 4,000 per cent., to a peak early in 1944 of no fewer than 1,821,000 men and women.

Major factors in this stupendous achievement were the shadow factory scheme and the group system of production. Originated in 1936 by Lord Swinton, then Secretary of State for Air, the "shadow" scheme was a powerful medium for the introduction to aircraft and aero-engine manufacture of companies engaged in other industries, notably at first in the motor-car industry and later in others.

Concurrently with the beginnings of the "shadow" scheme, a few large engineering concerns, mostly from the electrical and shipbuilding industries, entered the field of aircraft manufacture. This movement, at first a trickle, became a mighty stream with the imminence of war. It may be regarded as the direct forerunner of the "group" system which, to mention three main operational types alone, has been applied to the manufacture of heavy bombers, fighters, and torpedo-bombers.

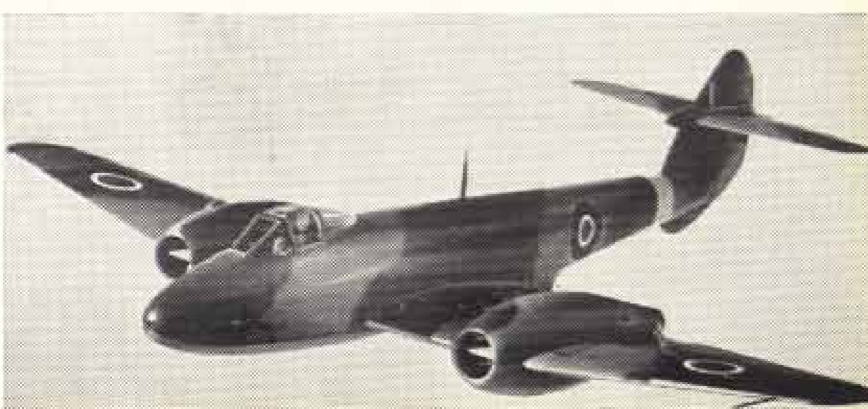
The working of the scheme is admirably exemplified in the production of the Halifax heavy bomber. The parent design company had the cooperation of four main contractors—one a company in the aircraft industry itself; another a motor-car manufacturer who had been in charge of a "shadow" factory since 1936; the third an electrical concern which began aircraft manufacture in 1937; the fourth a "group within the group," under the management of the London Passenger Transport Board.

Each of the four contractors built entire aircraft. In the case of the group within the group manufacturing processes were divided among the firms which made it up—one built centre sections, another front fuselages, another rear fuselages, while another constructed the complete tail unit.

A great responsibility fell on the parent company. Early in 1940 it formed a special department called the Outside Production Office, which had to deal not only with the group but also with repairs to the company's aircraft in Great Britain and Canada. This "O.P.O." arranged facilities at the parent company's main factory for the training of key workers from the group plants in production methods and inspection. It supplied technical information, including copies of airframe drawings, drawing modifications, and amendment sheets, component schedules of parts, lists of material requirements, and amendments corresponding to modifications, and planning operation sheets. It also directed the supply of templates, sample parts, and components for use in the preparation of jigs and tools. It supplied information and drawings for all jigs and tools and main assembly jigs. It helped the "daughter" firms in connexion with drawings, materials, and methods of manufacture. It advised and gave technical approval on repairs and, where possible, approved parts which were not to drawing and might otherwise have been scrapped—which entailed numerous visits by technical staff to the "daughter" firms and much close liaison work.

In short, the parent company acted as the consulting engineer for the group, with the main responsibility of proving the jigs, settling the manufacturing layout, and placing its experience unreservedly at the disposal of its daughters.

Similarly, centralization was the keynote for the supply of materials. Each company returned to a central office a list of all shortages as against the "target" requirements. Each company's needs for "embodiment loan" and proprietary articles were similarly listed, and adjusted month by month to show the delivery position to date. A network of committees and sub-committees, which called where necessary on the cooperation of Ministry officials, correlated major changes in production programmes, materials, and "embodiment loan" difficulties, and problems of supply which needed adjust-



The Meteor, the R.A.F. jet-propelled fighter aircraft. This single-seat fighter is powered by two gas jet turbine Welland or Derwent engines. It was used against flying-bombs in 1944.

ment within the group, or additional demands on other manufacturers. Spares requirements, allocated by the O.P.O., were also interlinked by a special committee.

The design company's local technical committee met frequently to discuss changes needed to give improvements in performance or to meet changing problems of the air war.

That was the general scheme of things for the production of the mighty armada of heavy bombers. The set-up was duplicated for the production of other types of aircraft, though with that flexibility which is characteristic of British industry, it was modified in detail to suit the differing conditions of production.

The men who flew the aeroplanes could depend on the industry always to adapt itself to new conditions and new methods of warfare as they arose. Moreover, the industry's technical development and design marched always in harmony with Air Staff policy, producing first the fighters whose heavy armament and protective armour contributed so much to the defeat of the *Luftwaffe* in 1940, and later rolling out in ever-increasing numbers the great four-engined bombers needed to pound German industry into the dust. As long ago as 1936 the Air Staff adopted the policy of stepping up the destructive power of the individual aeroplane by increasing its size and the weight and destructiveness of the bombs it could carry. So doing, they economized in aircrew man-power, eliminated congestion at airfields, and enabled "saturation" raids to be made in tremendous strength—culminating in such raids as that on Essen in the spring of 1945, when no less than 5,000 tons of bombs were dropped in approximately 20 minutes.

During the last full year of the war—1944—Bomber Command alone dropped on military objectives 525,000 tons of bombs. These bombs, carried for the most part in Lancaster and Halifax heavy bombers, aggregated more than twice the total weight of bombs dropped in the first four and a quarter years of the war. This, of course, did not represent the complete British bombing effort. The Spitfire, Tempest, Typhoon, Hurricane and other single-seat fighters of R.A.F. Fighter Command made extensive fighter-bomber attacks on enemy concentrations. Also there was the great activity of the Coastal Command, Fleet Air Arm, and the Tactical and Strategic Air Forces.

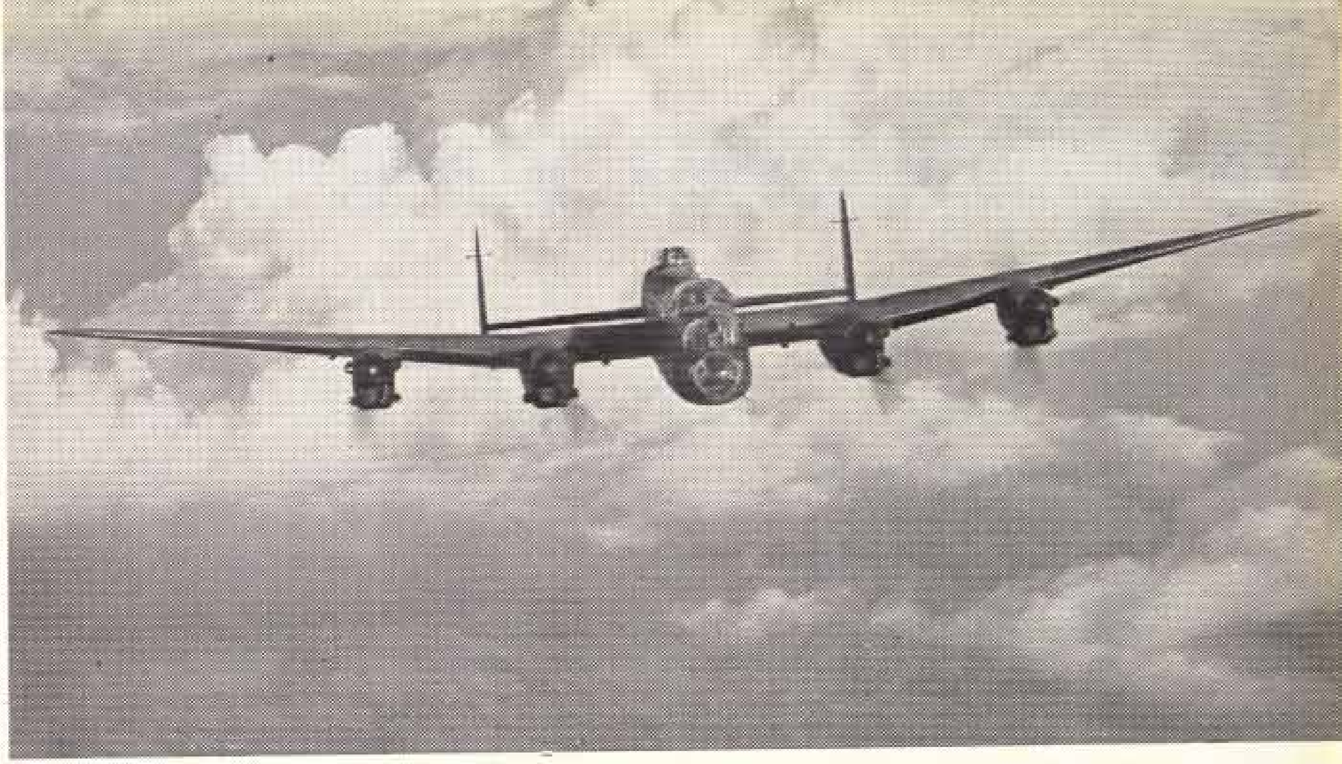
This extensive bombing plan was based on the belief that the Nazi military industrial output could be broken by large-scale bombing attacks and that British ingenuity could devise methods whereby night attacks could be made without recourse to the wastage inseparable from indiscriminate bombing.

Events proved the soundness of this belief. As the war progressed and the four-engined bombers planned in 1936 became operational, so the scope and range of the night bombing offensive grew more intense and more exact. To the destructive powers of huge bombs weighing 4,000, 8,000, 12,000, and finally 22,000 lb., was added the simplification of target location made possible by the use of pathfinders, who marked the objective with flares, and later by the introduction of the master bomber, who directed the attack on the spot.

By these methods and with the help of scientific instruments devised by British scientists it was possible for Bomber Command, on occasion, to concentrate upon a single target a force of more than a thousand aircraft and to deliver an attack with a force of this size in less than half an hour.

Although the methods adopted lightened the task of individual aircrews in locating the targets, they did not sanction any reduction in the quality of the aircraft, in the elaborateness of their equipment, or in the competence of their crews. Each bomber was a complete unit in itself, equipped with every essential instrument and armed for its own protection. Navigation to and from the target area remained an individual responsibility, as did the release of each bomb. The self-sufficiency of these heavy British bombers was often proved. Sometimes one would become parted from the main force, but unless a serious defect forced a return the crew would go on to bomb alone, knowing that they would expose themselves to the concentrated attention of the enemy's defences. The utter devastation of Germany's industrial centres is proof enough of the wisdom of this policy.

But the history of Great Britain's bombing policy goes farther back than this. In 1918, when the Royal Air Force was founded, British strategists expressed their recognition of the fact that successful bombing demanded the big bomber able to carry big bombs. The first British twin-engined "heavy" bomber was in design and



The Lancaster bomber, one of the group of three four-engined aircraft—Lancaster, Halifax, and Stirling—which gave a new meaning to strategic bombing. Lancasters were used on many of the biggest and most important attacks on industrial Germany.

production in 1915. Fleets of these aircraft did valuable work and initiated strategic bombing with the Independent Air Force in the later phases of the 1914-18 war. When the Armistice was signed in 1918, their successors—four-engined biplanes, weighing, fully loaded, nearly 15 tons, and designed to carry 1,000lb. of bombs to Berlin—were waiting for the order to attack the German capital.

Rundstedt has stated that the biggest single reason why Germany lost the war was the strategic bombing by the British and American Air Forces which paralysed the German war machine. Kesselring provided corroborative testimony. He ascribed Germany's defeat to:—(1) Strategic bombing of communications behind the lines; (2) fighter-bomber attacks; and (3) bombing of the German war industries.

Although in 1936 specifications of a new fleet of strategic bombers were drawn up and design and construction put in hand, not one of these new types was ready for squadron service when war began in 1939. The initial attacks on Germany were therefore made by twin-engined Wellingtons, Whitleys, and Hampdens.

By 1941 the factories had been geared for high-speed production and the new four-engined bombers—Halifax, Lancaster, and Stirling—were soon giving a new meaning to strategic bombing.

But even this did not satisfy the Air Council or the industry. British determination to bomb the enemy with every available weapon and the unfolding of a new technique of low-level "precision" attack led to the introduction of the unarmed twin-engined Mosquito bomber, which delivered 4,000lb. bombs over long ranges at fighter speed—more than 100 miles an hour faster than standard American four-engined bombers carrying approximately the same bomb-load.

The Mosquito has proved a splendid example of the flexibility of the British aircraft industry. Built as a bomber, it later became a reconnaissance aircraft, target marker, day and night fighter, fighter-bomber, U-boat hunter, and fast transport. Its prowess—the proof of the wisdom of its designers—may be seen in the fact that in the final 36 consecutive night bombings of Berlin Mosquito losses, in thousands of sorties, were about one-half of 1 per cent.

An important section of the aircraft industry in war-time has been concerned with repair. Aircraft face many hazards, apart from enemy gunfire and bombs. Weather and landing on improvised airfields and the disadvantage of

their having to be used by inexperienced aircrews in the early stages of training all help to make heavy casualty lists of the aeroplanes themselves.

Steps were taken to provide for repairs, however heavy they might be, for every aircraft repaired was equivalent to a like increase in output. During one year alone 18,000 aircraft underwent major repair and were returned to the combat list. Up to the middle of 1944 60,000 aircraft were repaired after major damage and returned to full service in an average time of eight weeks an aircraft. The Civil Repair Organization employed tens of thousands of workers.

British manufacturers faced a host of difficulties—many of them unshared by our American allies in their own magnificent production effort—in trying to step up output to an unprecedented level. There was the black-out and its accompanying irritations—screening of factory windows and hindrance to transportation. There were labour problems galore—thousands of workers needed by every main contractor for every 100 employed before 1935. There was the introduction of women into the industry and the necessary instructional courses. Men and women—from the schoolroom and the office, from the farm and the departmental store—had to be trained to do what up to then were regarded as highly specialized jobs. Not the least of the industry's handicaps was the dispersal of its production, which was rightly insisted upon by the Government to prevent serious damage by air attack.

The growth of the aircraft industry during the war can perhaps best be illustrated by taking one of the principal companies, which in January, 1938, consisted of a single organization of three separate factories under one control and all in the same area, one small sheet-metal unit near by, two elementary flying training schools and one navigation and wireless school. By 1943 the company's organization was in four separately managed divisions, the different

A view of the main shop of an aircraft factory showing Bristol Blenheim bombers being completed.

establishments totalled 150 and the number of employees had increased elevenfold.

Taking the industry as a whole, the total number of establishments in which the work of 19 leading aircraft and aero-engine companies was carried on was 52 at the beginning of 1938. By January, 1943, this number had grown to 473, the establishments being scattered all over the country. Moreover, the figure of 473 covered only establishments employing more than 100 workers. The actual number of units was much larger.

One group of companies alone at its peak employed more than 100,000 men and women The group's output represented some 30 per cent. of all the aircraft supplied to the R.A.F. from British factories during the war against Germany. It turned out 40,089 aeroplanes of various types and 38,564 aero-engines, as well as 6,774 tank gear-boxes and 11,882 torpedo engines. In addition, it repaired and returned to service 11,010 aircraft and 9,777 aero-engines. The group's products included such famous fighters as the Hurricane, Typhoon, and Tempest; the Lancaster heavy bomber and its still bigger brother, the Lincoln. The same group also provided the airframe for the first British-made jet-propelled fighter, the E27/39, from which the Meteor, the first allied jet-propelled fighter to go into action, was developed.

The development of the gas turbine is another branch of aeronautical science in which the British industry led the world. Both Britain and the United States have benefited from the pioneer work which Group Captain (now Air Commodore) Frank Whittle undertook in perfecting a gas turbine. More recently a British company has produced the jet-propelled Vampire, for which it also made the engines, while two other companies have announced that they are developing gas turbine "jet" engines.

The principal manufacturers in the aircraft industry had to design their new factories and took charge of the building of them. The industry was also faced with the new and important responsibility of supervising the sub-contracting of jobs to thousands of companies which had never before had any experience in the aircraft industry.

It was in a large measure the development of the shadow factories which helped to drive the *Luftwaffe* out of the skies. But there were other factors—the outstanding technical advance made in this country, the adaptability and flexibility of the British industry to meet every need. Hurricanes and Spitfires, now nearly 10 years old (a good age for an aeroplane), advanced in speed, fire-power, and manoeuvrability as the menace to our shores became greater; the Lancaster and the Halifax carried bigger and still bigger bomb loads; the Mosquito was devised to bomb and evade its attackers merely by its speed. There are many examples of this flexibility in the war-time development of the British aircraft industry. Always, in every emergency, the designers and builders got together to produce something to meet it.

Few of the main manufacturers escaped war damage in some way or another. German raiders early in the war, whether by design or chance, dropped their loads on or near several of our leading aeroplane factories. But improvisations and flexibility were the watchwords and the industry did not allow damage to factories to affect their output unduly.

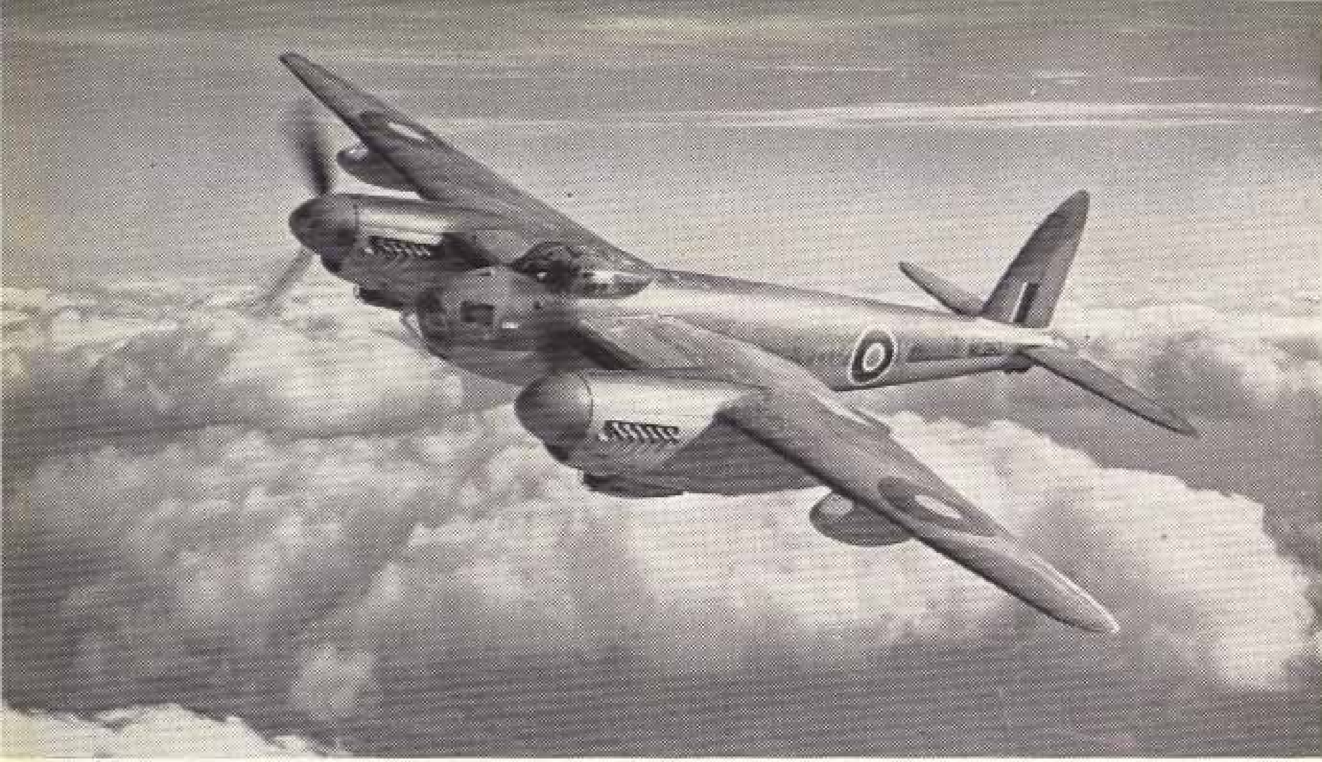
There is another important aspect of the air war production picture. On the technical side, whether it be in connexion with aircraft, aero-engines, airscrews, or other components, Great Britain has long led the way. So she did even when the cry was for more and more aeroplanes, when one would think that the quantity of the existing types was more important than striving for new things. But not so. Take, for example, aero-engine sparking plugs.

Before the war began it appeared that the aero-engine had, technically, outpaced its plug. So research for the purpose of solving plug troubles arising from the use of higher operating temperatures and pressures and the introduction of chemically treated fuels was begun. The chief difficulty was to find a satisfactory insulating material to replace mica.

Electrical porcelain and steatite were found to have good insulating qualities, but fell short of the standard required. Then the scientists began a study resulting in the discovery of a new insulator which has an electrical resistance, when hot, a million times greater, and a capacity to dissipate heat 20 times greater, than electrical porcelain.

Perhaps the greatest tribute to Britain's supremacy in this field was paid by President Roosevelt. In referring to a British sparking plug in the last Lend-Lease Report to Congress before his death, he stated :—

"... It has a life from four to five times as long as a standard aeroplane spark plug. ... Since 1943 virtually every Flying Fortress has taken off from British bases with these plugs in each of its four engines.



The de Havilland Mosquito which was used with great effect in the consistent night bombing of Berlin. It was used as bomber, reconnaissance aircraft, target marker, day and night fighter, fighter-bomber, U-boat hunter, and fast transport.

It would be impossible to estimate how many thousands United States bomber crews may since then have owed their lives to these plugs. . . .

" . . . The British made available to the United States all the formulae, designs, and production technique involved in this plug, and Chinese copies of it are now being mass-produced in the United States to meet our operational needs in theatres all over the world."

Then there was, of course, the question of supplies of raw materials. This problem was a real one for the industry. As the U-boat warfare became more intense and ships were lost when on their way to Great Britain with precious cargoes, the aircraft manufacturers had to look to other sources of supply and to compromise with materials conveniently available in this country.

This often required research to meet a crisis. Here is an example of the study and research into technical matters which British industry undertook during the lean years between the wars: an alloy, developed as long ago as 1927, to fufil the requirements for castings for a particularly highly stressed aero-engine, is still in service. This alloy has been modified from time to time, but it still satisfies both the engineers as regards its performance in high output engines and the foundry production engineers and metallurgists in its suitability for the production of sand, die, and pressure die casts in high-quantity production. It is a tribute to the inventors of this alloy and to those entrusted with its subsequent development that when manufacture of a particular aero-engine was undertaken in the United States during the war attempts to replace this alloy with one of more modern development were unsuccessful.

Before the war the output in Great Britain of aluminium castings averaged about 10,000 tons yearly. By 1944 annual production had reached 65,000 tons. The increase in production of magnesium castings was even more spectacular —from 400 tons in 1936 to 23,000 tons in 1943.

Official recognition of the enterprise of the aircraft and its associated industries has been generous. Only recently the report of the Government's Select Committee on National Expenditure criticized wasteful expenditure, due largely to starvation of research between the wars, and paid great tribute to the aircraft industry of this country.

In spite of disabilities, the report states, excellent results were in many instances ultimately achieved by ingenious and sensible improvisations and by the unremitting work of innumerable individuals and organizations in science, industry, and the public service. As an example, the report cites the results that flowed from the

prosecution of active research during the years before the war in the development of the Hurricane and the Spitfire, which had already, by the outbreak of war, been brought to a state when they could be put into immediate production. The report adds: "What the possession of these aircraft, developed on the initiative of the aircraft industry, meant to this country is a matter of history."

Such testimony has been corroborated many times. Lord Beaverbrook, the first Minister of Aircraft Production, stated: "We have nothing to be ashamed of in Great Britain in regard to the British aircraft industry. There is no superior aircraft industry in the world—I would almost say no rival." Moreover, Lord Beaverbrook, in the same speech in the House of Lords, showed that it was private enterprise—the enterprise of the aircraft firms—which brought about this superiority. He said:—

Aircraft of the Fleet Air Arm and all other types of aircraft depend for quality on the firms producing them. Beginning with the design of the aircraft—the responsibility of the firm prevails there. The work of the firm is almost invariably a private venture; the design is a private venture, put forward by private enterprise, by private capital. The individual responsibility for the design of the aircraft and for development of it prevails completely not only in the Spitfire, which was designed by Mitchell and produced by Vickers-Supermarine, but in the Hurricane, designed by Camm and produced by Hawkers. In fact, raw materials were provided for 1,000 Hurricanes by the Hawker firm without any order from the Ministry at all. The Hawker firm had to go and get the authority for ordering the raw material after the purchases had been made. The same argument applies to the Lancaster and the Mosquito. . . .

It is true the Ministry issues the specification, but that specification is sometimes rejected and frequently amended by the firm—usually improved. In the case both of the Spitfire and the Hurricane—both great aeroplanes—the design that was produced by the firm did not at all resemble the specification issued by the Air Ministry. . . .

Engine design is entirely in the hands of the firm. The Ministry has no relation to engine design at all. The great Merlin engine is designed by Hives and he is responsible for it; the Bristol was designed by Sir Roy Fedden, backed up by good men—and I believe Bristol to be a good company. . . . Although the Ministry is consulted, and although the Ministry gives advice, the job rests upon the capacity and the industry of the engine firm and the aircraft firm. . . . The shareholders took the risk of producing prototypes. The shareholders, therefore, have to be given some of the credit for production of the craft that won the Battle of Britain and for production of the craft which are bombing Berlin to-day—types that are greatly admired in the United States of America.

29

RAILWAYS AT WAR

THE war history of the British Railways is rich in important results for the allied cause. The perspective is not, however, the six years of continuous work during the war itself, for soon after the close of the war of 1914-18 discussions began between various Government Departments and the railways on particular emergency arrangements in the event of another war. In the middle thirties detailed plans began to be made; it was then decided that, should there be a major war in Europe, Government control of the railways would be necessary, as they would be needed to secure the maintenance of supplies and services essential to the community in time of war.

While these plans were in the making, normal work had, of course, to be carried on, and it is important to appreciate that this normal work, which to a large extent continued during the war, is in itself a formidable task. It entails the running of about 65,000 trains of all kinds every day, and during the war this number has been increased to over 70,000 daily by the addition of special trains, mainly for Service requirements.

It has to be remembered that the methods a railwayman uses are much the same in peace or war. His is not a job for the amateur; it requires the specialized training of a working life, and it cannot be picked up in the course of a year or two, particularly in the stress of a great war. This is the reason why, during this war as in the last, the actual operation of the railways has wisely been left in the hands of those normally responsible for running them, and they, in turn, have provided the backbone of the transport needs of the fighting services.

The job of transport, in peace or war, goes on steadily throughout the 24 hours of every day, seven days of the week. Even after the end of the war in Europe, there was no respite; indeed, in many ways work was intensified to overtake the arrears that had piled up. It is in this way that the contribution of the railways to the war effort should be visualized. The regular movement of passengers and freight (*e.g.*, the daily task of transporting millions of people into and

out of the cities and towns throughout the country) is affected by the special priority movements, which have to be fitted into the flow with the least possible interference, and in this category are the spectacular events of the war, such as Dunkirk (requiring 620 special trains), the North African Expedition (1,500 special trains), D-Day (24,500 special trains). Some idea of the magnitude of the task can be seen from the fact that in the last full year of the war, *i.e.*, 1944, the main line railways ran 1,000 passenger miles per second and 800 freight ton miles per second throughout the year.

The equipment at the disposal of the railways to deal with this huge traffic was severely curtailed. The railway workshops were busily engaged in the production of munitions, and this put a brake on the construction and repair of locomotives and rolling stock; moreover, there were substantial transfers abroad of even what was available. The effective number of locomotives available to the railways from September, 1939, to the spring of 1943 never exceeded by more than 1 per cent. the number available immediately before the war; thereafter, as the Government temporarily made available locomotives built in Britain and America for service abroad, the number rose slowly to reach a peak in July, 1944, of 8 per cent. above pre-war, after which date it fell as the locomotives were sent to the Continent.

The railway track has stood up to war traffics far better this time than in 1914-18, although arrears of maintenance now represent over a year's work. This will, of course, take a much longer period of time than a year to overtake in addition to current wastage, as most of it requires occupation of the track by the engineers between the passage of trains. The main reason why train speeds have not had to be restricted because of the condition of the track is the careful preparatory work which was done in the pre-war period. No fewer than 21,000 miles (*i.e.*, three-quarters of the track) were completely renewed, and altogether £170,000,000 was spent on track modernization and re-equipment. There were also considerable advances in engineering and metallurgy, which increased the wear of the rails. Two promising track developments are the use of flat-bottom rails and concrete sleepers; the former, particularly, shows signs of leading to improvement in maintenance.

Space permits only this brief mention of the continual struggle which the managements had to get and maintain the tools to do the greatest job in the history of railways. It is now necessary to trace the course of events as the war proceeded. Before 1939, the preparations in the event of war had to be made in great secrecy and while normal business was carried on. The only indication in this period to the observant eye was the accumulation of materials and the erection of structures which could not be hidden. New passenger time-tables were compiled, and alternative plans were made for the diversion of freight to meet new conditions, such as diversions of shipping from one coast to another. Much of the work was precautionary, as no one knew how the war would develop. Consideration had to be given to the effect of air raids, and new regulations were made for the safe working of the railways under possible war conditions.

A week before war was declared the preliminary stages in the changeover from peace to war were set in motion. Then, on September 1, 1939, the Minister of War Transport took control of the railways, and the railway executive committee was appointed to act as the Minister's agents for the purpose of giving directions to the companies, and, subject to such directions, the railways were instructed to carry on as usual. The emergency passenger time-table was introduced, involving a severe curtailment of normal services; after a few weeks people began to move about again, and services and speeds were increased.

The mobilization of the Forces lasted over three weeks and required some hundreds of special trains. Railway staffs were dispersed to emergency offices in areas considered less vulnerable to air attack. The evacuation of the civilian population from London and provincial cities involved nearly 4,000 special trains. The art treasures had to be moved to safe places in the country from the National Gallery, British Museum, Tate Gallery, and Westminster Abbey; this required specialized planning.

From the beginning of the war the black-out was a serious handicap. Normally the aim is to create artificial light at night as near to daylight as possible, and the restrictions were probably the most serious single factor with which the railways had to deal; for example, during one month of the air raids in 1940 the lights in the London marshalling yards had to be totally extinguished for three-quarters of the total hours of darkness. Anyone who has seen a railway marshalling yard at night will know

what that means. On top of all this came the abnormally bad winter weather. The first winter was the worst; lines were blocked with snow for long periods; frost slowed everything up. Even couplings and the lubricants in the axle-boxes froze; coal froze hard in the wagons and had to be hacked out. When the thaw came it brought landslides and floods.

Meanwhile, railway freight traffic increased sharply and a major problem was created by the changes in its flow. Air warfare and the threat of invasion caused the west coast ports to be used for practically all the long and medium distance sea traffic; the convoy system often resulted in acute congestion, as the sudden accumulations of traffic exceeded the clearance capacity. Further, the dispersal of industry throughout the country and the establishment of war factories often threw a heavy burden on railway facilities designed to deal with industrial peak requirements; extension schemes had to be introduced at many points.

Examples of particular traffics may be given. The railways relieved the coastwise services of vast tonnages of coal normally sent by sea from the Scottish, North-East Coast, Midland, and South Wales coalfields; the import of iron ore largely ceased and the consequent large-scale expansion of home production placed heavy demands on rail transport, particularly from the counties of Northampton, Oxford, Rutland, and Lincoln; enormous quantities of petroleum were conveyed by rail until the main pipe-line system came into use towards the end of 1943 and eased the west to east rail movement; stores for the American Army grew rapidly from the summer of 1942, and from about the same time material had to be transported in great bulk for the construction of nearly 150 airfields in East Anglia; explosives, requiring special handling, were regularly conveyed all over the country.

Military traffic never ceased after the first mobilization of the Forces in 1939. The conveyance of men to the Forces, Army and Air Force postings, the conveyance of troops to the ports for service oversea—such movements followed swiftly. Then came the evacuation from France and the consequent movements to defence stations in Britain and Northern Ireland. Contingents arrived from oversea, mainly at the Clyde and Liverpool, and often alterations in the times and ports of arrival of convoys played havoc with the special time-tables and concentrations of trains and staff that had been made in advance.

There was constant redistribution of troops and internal transport between training establishments. Leave traffic created a problem of its own, as also did military manoeuvres and prisoners of war. Formations equipped with armoured fighting vehicles had to be moved about the country, and, of course, there was a constant flow of ammunition, tanks, and stores. The total number of special trains solely with Service personnel and stores between September, 1939, and May, 1945, was 451,765.

Naturally, this superimposed traffic affected the passenger service for civilians, although large numbers of additional trains were required to convey people to and from munition factories. The ordinary train service had to be reduced to about two-thirds of what it was before the war, and consequently the loading of the trains that remained was doubled to accommodate the increased traffic. Restaurant cars came off and sleeping cars were restricted, but no scheme was introduced for rationing civilian passenger travel. There were some who thought this could have been done so as to make travel less irksome to those who required to take rail journeys for reasons of business or health.

Railway fares and freight charges were increased by 10 per cent. in May, 1940, and, except in the case of workmen's fares and season ticket rates, by a further $6\frac{2}{3}$ per cent. in December of the same year. Reduced fares, other than monthly return fares, were suspended at the outbreak of war or later, and first-class travel was withdrawn from the London suburban services in October, 1941. From 1941 all Government freight traffic was charged at flat rates per ton, and later similar arrangements were adopted for merchandise by passenger train.

Looking back, the main impression one has is of a great organization spread over the country, controlled to a large extent by a marvellous intercommunication system, and successfully meeting the unprecedented and changing demands made upon it, either by careful advance planning or individual initiative on the spot. The railways fulfilled their obligations to the nation in full measure. They paid a heavy price, not least in the 16,000 railwaymen who became casualties when doing their duty. Perhaps symbolic of them all was Lord Stamp, then chairman of the Railway Companies' Association, who at the crisis of the war and during the period of greatest strain on the railways, went one night straight from his desk to his home, there to be killed by Hitler's murderous hand.

One of 150 locomotives of 2-10-0 type designed and built by the North British Locomotive Company for War Department service.

30

LOCOMOTIVE BUILDING

THE British locomotive building industry, now returning increasingly to the production of locomotives for peace-time use, was heavily engaged on the manufacture of various types of armament for over six years. When war became inevitable it was one of the first of Great Britain's heavy engineering industries to be mobilized for the production of munitions. Its plant and equipment were such that it could be converted readily to the national effort, and for the first two years of the war the greater part of the capacity of the industry was engaged in the manufacture of direct war requirements of all kinds.

The war products on which the industry concentrated covered a wide field; they included a variety of tanks, notably the Matilda and the Churchill, shells and bombs of various calibres, numerous types of guns and gun mountings, torpedo parts, practice loading sets, landing craft, prefabricated components for aircraft, and various important devices which did much to hasten victory.

By the autumn of 1942 it became apparent that the locomotive was as much a weapon of war and as important as many kinds of armament. The earliest possible delivery of locomotives of a variety of types became increasingly urgent, for use both in the theatres of war and for the movement of essential raw materials and supplies in countries far distant from the battle zones. This demand from all over the world for transport was so pressing that it became necessary to reconvert a large part of the industry's works to the production of locomotives, which had become of first-class war priority.

In all the industry, in addition to its vast production of general armaments, has built over 2,500 locomotives of nearly 50 different types for direct war purposes, many of them of entirely new design. These have included the large 2-10-0 and 2-8-0 "austerity" general purpose locomotives for the standard gauge, of which over 1,000 were sent to the European theatre of operations and over 200 to the Middle East; numerous narrow-gauge locomotives, ranging from small and medium-sized ordinary types to both light and heavy articulated engines of various designs; and, in addition, Diesel locomotives of several types. These locomotives were operating on the Continent and in the Far East, and in countries in other parts of the world whose products were vital to the allied war effort.

The British locomotive manufacturing industry is now engaged, in large part, on the production of locomotives for priority demands, but after more than five years of intensive war effort it is equipped and ready to play its full part in meeting the requirements of those railways which have had to forgo or postpone the renewal of their motive power because of the urgent calls made by the war on manufacturing resources.

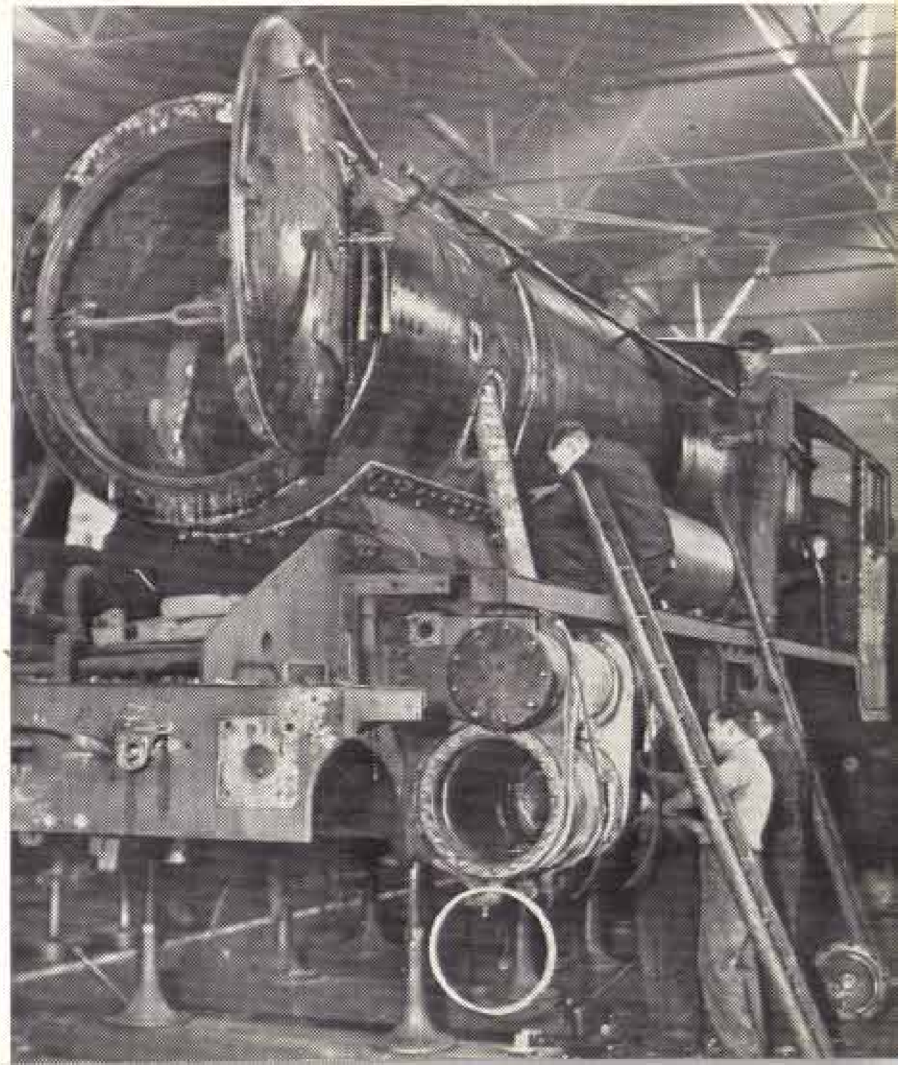
A partial resumption of manufacturing for export is already being planned by the industry; this will expand as the demands of war decrease and as more labour becomes available. Thus there will become available on an increasing scale engineering experience, sharpened by the

diverse nature of urgent demands, which has maintained designing and production at a high pitch of efficiency. In fact, it can be said that British locomotives to-day are being built to even higher standards of precision than ever before.

The British locomotive building industry is an important section of the heavy engineering export trade of Great Britain. The 10 companies which comprise it have a total capital of some £6,000,000 and employ directly nearly 20,000 craftsmen. The industry has a production capacity of well over 1,000 locomotives a year, and the works of its members are situated in important industrial regions of the United Kingdom.

Great Britain was the pioneer of railway construction, and in the early days of railways, from 1825 onwards, the British private locomotive builders designed and supplied engines for the great number of railways then being built in many parts of the world. Even now, when some other countries have developed locomotive building industries, there is none where British locomotives are not still in evidence. The high quality of their original construction has enabled them, however old, to be brought into use to further the war effort. In India and the Far East, the Near East, the British Dominions and the Colonies, and in South America, on every gauge and in every type of service from express passenger to mountain lines and rack inclines, the British locomotive in economy and performance has proved itself second to none.

Since the war of 1914-18, in particular, the British locomotive industry has expanded its manufacturing facilities by the installation of modern equipment and the adoption of improved methods of production. It is recognized that the calls which will be made on the industry in the post-war years will be heavy. All over the world there is an accumulation of deferred maintenance and renewal of locomotive power the meeting of which will be of primary importance to the countries concerned. In Great Britain the industry will have to assist in the rehabilitation of the home railway companies



A large number of British locomotives were sent to Persia for conveying supplies to Russia. Here is one being prepared for dispatch. The engines were adapted to burn oil fuel.

in a programme designed to replenish their depleted stocks of locomotives which have resulted from the war, and to this end a five-year programme of building has been arranged between the railway companies and the locomotive builders which, nevertheless, will permit of the execution of overdue export orders.

The locomotive industry since the outbreak of hostilities in Europe has had to devote its full energies to the war effort, and to a considerable extent has had to forgo opportunities of participating in markets which were its pre-war prerogative and which otherwise would have been open to it. Its war-time experience, however, has not been without its value, in that it has keyed up the industry to the speedy meeting of heavy demands for items requiring the best engineering experience. Thus the British locomotive industry looks forward to serving again the world's railways when, in the near future, its full capacity can be devoted to peace-time production.

31

CARRIAGE AND WAGON BUILDING

THE railway carriage and wagon building industry in the United Kingdom has made a progressively increasing contribution to the nation's war production and at the peak period the greater part of its manufacturing capacity was engaged on work of this kind.

The larger factories in the industry have devoted the greater part of their activities to the fulfilment of important contracts placed by his Majesty's Government for the building of fighting tanks, including light, medium, and heavy types. The industry has, in fact, been one of the largest producers of fighting tanks in this country, having completed nearly 8,000 machines as well as having undertaken the conversion and reworking of some 1,750 tanks for special operational purposes.

Large shops which were used in normal times for building railway carriages were turned over for the building of aircraft fuselages, gliders, and radar vehicle bodies.

Among the other more important items of war material produced by the industry were several thousands of armoured car and scout car bodies, fabricated hull sections for small ships and landing craft, multiple rocket projectile mountings, artillery trailers, Bailey bridges, prefabricated parts for the Mulberry harbour, Bofors gun mountings, &c.

In addition, the industry's forging, press and machine shops were utilized to their fullest extent, not only in meeting its own requirements but also in undertaking a very considerable amount of sub-contract work for outside firms producing different forms of war equipment.

Although the greater part of its manpower and extensive factory accommodation was diverted from its normal business of building carriages and wagons for oversea and home railways and was employed instead upon the provision of this wide range of equipment for the armed forces, it was necessary to retain a part of these resources for the building of wagons required for war transportation and operational purposes. At the beginning of the war a committee of the industry was formed to collaborate with the Ministry of Supply so that the remaining somewhat limited wagon-building capacity could be utilized to the best advantage.

To meet operational requirements a large number of petrol and oil tank wagons have been built continuously throughout the war, besides bogie flat and well wagons specially designed for carrying fighting tanks, and coal hopper wagons for the Ministry of War Transport. Bogie wagons have been supplied to South Africa for the conveyance of coal for military purposes, and the industry recently undertook a contract for the supply of 10,000 wagons for India to meet traffic requirements of the Far Eastern war. In addition, the industry has allocated capacity for the building of several thousands of wagons required for the rehabilitation of liberated countries in Europe. Some of the smaller firms in the industry had their capacity entirely absorbed on repairing wagons for this country and have, therefore, rendered invaluable service to the home railways.

During the war the industry has been called upon, particularly for fighting tanks, to undertake work involving finer limits and different technique from those appropriate to its normal trade. Light and heavy welding of armour plate has been developed successfully; welders and men for engine fitting were trained, and the forging and stamping plants normally employed on mild

steel have had to deal with alloy steel for tank parts. Those firms dealing with similar war products have worked in groups, either formed within the industry or with other industries, and in this way technical information has been pooled and a central control established to deal with the supply of raw material and components.

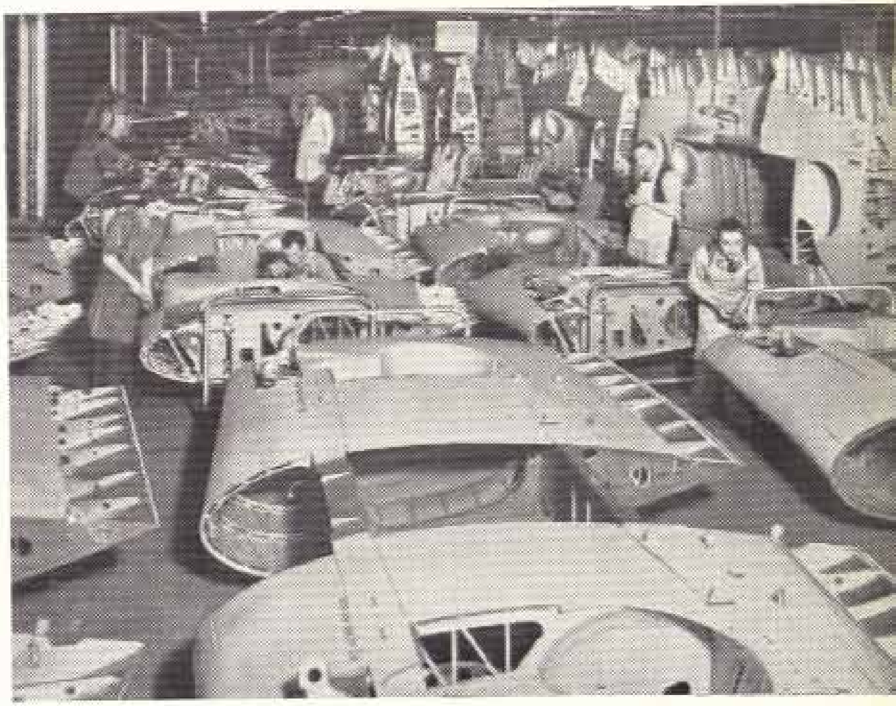
Before the war the industry made an important contribution to the country's export trade in supplying carriages and wagons to railways all over the world. During the war no carriages were built at all, and normal oversea markets had to be sacrificed for the time being. Much of the capacity of the trade is still taken up with war contracts, and though every effort is being made to accelerate the reconversion of plant to the purposes for which it was designed, there is much leeway to be made up. It is hoped that home and oversea customers will appreciate not only the great contribution made by the industry towards the winning of the war, but also the inevitable delay in getting shops and personnel back to normal production. The very large outstanding demands for rolling stock will be met successfully once the trade can get into its stride again and undoubtedly, as a result of war experience, improved technique will be utilized.

32

THE MOTOR INDUSTRY

THE British motor-car and commercial vehicle are products of an industry which, at the time war broke out, ranked among the premier industries of the country. It gave employment directly and indirectly to about 1,500,000 persons, and its products provided in taxation approximately one-eleventh of the total revenue of the national Exchequer. Its annual output in terms of chassis and vehicles was round about 500,000, of which some three-quarters were private cars and the remainder commercial vehicles.

The total number of both types in use in the United Kingdom in the last complete year of peace (1938) was rather more than 2,500,000, private cars accounting for nearly 2,000,000 of these. Exports in the peak year of 1937 totalled close on 100,000 (78,113 cars and 20,436 commercial vehicles, chassis being included in both cases). The exports for 1938 (the year of the Munich crisis) declined somewhat, totalling about 82,500 vehicles with a value of rather more than £11,000,000. Be it noted, however, that these figures represent vehicle and chassis only; the total value of automotive exports, including parts and accessories, tractors, marine motor craft, and tyres, reached £18,500,000 in 1938.



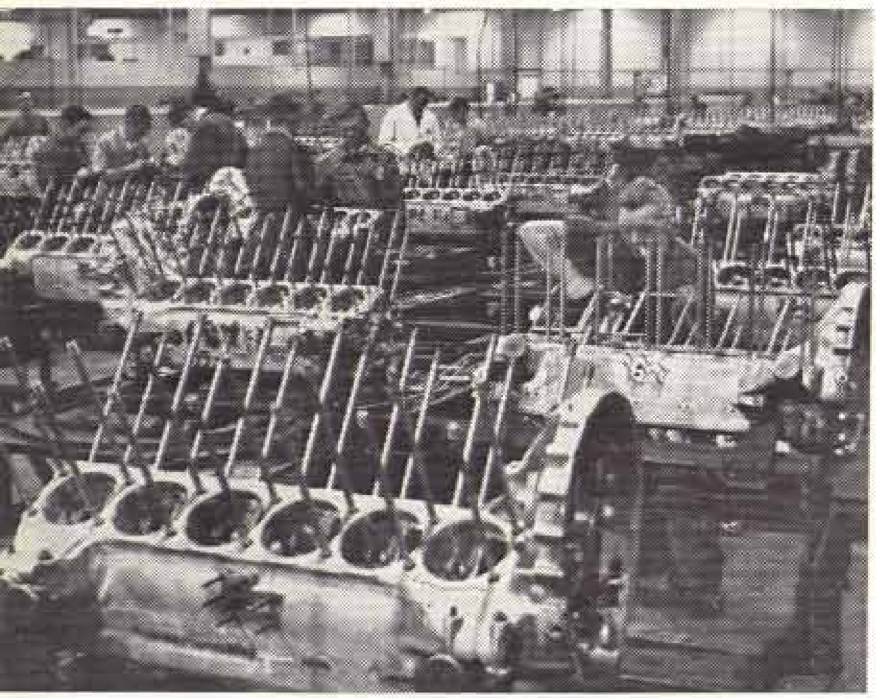
The small Miles Master aeroplane has been one of the principal training machines for the R.A.F. Here are some in production in a British motor-car works.

The foregoing précis will serve to indicate that the motor industry of Great Britain had attained considerable magnitude and that its claim to rank in the country's first three industries had substantial foundation; indeed, it might be argued that, if the contribution it made to the country's economic system in terms of money were also taken into consideration, it was well in the running for premier position. This contribution is put in the region of £500,000,000 annually, of which the retail value of manufactures, sales of second-hand vehicles, maintenance, taxation (£88,000,000 alone), rates on garages privately owned, fuel and oil sales, and insurance are the principal ingredients.

None the less, it is putting the facts mildly to say that, in September, 1939, the armed forces of this country were inadequately equipped with mechanized vehicles for both fighting and transport purposes. We had disarmed only too genuinely in the years that followed the signing of the fictitious peace, and financial stringency consequent to a great extent upon the depression of the thirties caused the War Department to starve its mechanization branch of funds. Research and development on a scale commensurate with its importance could not, therefore, be undertaken, but, none the less, the small but efficient and enthusiastic band of officers which constituted the staff of the Director of Mechanization managed to achieve some valuable spade work.

This had, however, been done only through the cooperation of several of the leading British motor manufacturing firms. Although public money had not been forthcoming in sufficient quantity to enable large fleets of vehicles to be built, a substantial amount of experimental and testing work had gone on consistently, as a result of which some useful prototypes had been evolved. The principle upon which the cooperation was based was that the War Office would indicate its requirements, and the motor manufacturers would translate these into practicality so far as was possible by the employment of components which were already in commercial civilian production.

While this practice resulted in a reasonably serviceable compromise being arrived at, it possessed the serious drawback that vehicles for the Army had to take the form of near-civilian types. It should be noted, however, that as manufacturers had perforce to design their productions along lines governed by current legislation, which imposed restrictions upon measurements, weights, axle loadings, and kindred matters, it followed that the Army had to a considerable extent to adapt its usage of mechanized vehicles to the types it could get rather than to



The Rolls-Royce Merlin engine not only figures in fighter and bombing aeroplanes, but has been adapted to tanks. Workmen are seen at work in the crank case assembly shop.

what if really needed. Thus the military authorities at the outset of the war had to make do with vehicles built upon the lines of those employed in ordinary peace-time commerce. None the less, they performed excellent service in the early days, and, in any case, all that were on the Continent at the time of Dunkirk had to be abandoned.

The interim period between September, 1939, and the disastrous June of 1940, however, gave the motor industry a chance to get going with the production of vehicles to the prototypes which, as we have just seen, had been quietly developed in the immediate pre-war years. Even so, it was soon realized that our enemies had progressed with their mechanization to a stage far beyond that to which our comparatively modest expenditure (as national expenditures go) had brought us. It was recalled that German manufacturers of commercial vehicles had displayed, at the last exhibition held in London of such vehicles, machines of enormous dimensions and capacity, with vast engines of Diesel type, which were totally unsuited to road conditions in this country; indeed, their gigantic size would have precluded them from legally using the roads of Britain.

It should here be mentioned that the remarks made above concerning "vehicles" apply equally to the tank position. We had allowed our Royal Tank Corps to degenerate into a small force, and financial grants adequate to the development of new types of tank had not been forthcoming. When the rearming of the nation was decided upon there existed divergent opinions as to requirements and specification. To ascertain what other countries were doing Lord Nuffield sent experts to Russia, where they discovered that numbers of tanks were being produced to a prototype developed by an American inventor named Christie, who had devised a type of suspension infinitely superior to anything yet evolved. Lord Nuffield provided the cash necessary to acquire specimens, from which the Crusader was developed, but actual battle experience was lacking to enable the machine to be perfected. The Germans had gained such experience at the time of their annexation of Austria: their tanks had shown up badly on this expedition, and in the interim period between that incident and the outbreak of war they were able to rectify most of the defects.

One of Britain's greatest initial handicaps in tank construction was that she had no engines in "quantity" production large enough to provide a heavy, well-armoured tank with adequate speed, and for this the incidence of the horse-power tax cannot be held blameless. However, when the Rolls-Royce Merlin engine design was modified to form the Meteor, developing 500 h.p., the British tank became fully potent. Since then this country has produced what are admitted to be the best all-round, battleworthy tanks of the war. Their speed was a great asset in chasing the enemy out of France after the Caen break-through, outpacing the Germans' armour and preventing them from making an effective stand.

Before we go on to deal with the actual war-time products of the motor industry there is one more pre-war, but warlike, activity which must be touched upon in order to put matters into their proper perspective. This is the Shadow Aero Scheme, whereby the leading motor manufacturers were called upon to make plans to expand, in emergency, the production of aero engines and aircraft. The scheme was broached in 1936, at a time when the vociferously proclaimed lack of territorial ambition on the part of Hitler was causing disquiet. Its object was to provide means whereby the output of the regular aircraft manufacturing firms could be supplemented if emergency arose, but not unless it arose. The motor manufacturers, with their experience of production in quantity, were requested to supervise the erection and equipping, and subsequently the management, of factories capable of making components for engines or the assembly of aircraft. The actual products were to be of designs emanating from firms in the regular aircraft industry.

Five of the principal British motor manufacturers took part in the Shadow Aero Scheme which, in point of fact, never was a "shadow," because the emergency came upon us even before the majority of the factories had really been completed. Fortunate indeed was it that the scheme was evolved, and that the skill and experience of the motor manufacturers turned it into a big success. It most certainly increased the output of vitally needed engines and bombers at the critical moment, when the country was in the greatest danger with which it has possibly ever been faced.

In the early days of the "Shadows" the motor industry helped to mass-produce the renowned Blenheim, one of the bombers which, it will be remembered, was used so extensively at the outbreak of the war. During recent years the industry has been engaged in producing on a quantity basis the formidable Halifax, the bomber which contributed so greatly to the task of hastening the

end of the war in Europe. And last, but by no means least, that speedy, terrifying, and versatile fighter-bomber the Mosquito was largely produced in the " Shadows." To-day those shadow factories have, almost without exception, been taken over by the motor firms which erected and operated them, and will be employed upon the production of post-war cars and commercial vehicles.

During the war the motor industry has been engaged upon a vast number of different products, some of similar nature to what may be termed " normal," but many bearing no relation whatever to that term. If one may deal first with the former, then the official " Statistics relating to the war effort of the United Kingdom " reveals that, up to June, 1944, the number of " Wheeled vehicles for the Services " manufactured totalled 919,111 and tanks 25,116. While it is not claimed that the motor industry alone has produced all these, there is little doubt that the majority of at any rate the first category have emanated from the motor factories. Of the total, the analysis shows that 82,000 were light vans and cars and 492,700 heavy-type vehicles. Armoured cars, including carriers, are returned at 74,802, and motor-cycles at 400,000.

Another item in the Statistics that holds particular interest for certain firms which in peace-time manufactured motor-cars is that relating to the repair of aero engines, which are shown as reaching a grand total (from the inception of the scheme in mid 1940) of 113,005. The repairing of an aero engine is a major operation, involving complete stripping down, overhauling and rebuilding with new parts to replace those that do not pass the stringent inspection of the Aeronautical Inspection Department. Recently one of the motor car factories which had been engaged upon this work announced the completion of its 10,000th aero engine overhaul.

Another manufacturer of one of Britain's most popular cars administered the Civilian Repair Organization for the Ministry of Aircraft Production. This was only a small part of the firm's war effort, yet it was responsible for making no less than 75,000 damaged aircraft fit to fly and fight again.

One product of the motor factory that was turned from peace to war without alteration—or, at any rate, with a bare minimum—and which filled many different roles, was the motor-car engine. Apart from its employment in its normal or allied spheres, such as in trucks, armoured cars, and other vehicles for use on the road, it was pressed into service for a variety of stationary power units, including generating sets for radio stations, lighting plants, and the like, also for driving the winches of the barrage balloons which are fast receding into but a memory. In the early days they were employed to generate current for the device which exploded the now almost-forgotten magnetic mine; they also drove the fire-pumps that fought the blitz.

If one glances at a list of Government contracts undertaken by some of the motor manufacturers, one may obtain a kind of potted history of the progress of the war. First of all, vehicles for the Army and Forces generally—trucks, ambulances, utility vans. Then, the expansion of the R.A.F.—for training aircraft, for aero engine components. Next, the expansion of the Army; millions of steel helmets, of ammunition boxes, of shells.

Then came the Battle of Britain; steel helmets for civilians, trailer pumps for the National Fire Service. For the war in the Atlantic, orders for depth charges and sea mines; for torpedoes; engines for life boats and for special pumps to spray water over survivors of torpedoed tankers swimming through a sea of burning oil. For the mounting blitz of 1941, an order for power units to light up decoy aerodromes. For the siege of Malta, an order for special long-range tanks for Hurricane fighters. For the rearming of our tanks in Libya, stampings for 6-pounder instead of 2-pounder guns.

Millions of " Jerricans " for petrol and water—the original version, captured from the Germans, was flown direct from the battlefield to one of the factories that were to produce them. Magazines for Sten guns, at the rate of 10,000 a week, to use up ammunition captured from the enemy. Bofors guns, for anti-aircraft, went into big-scale production at more than one motor factory. The fuselage of the Horsa glider called for the most highly skilled pattern makers, timber machinists, woodworkers, trimmers, and painters, men who had formerly made elegant bodies for luxurious cars. At another factory where small cars of sporting type had been made the Mosquito came into production.

When D Day was being organized, the necessity for amphibious operations demanded that motor-vehicles should be " waterproofed " so that they could be off-loaded from landing craft into the sea, and make their own way ashore through water several feet deep. The system whereby this could be done was developed in great secrecy over a long period, and certain streams near Coventry witnessed some of the experimental work. Gradually the desired results

were achieved, and engines could be run flat out in bottom gear for 10 minutes in a considerable depth of water, and be capable of covering 200 miles on dry land immediately afterwards. Shortly before the invasion took place, however, sudden requirements called for the performance to be repeated in water of even greater depth, and hundreds upon hundreds of trucks had to be quickly altered to comply.

Garages as Factories

In the foregoing columns the major products of the British motor manufacturing industry during the period of the war have been briefly described. Let us now revert to the time of the evacuation of Dunkirk, when practically every one of the mechanized vehicles that the British Army possessed had to be left behind in France. Yet this loss was replaced, from factories in the United Kingdom, within the short space of four months—and replaced with machines that were in every way an improvement on the earlier types. During these months the *Luftwaffe* began its attacks upon the country's industrial areas, and both Coventry and Birmingham suffered severely, with the result that dispersal became the order of the day.

Until the necessity for dispersing production centres was realized, the authorities had been slow to take advantage of the potential manufacturing facilities which another section of the motor industry had to offer. Up and down the country, in every city, town, and village, there were the retailers, the distributors of motor-vehicles who sell the cars to the public and operate service stations and garages. When hostilities broke out they were severely hit, for their livelihood disappeared overnight. This, for a trade employing some 150,000 hands, was serious; however, since many of the workmen were skilled mechanics and machine tool operatives, a big proportion of them were able to take on new employment right away in munition factories.

For the rest, and for the proprietors and managers, the outlook was dark in the early days, when private motoring was drastically curtailed. Yet the country needed munitions, and needed them in quantities far exceeding anything that was then being produced. The motor traders looked at their idle workshops and wondered why they could not be set to work on national necessities. Their associations formed a Motor Trade War Executive, which

A Royal Signals mobile wireless station on the road. It was used during operations on the Continent.

A line of ambulances presented to the Army by the Royal Antediluvian Order of Buffaloes.

brought to the notice of the authorities the facilities for production that were going begging. For a long time there was little response, but eventually, rather grudgingly, some of the service stations were given Army trucks to overhaul. The Executive persisted in its efforts and was making some headway against official apathy when the coming of the *Luftwaffe* gave a great fillip to the negotiations. Soon the importance was appreciated of having factories, albeit small ones, here, there, and everywhere. Quickly now the potentialities were explored and contracts handed out, and the service stations were before long busy hives of industry.

By this time, however, most retail motor traders had parted with a large proportion of their skilled mechanics and fitters, and retained, on the average, only perhaps two or three out of their pre-war staffs. When called upon to undertake official work, therefore, they had to import and train quantities of " green " labour, much of it female. And what did they do, these workshops wherein motor-cars had been greased and " decoked " and washed and polished? To answer that question categorically would require a volume, for the list of articles manufactured and the services performed is a long one. All that one can hope to do within the compass of this article is to record a comparatively small number of actual accomplishments, which form a cross-section of the vast whole.

First, there was the overhaul and reconditioning of Army vehicles, already touched upon, which developed into the Army Auxiliary Workshops scheme, and handled some 80 per cent. of repairs to transport vehicles, including Bren carriers and armoured cars. We may, perhaps, quote from the story related by the head of a large firm of motor-car distributors to indicate how the scheme was developed.

This particular firm had a well-established business in peace-time, supplying and servicing cars, commercial vehicles, and farm tractors over an extensive area. They maintained a staff of 65 skilled mechanics, but at the outbreak of war they had to part with many of them, and gradually, as work grew scarcer and scarcer, the number was whittled down to five. For some time there was barely sufficient to keep even these five fully occupied, although the servicing of tractors on farms in the vicinity provided a basic ration, so to speak, of work. At length there arrived an official contract for the repair, alteration, and modification of Army vehicles, together with an assurance that more skilled men would be provided to cope with it. This assurance, however, proved incapable of fulfilment on account of the universal shortage, and there was nothing for it but to engage such female labour as was available locally and to train it.

Therefore two of the precious five key-men were told off to act as instructors, and the now disused cellulosing shops, wherein glossy new coats had been sprayed on to motor-car bodies, were transformed into a school. In the workshops, the other three skilled men gave practical

tuition and supervised the partly trained women in their allotted tasks.

Slowly, but none the less steadily, the work got under way: the Army vehicles came into the service station in ever-increasing numbers, were stripped down, reconditioned, and rebuilt. When the flow of work through the shops was slowed down by a lack of replacement parts, the firm decided to make them themselves, so the works manager scoured the country and was able to get together a collection of machine tools, which he had repaired and adapted, eventually forming them into a very creditable semblance of a factory. This eased the situation greatly, and later the machine shop became so efficient that the firm was able to take on a contract for the manufacture of precision parts for small arms.

Another retail motor firm, which had been given an order to make aircraft parts, conceived the idea that it could make guns. It confided this belief to the appropriate authority, and a somewhat sceptical general of the Ordnance branch paid it a visit. When, after investigation, the general departed, he had lost his scepticism, and a contract came along in due course. Within the space of five months this firm was being credited with the highest output of breech mechanisms in the whole country; its secret lay in the fact that, by applying certain methods which, although new to Ordnance, had proved successful in the class of work in which this motor firm had previously specialized, the job was simplified to a substantial degree.

As the war progressed there was seen to be more and more that the service stations could do. Some of the small workshops were found to be more suitable for certain types of production than were even the big factories. One of the motor distributors in the southern counties was entrusted with the making of enormous van bodies in which the parachutes discarded by airborne troops after landing are renovated, repacked, and housed ready for further use.

At another garage was carried out the equipping of special trucks for the Signal service with intricate electrical apparatus and short-wave transmitters. Incidentally, a motor firm in the heart of the West End of London participated in this work, the testing of the equipment, secret though it was to the *n*th degree, being carried out in Hyde Park!

The natural versatility of the motor mechanic enables him to turn his hand to work involving a number of different crafts. For this reason, largely, some of the smaller workshops were entrusted with the making of secret " gadgets " which, being dropped by parachute to the French *maquis*, were doubtless put to effective usage.

Another specialized product concerned a certain tool which enabled the recuperator buffer on the 25-pounder gun to be repaired on the spot instead of the whole gun having to be sent back to an Ordnance workshop 150 miles away. When the need for this arose, Cairo then being in danger from Rommel, every employee willingly worked round the clock to produce the first 250 tools.

Not alone have the service stations been pressed into use as workshops and small factories; showroom windows of motor distributors have, in many cases, continued to display examples of the normal stock-in-trade of the firm while, behind the scenes, the showroom itself has been converted into a shell-turning shop, with lathes humming and overalled girls busy feeding them with fresh material.

In addition to what has been manufactured in Britain's garages the retail motor trade has performed services which have been of equal value; it has trained enormous numbers of men as drivers and mechanics for the forces. Soldiers have been turned into mechanically minded road users by the thousand since the first schools were established in 1940. Through one school alone passed nearly 5,000 trainees, on courses of instruction of varying nature which ranged from six to 14 weeks in duration. Invaluable work was done by these schools, especially in the early days of the war, when the Army was much less advanced in its mechanization than it is to-day.

Still a further activity which has fallen to the lot of certain motor traders concerns the building up of vehicles which have arrived from the United States in " c.k.d." (completely-knocked-down) condition. At different places accessible to the ports of entry piles of large crates suddenly appeared, dumped down on waste ground. Transported to the workshops near by, which often were service stations of the local motor traders, these crates would deliver up all the component parts of a jeep, or a United States Army truck, or a snow plough, or a tractor, and from the other end of the workshop would emerge,

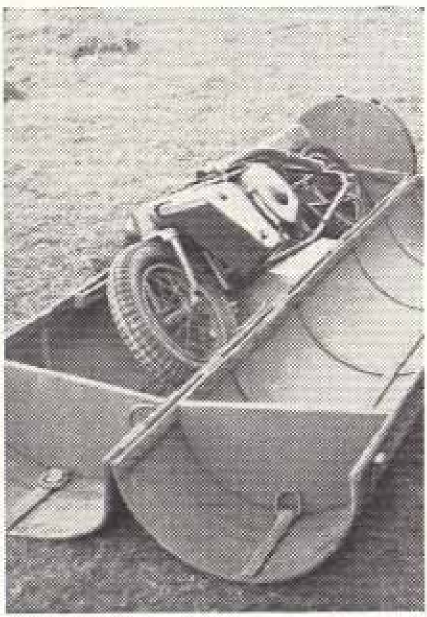
probably under its own power, the complete vehicle all ready for delivery and service. An output of hundreds per day was achieved at the peak of this activity, and great was the shipping space saved on the transatlantic crossing by the use of this method of shipping.

It would be impossible to conclude a review of the British motor industry's war effort without paying tribute to the products of the concerns which, while not being manufacturers or distributors of motor-cars or commercial vehicles, are just as much part of the industry. For example, the tyres, electrical equipment, and instruments are essential components of any motor-vehicle, whether it be a luxurious private car or a plebeian refuse collector. They are just as important also on an Army truck, or tank, or armoured car, or ambulance.

Lamps, ignition, screen wiper, starter, dynamo—all these are vital to war; and war brought a host of new demands to the firms who make electrical equipment.

Gauges, speedometers, and clock mechanism are likewise essential components in war as in peace, and fortunate indeed it was that the principal firm engaged in this section of the motor industry had, a few years before war broke out, decided to build up a watch industry in Britain.

It certainly would appear that the motor industry, for enterprise, initiative, and versatility, deserves well of the British Government and of the whole country in the days to come. It will be ready to contribute the same degree of energy and enterprise to production for export as it has displayed in production for victory.



A folding motor-cycle and container of the type used by airborne troops. This equipment was used in all major paratroop operations in Europe.

33

MOTOR CYCLES AND BICYCLES

THE value of the motor-cycle and bicycle industry's contribution to the national war effort cannot be measured solely by the yardstick of the great quantities of munitions it delivered; the time factor must also be taken into the reckoning. It was indeed, in the blackest days of the war, when the survivors of Dunkirk had to be re-armed and re-equipped against the threat of invasion and when a great number of new and converted factories were producing only a tithe of their scheduled output through lack of machine tools, that the industry was able to come to the rescue with large-scale deliveries of vital weapons, ammunition, and arms.

The very nature of its peace-time products enabled the industry to switch smoothly to munitions; its machinery was for the most part well suited to the manufacture of certain weapons of war, its workers were already skilled in precision production; a large section of it was centred in the Birmingham area, traditional home of the small arms trade.

At the outbreak of war some 75 per cent. of the plant in the industry was immediately freed for armament production, and as additional machinery became available and unskilled labour trained to use it, so the output steadily increased. In fact, it became difficult to use the term "maximum production" with any degree of accuracy; improved manufacturing methods, simplification of design, elimination of machining operations found to be unnecessary—all these, combined

with the determination of the workers, served to step up output from record to still greater record.

To enumerate the varied munitions produced by the industry, in addition to Army motor-cycles and bicycles, would be well-nigh impossible, but they ranged from gun-carriages to rocket projectiles, from rifles and machine-guns to fuses, aircraft components and shells. And their totals had to be reckoned in tens of millions.

Of special interest to the industry was the fact that in the advance of the science of warfare a new use was found for the bicycle, which, as a means of bringing infantry speedily into action, had been virtually banished from the front line early in the Great War. In the autumn of 1941 the War Office foresaw that a bicycle of a specialized type would be of great benefit in paratroop operations. After long experiment and the adoption of an unorthodox design, one company produced the ideal machine ; it weighed only 21lb. and was of the folding type, enabling it to be strapped to a man's back. A large "rush" order was the immediate result, and it was completed only a few weeks before the first use of these bicycles in an airborne operation—the Anglo-American landings in North Africa in 1942. So successfully did they fulfil their function that they were employed in every subsequent major paratroop operation of the war in Europe—on D Day, at Arnhem, and finally by the Sixth British Airborne Division when it landed east of the Rhine in front of Montgomery's advancing troops.

The industry has learned much in the past six years in the way of new materials and new processes. Of the latter one of the most important has undoubtedly been the application of hard chromium plating direct to all metals, ferrous and non-ferrous, to prevent corrosion and wear of moving parts. After long experiment in the research department of a Birmingham gun and cycle company the process was successfully applied to the .303 Browning machine-gun—the Battle of Britain gun—to eliminate fouling and a consequent slowing of the rate of fire ; subsequently all valve rockers for Rolls-Royce Merlin and other aero-engines were sent to a Redditch factory to be similarly treated. The process was also used to solve problems arising from the fact that certain steels were sometimes in very short supply ; it was found that other steels could be satisfactorily employed when the surfaces were plated with hard chromium. Experiments are now being made with a view to applying hard chromium to car and motor-cycle engines and even to the rims of bicycles, where ordinary decorative chromium tends to wear off through the action of the brake block.

The chief features of post-war motor-cycle and bicycle manufacture will be greater comfort, cleaner design, and easier handling, which will reduce the amount of money and time required for maintenance.

34

ROAD TRANSPORT

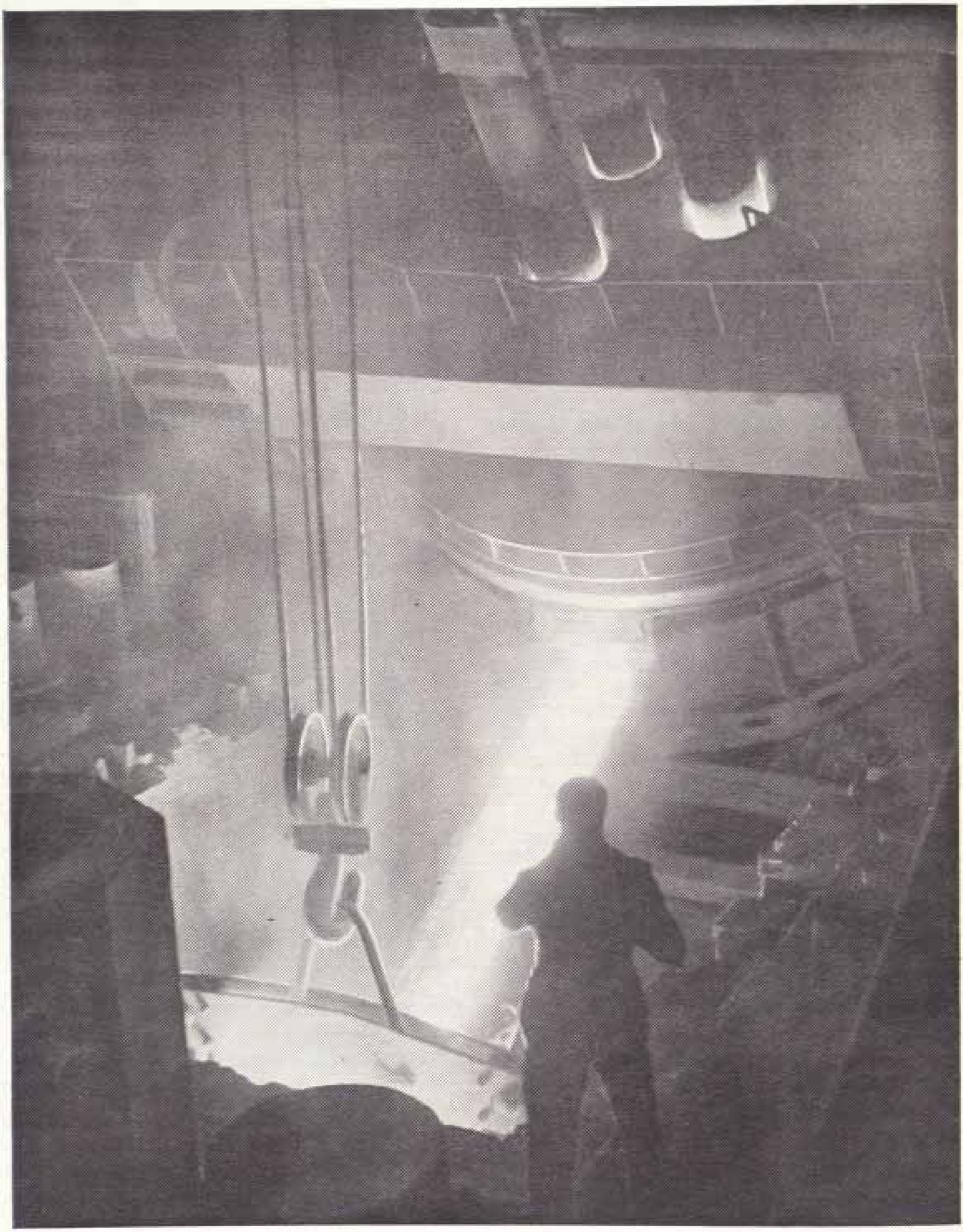
Since May, 1944, nearly all long-distance movements of general traffic by road have been arranged through the Government Road Haulage Organization, which was set up in the summer of 1943. This organization also employs vehicles to carry Government traffic for all distances.

During the preparations for D Day, vehicles were provided for road movements from the ports, from the factories, and from the depôts. For example, the Road Haulage Organization was largely responsible for the road movements of materials and parts of the "Mulberry" ports. After D Day the organization continued to meet all essential needs, as, for example, in providing 1,250 vehicles for urgent movements of guns and materials to deal with the flying-bombs. Two complete road haulage units, each with a carrying capacity of 500 tons, were sent to the Continent to assist in carrying supplies to the people of liberated territories.

The value of the contribution to victory made by road transport through the Road Haulage Organization is shown by the following figures of tonnage handled during 1944 :—

	Tons.
Long distance (including Government traffic)	11,081,830
Other Government traffic :—	
General	16,183,972
Opencast coal	8,087,781
Meat	3,610,603
Other Commercial traffic	14,834,251
Total ..	53,798,437

In addition, 4,685,489 head of livestock were carried.



MOLTEN STEEL

A striking scene in a North of England foundry showing alloy steel pouring from an electric furnace.

V. BRITISH INDUSTRIES AT WAR

35

STEEL FOR BRITAIN'S ARMAMENTS

THE most difficult side of the steel industry's work to illustrate is the achievement of the metallurgist and production expert. The results of a great deal of laboratory research and intensive experiment in steel works and engineering plant are often represented by no more than a changed formula; but that alteration may mean, in fact, that it is possible to produce a vitally important steel that would not otherwise be available in sufficient quantity, or it may be the key to the practicability of some invention or development.

Alloy steels are used when the stresses or strains on the finished parts are greater than could be withstood by the straight carbon or carbon-manganese steels. And the steels used for tools contain the highest alloy content of all, the chief materials being tungsten, molybdenum, chrome and vanadium. These steels are clearly one of the fundamental necessities of war production, for they are used to machine all kinds of steel, other metals and plastics, and without them industry could not carry on.

At the beginning of 1941 deliveries of finished tool steel, owing to the effects of enemy action, dropped to a level considered dangerously low. Apart from immediate steps, such as the transfer of experienced forgemen from one plant to another, a meeting was held with the Machine Tool Control, who specified their expected requirements; and later the makers of the high-speed steel needed in tool production met representatives of Control to agree a programme and indicate the tonnage each plant could guarantee. Although there have been many changes since then, requiring modifications of the plans and altered schedules, it is a fact that from that time there has never been any doubt about the industry's ability to meet the demands for tool steel made upon it.

The most important change of all came after Japan's entry into the war, when it was realized that our main source of tungsten in Burma was in danger—a danger that very soon became a fact. The first step was to devise steels that would use less tungsten than the 18 per cent. usually included, and three new types of high-speed steel were very quickly evolved with analyses that effected the necessary economy. The work involved was considerable, and had to be carried out under the spur of urgency. Apart from laboratory research, the necessary full-scale steelworks tests, and the proving of the suitability of the new steels in actual operations for a great number of different jobs, there was also the need of explaining to all users their characteristics and ensuring that the steelworks concerned were fully advised on the technique of production.

That catalogue of things to be done conveys an inadequate conception of what it meant to introduce new tool steels, but it may indicate the

complications. It was a major problem not only in metallurgy but in efficient organization, and the smoothness and speed with which the situation was handled represented a notable achievement.

Research and production were not the only factors. Economy in use and the prevention of wastage also played an important part in helping the industry to meet its commitments. For example, the use of tools only tipped with high-speed steel reduced demand. A great deal of work was done in organizing scrap collection and sorting. Control over industry ensured that tools were not used for non-essential purposes. Propaganda improved the care of tools by the operatives so that their working life was increased, and various technical developments tended to the same end. In fact, success in supplying war industry with the tool steel it needed was achieved by full coordination and day-to-day control adaptation.

During some phases of the Italian campaign there was a Bailey Bridge to every mile, and in one case nine were erected in three miles. The story of the development of that bridge (described on pages 73-75) is a good example of the steel industry's work in providing the Army with the equipment it needs. At the prototype demonstration in May, 1941, troops were borrowed one afternoon, and the next day built a bridge 70ft. long in 40 minutes. After that it went into production, and has proved its merits over and over again. It can be erected very rapidly—a 350ft. bridge was thrown across the Trigo River in 36 hours—carries even the heaviest tanks and transporters, and can afterwards be dismantled to make way for more permanent structures, its components being used again and again. It is adaptable to many purposes and varied conditions, and is capable of quantity production.

There is no intention of describing here the achievements of the Bailey Bridge—Field-Marshal Montgomery said that the Army could not have too many of them. The point is rather to show how the steel industry made possible its production in large numbers. To understand what was involved it is necessary to indicate briefly the nature of the bridge, which may be said to be on the Meccano principle. Standard high-tensile steel-trussed panels form the basis of the structure, and these can be used to build up virtually any kind of bridge. For light loads and spans of moderate length there may be single panels on either side of the decking. For heavy loads and long lengths the panels are doubled or trebled side by side and also, if necessary, superimposed. As a result, although the Bailey Bridge can carry the heaviest known military traffic there is no one part that cannot be lifted and fixed by only six men. The special features of the design are the use of high-tensile steel welded construction of the panels and decking-frame units, with alloy-steel pins for coupling panels together, and the fact that very few bolts are employed except for holding down the wooden decking.

It is worth noting how the essential characteristics of the bridge reacted on the steel industry. As lightness was of the first importance for manhandling, the factor of safety had to be kept as low as possible ; the sections must be extremely accurately rolled and free from flaws, the quality of the steel must be fully up to specification, and the carbon content very low, not only because of the use of welding but also to ensure the prescribed strength. This meant variations in the appropriate British Standard Specifications for the high-tensile steel to reduce the carbon content and give a higher minimum yield point. And the steel makers had not only to work to unusually narrow limits in these respects, but also to ensure very close accuracy in the profile of the section.

The position was made more difficult by the fact that the second order, in December, 1941, for 1,100 bridges, specified a proportion of high-tensile steel different from that in the first 200 ordered, while extra demands were made on British mills at a very difficult time. The mild steel required was readily available but the original regional arrangements for regular supplies of high-tensile steel to the fabricators and their many sub-contractors were soon seen to be inadequate.

Special organization was therefore introduced. The closest contact was maintained between the Director of R.E. Equipment and the Heavy Steel Products Department, so that Control, knowing immediately each programme was settled and each contract approved, could plan its production and allocation to the best advantage. Contact was also made with the Chief

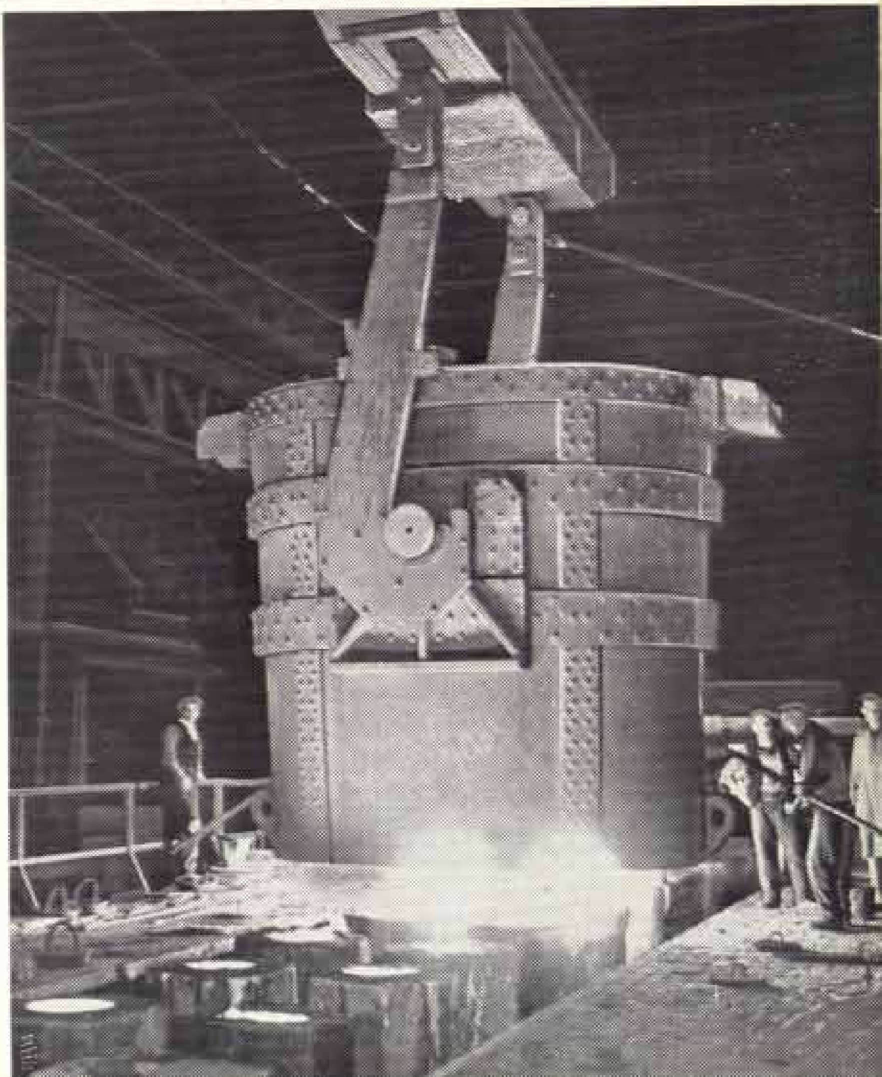
Inspector of Electrical and Mechanical Equipment on questions of quality and specification.

The number of firms rolling high-tensile joists and sections was increased from four to 16, and each maker was required to give a weekly statement of production, so that the monthly rolling allocations could be controlled and maintained. The "parent fabricators" were in constant touch with the Heavy Steel Products Department to keep check on the quantities demanded and to make up deficiencies where necessary. It was only by the setting up of this machinery that the Iron and Steel Control was able to assure deliveries of between 8,500 and 9,500 tons a week of high-tensile steel channels and joists, and enable the R.E. Equipment Production Branch to meet all War Office requirements.

It is worth noting, incidentally, that the fullest co-operation of the workpeople was materially helped by arranging demonstrations at which those who made the steel could see the bridges being actually handled by the troops. It has already been mentioned that the accuracy required both in quality and in the profiles was considerably finer than in normal practice. There was sometimes a tendency—understandable enough—to consider the Army "finnicky" and unnecessarily severe in their limits. When the workers—and managements—had seen the erection of the bridges and the loads they had to carry, they appreciated the reasons for precision.

This is only an outline of the steel industry's part in the Bailey Bridge programme, but it may illustrate the effect of demand on production and what is involved in providing the steel for just one important type of equipment. And it must be remembered that the same sort of adaptation and organization has been necessary in many other fields.

One company also played a vital part in the construction of the invasion harbours. One of their largest constructional shops was laid out and equipped for rapid mass production of highly specialized floating bridge work, and for almost



Teeming steel from a 90-ton ladle into moulds. The picture was taken at a British steelworks where some of the products of the country's collection of scrap metal emerged in the form of high-grade steel.

six months they operated day and night shifts and week-end working.

The most urgent call upon their resources came in the middle of April, 1944, when they were asked to accept the responsibility of coordinating the work of building the "Whale" or pier-head equipment for "D Day," which building was transferred from military to civilian personnel. After an appeal to the whole of the structural steel industry this vital task was put in hand without delay under the executive direction of the company's constructional officials and finished a few hours ahead of schedule.

Another firm supplied 15,000 miles of tubes to the Admiralty for defence purposes and over 1,000 miles of water-mains for laying in the streets of our principal towns. This company also had produced before the end of 1944 50,000,000 shell forgings for the artillery, in particular the 25-pounder and 9.2 howitzer. Forgings for 25-pounder shells were produced at a rate varying between five and seven a minute. Another company rolled over 9,000,000 tons of steel during the same period at a rate of nearly four tons a minute. This was mainly for ship plates used on the Clyde and in the shipyards elsewhere.

In all, the iron and steel industry produced and handled a grand total of 86,000,000 tons of steel during the war ; of this 14,000,000 were imported and the rest manufactured at home. During this period the industry mined and used 101,000,000 tons of iron ore, and approximately 5,000,000 tons of scrap was obtained from three great scrap collections—the national survey, which produced over 3,500,000 tons ; steel scrap recovered from "blitzed" buildings, which provided, approximately, 600,000 tons, and railings, which also amounted to about 600,000 tons. During this period the statistics covering the relationship of demand against supply show that in 1941 deliveries met 92.6 per cent. of allocations, in 1942 96.1 per cent., and in 1943, the highest consuming year, 100.8 per cent., while in 1944 the figure was 98.1 per cent. This is a record of which any industry might well be proud.

A photograph taken in a steel melting shop. It shows ingot moulds and also ingots stripped from the moulds. During the war 72,000,000 tons of steel were manufactured in this country.

The Struggle for Raw Materials

About half the British steel industry's pre-war production depended on imported raw materials, and that half included the steels most vitally needed for war. The plants were in the main not suited to an increased use of native ores, which are mostly low grade, with only about half the iron content of those we obtained from oversea and with a high proportion of phosphorus. It may not be appreciated that, apart from iron, coal, and ferrosilicon, other materials are needed in quantity for steel-making, none of which is produced in Great Britain. The countries from which they came normally were largely overrun by the enemy or otherwise cut off. Moreover, the shipping position for a long time imposed limits on imports even from accessible sources, and supplies of foreign scrap were reduced and finally almost eliminated by July, 1941.

Raw materials have, therefore, called the tune to the whole steel industry in war, impinging, for example, on transport, because of the need for carrying internally a greatly increased native ore traffic, and on steelworks practice, because it was necessary to adapt plant to handle iron of high phosphorus content and because new steels had to be devised to economize alloy substances in short supply.

The industry has never been under any illusion about the vulnerability of its supplies, and by the beginning of 1938 a survey of the steel position in the event of war had been completed. As a result, individual companies were urged to build up their stocks of all raw materials to the greatest possible extent, and in February of that year the Government were pressed to finance the laying down of an emergency stock of 1,000,000 tons of pig iron. This was turned down by the Committee of Imperial Defence.

In September, 1938, new representations were made for the financing of 500,000 tons of Swedish ore as additional stock, and when this proposal was also rejected it was reiterated, the industry urging also that a like quantity of low phosphoric ore should be added. The Government finally agreed in August, 1939—too late. A good deal had been done, however, by the steel companies themselves, and on the outbreak of war the stocks held were considerably higher than normal.

During the early months of the war the supply position remained fairly easy, for the nation's industry was still expanding relatively slowly, and during this period considerable imports were secured—where neutral countries were concerned often by " economic warfare " buying, designed as much to deny the material to the Germans as to supplement our own resources. But as soon as the attack on Norway was launched there was no longer any doubt of the justification for the industry's forebodings. Annual imports of ore from Sweden alone amounted to several million tons.

A stage in the making of a railway carriage spring
The workers are bending a red-hot leaf to shape.

After the fall of France the situation was even worse, the steelworks having by then lost the greater part of their normal sources of supply, and the subsequent conquest by the Japanese of Burma and Malaya added fresh difficulties by cutting off the most important sources of tungsten. As British industry awoke to a feverish activity, the stocks that had been built up stood us in good stead until alternatives could be found, but even so the position was serious.

Apart from the desperate expedient of breaking the Nazis' blockade of the Baltic, the raw material

problem was met by technical ingenuity and economy. The turnover to a greater use of native ore presented primarily a study in transport, for there was no insuperable difficulty in increasing the output of ore, which was, in fact, approximately doubled. The modifications in works practice, furnace design, and specification to make possible the use of high phosphoric ores presented a much more complex problem, but it is not practicable here to go into the technical questions involved. One example of results must serve to indicate what was achieved.

It was especially essential to reduce materially the use of hematite pig iron, which is principally a base for alloy steel making. At the beginning of the war we were consuming 36,000 tons a week. By cutting out the use of high-class hematite altogether from the iron castings industry, which formerly used one-third of the total, by substitution of other types for oxidizing ores, and by replacing the use of hematite with pig iron containing a high phosphoric content very large savings were made. By 1942 weekly consumption of hematite pig iron had been reduced from 36,000 tons to 24,000 tons, although the output of alloy steel had trebled in the same period.

One of the most important measures to cope with the raw-material crisis was undoubtedly the development of every possible source of scrap in the United Kingdom, particularly since the cessation of supplies from America, which up to the end of 1941 sent us about 500,000 tons a year. Scrap helped to solve the industry's problems from several points of view. Properly sorted—and sorting became a matter of the highest importance—it provided a source of low phosphoric material. Moreover from normal scrap about 95 per cent. of its own weight of steel is obtained, so that the difficulties arising from the use of low-grade native ores were mitigated, and this in turn economized in the consumption of fuel, which was in short supply, and also saved transport.

The scrap merchants, through whom the material is normally handled, did a good job. In 1937, the peak year of steel production, they handled 3,500,000 tons of scrap. In 1941, in spite of labour shortage, black-out, and other war troubles, they increased this by 250,000 tons. Nevertheless it was clear that the industry could not rely on their efforts alone and that a national campaign was necessary.

At this juncture the enemy provided some assistance, for the destruction of property of all kinds by bombing made available great quantities of valuable material that would not otherwise have been obtained. Anyone who was in London during the early days of the blitz will remember that for a time the débris accumulated faster than it could be cleared ; the Iron and Steel Control were interested in the steel, and in cooperation with the Regional Commissioner, whose concern was primarily with street clearance, they sought means of speeding up scrap collection. It was soon apparent that the difficulty was mainly transport. There was sufficient plant and labour to extract the scrap and cut it up, but it could not be got away to railhead sufficiently quickly. The area was divided into two sections and transport experts were called in, who devised a new scheme with special road-haulage arrangements to convey the material to railhead. In a very short time the iron and steel scrap clearance was raised from 3,000 tons a week to no less than 15,000 tons a week, and the railways, in spite of their manifold difficulties at that time, did their part, carrying it to scrap merchants who had sorting facilities, to steelworks, or to dumps for stock. Out of the total of about 600,000 tons of blitz scrap collected in the whole of the country, nearly half came from London, and by the middle of 1944 all but about 50,000 tons of that 600,000 had actually been melted.

A National Survey of scrap resources was carried through in the midst of bombing, and it covered everything that could be converted into scrap—derelict railways, disused bridges, redundant plant of all kinds. Of the total scheduled 2,500,000 tons has been cleared ; of 591,000 tons of tramlines 522,000 tons had been melted early in 1944. The total blitz and emergency scrap of all kinds, including local authorities' salvage collections, amounted to about 4,000,000 tons, and of this by mid-1944 little more than 76,000 tons remained in stock.

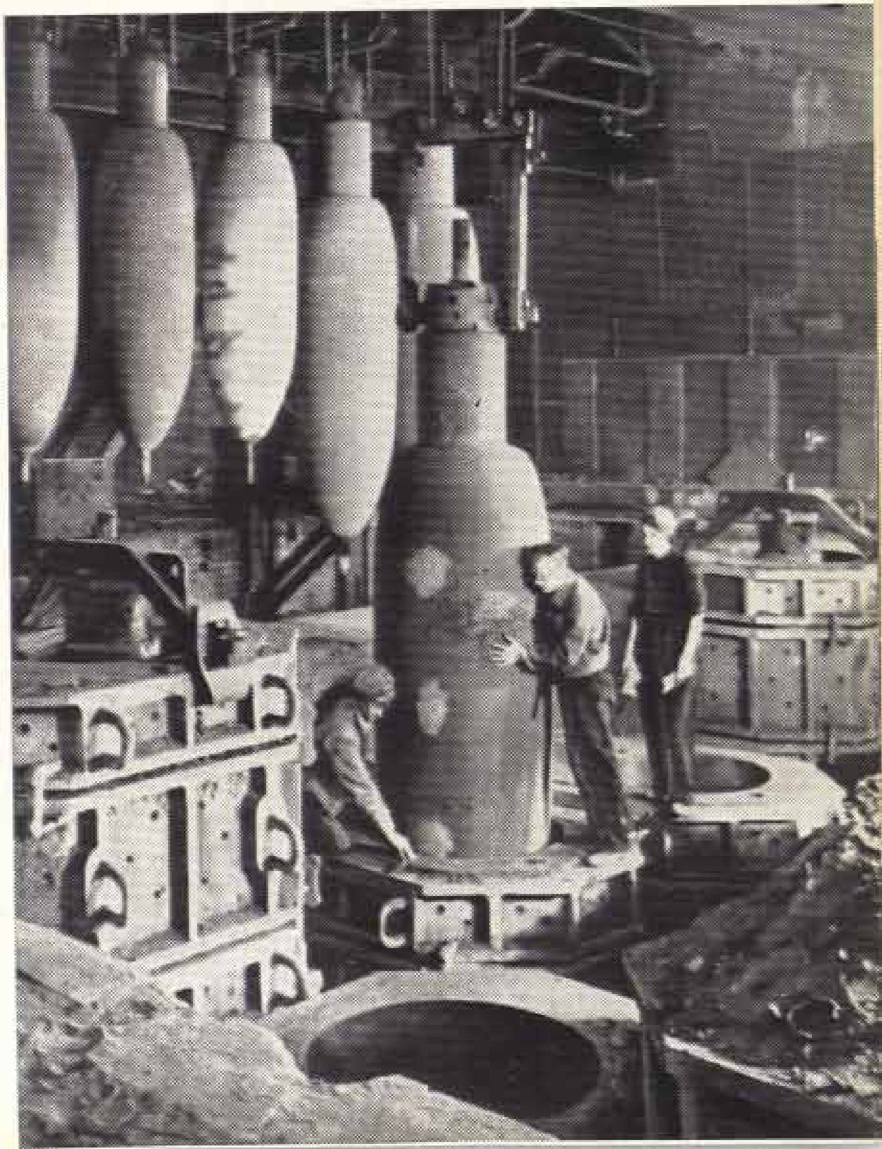
The public accepted willingly and philosophically the inconvenience caused by the sacrifice of gates and railings, but there was at the time a good deal of feeling about the apparent failure to make use of them. This material, like blitz and other classes of non-recurring scrap, represented a draft on capital, and the fact that it was to be seen lying about in dumps meant only that stocks were being built up against future needs. In the same way scrap that had been scheduled in old factories or derelict railway lines might be left *in situ* until they were wanted. The high pro-

portion that was melted bears witness to the soundness of the policy that was followed and to the necessity for accumulating stocks.

The war-time part played by scrap may be illustrated by a few more figures. For the output of steelworks 50 per cent. of scrap has been used, steel foundries 75 per cent., iron foundries 50 per cent., wrought iron works 80 per cent., and refined pig iron 60 per cent. Including the quantities handled by merchants, but excluding works or " process " scrap (the waste material occurring in factories during manufacture), over 100,000 tons of collected scrap were melted by the iron and steel industry every week.

One further indication of the importance of scrap has been the organization of a department of the Iron and Steel Control for marine salvage. Although the majority of the recognized salvage ships were not available, various vessels were converted for the purpose—old passenger ferries, dredgers, &c.—and crews were trained in the difficult technique of salvage. In four years more than 350 ships of all types from liners to small tugs were dealt with, often under the most difficult conditions, and many thousand tons of valuable scrap was made available, in addition to the cargoes which were also often rescued.

An interesting example was an unloaded American Liberty ship of 8,000 tons gross, which early in 1944 was driven ashore on an exposed island off the west coast of Scotland, and which the United States War Shipping Administration handed over as a possible source of scrap. She lay heavily on the rocks, with the stern broken away, at a point inaccessible from the sea and barely accessible from the land. It was decided that the only course was to build a steel scaffolding jetty with a light railway from the island to the ship. Although this was over 500ft. long, it was completed in less than three weeks, and operations went forward uninterruptedly. In spite of the temporary and apparently flimsy nature of this



The huge bombs used by the R.A.F. on industrial targets in Germany during the later period of the war severely crippled the enemy's armaments production. The core for a 22,000lb. bomb is seen being lowered into the mould at a factory.

structure, it successfully withstood the heavies weather.

This wreck offered an instance of an incidental service to the war effort provided by salvage. Another Liberty ship on passage to Britain from Russia sustained serious damage to her engines and needed a complete new low-pressure installation weighing over four tons. A signal was sent to the salvage workers, and they succeeded in recovering the unit from the wreck, so that it was available at a British port in less than a week to

Women steelworkers in their working outfits. These two operated a machine for punching holes in plates.

await the arrival of the damaged vessel. Many other similar cases could be quoted, and this work, demanding high skill and ingenuity under the most difficult conditions, has been of the utmost value in saving time, labour, and material.

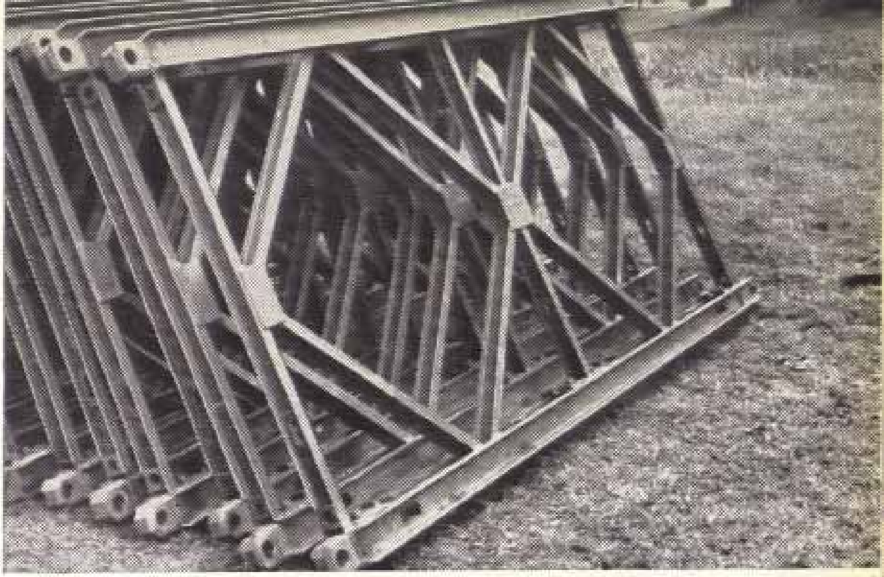
This brief review of some aspects of the struggle for raw materials obviously leaves a great deal unsaid. No reference has been made, for instance, to the negotiations with foreign countries for the supply of vital materials—Turkish chrome ore, Spanish and Portuguese wolfram—nor to the development of resources in Empire and allied countries. And the Raw Material Branch of Control has had to deal with such matters as the supply of limestone and lime, of refractories, and of electrodes, which are essential for the production of alloy steels in electric furnaces; with the complicated organization necessary to ensure sufficient stocks of each material at the right place to suit the individual needs of each steelworks. But enough may have been recorded at least to show under what great handicaps the industry worked. The measure of success is that no steelworks was idle for lack of raw materials.

Changing Phases

The true evidence of the British steel industry's success in satisfying the exacting demands of war is the plain fact of the nation's rearmament. In the House of Commons in March, 1944, the Minister of Production gave some figures of aggregate output for certain weapons from the beginning of the war to the end of 1943, quoting such totals as 83,000 tanks, armoured cars and carriers, more than 1,000,000 unarmoured vehicles, 115,000 guns of calibre larger than 20mm., and 150,000,000 rounds of ammunition for them. Add the steel needed by the factories producing them to the great quantities actually contained in these and other requisites of war, and one may gain some idea of the scale and complexity of the task that was successfully undertaken. If it had not been successfully undertaken the weapons would not have been there. From the battleship containing perhaps 40,000 tons of steel to the radio component with its fraction of an ounce of bright strip, paper thin, everything for war needs steel.

Cut off from four-fifths of its normal raw material supplies, the industry had to secure its output from inferior ores, and to meet, in spite of shortages of critical constituents, constantly varying war needs which required extensive changes from peace-time working. It had to do all this, moreover, within easy range of the enemy's bombers, and that involved, among other things, the Herculean task of blacking out completely every steelworks and blastfurnace in the country. Finally, it gave to the forces the greater part of its young men and operated with a high percentage of older workers, unskilled recruits, and women. Bearing in mind these difficulties, which are dealt with later, the maintenance of production at a level near the pre-war peak may be assessed at its true value.

The British steel industry, then, in spite of severe handicaps, succeeded in supplying the materials for Britain's great armament programme. How did it succeed and why?



Standard high-tensile steel-trussed panels for construction of a Bailey bridge.

In the first place the most comprehensive control was exercised at every point over raw material supply, steel production and consumption. As long ago as 1942 the Minister of Production could state that only 7 per cent. of steel production was going to civilian needs, and to devote 93 per cent. of output to war purposes means the elimination of all non-essential usage. Although the United States had not then had the same opportunity of gearing its industry to war, and the comparison is therefore less than fair, it is worth noting that their percentages at the same date were 60 for civilian consumption and 40 for war.

Secondly, raw material difficulties were partially overcome by the greatly increased use of home low-grade ores, by the finding of new oversea sources for essential materials in short supply, by the evolution of steels that met requirements while using smaller quantities of the critical constituents, by stringent economy, and by intensive scrap campaigns. The traditional knowledge and skill of managements, steelworkers, and metallurgists made possible the solution of the many acute technical problems that constantly arose.

Thirdly, the structure of the British industry lent itself to flexibility and adaptation, British steelworks have always catered for the customer with special requirements and taken a pride in being able to supply steel for any purpose whatsoever. Their experience enabled them to meet every change in war-time demand with the minimum of delay and dislocation. In this respect the British industry enjoyed marked advantages over those of other countries. The differences in the structure and aptitudes of the British and American steel industries benefited the common cause after a high measure of rationalization had been achieved in their relations, because it was possible to make their capacity in many ways complementary.

The turning over of a great industry from peace to war is primarily a problem in organization, and with such a fundamental material as steel the change-over must be rapid. Speed is difficult when a new system and new machinery have to be created from the beginning and run in, and effective control could never have been established as quickly as it was without the pre-war integration of the industry. The steel industry, through its official representatives, was itself entrusted with the task of ensuring that supplies for the war effort were forthcoming.

The great number of steels that are needed for the various purposes of war has already been mentioned. Not only must steels of the right analysis be available, but there must be the plant to process the required quantity of the product. For instance, if demand is for strip of a certain thickness, supplies of the necessary steel will not alone solve the problem unless there is also the capacity to roll that particular kind of strip.

The difficulties were made more complex because the nature of demand has changed very greatly from time to time, and has never been in line with the normal requirements of peace-time. After Dunkirk, for example, there were great alterations in the types of steel needed, and in priorities. More recently the waterproofing of tanks and other vehicles for the invasion of

western Europe demanded the temporary concentration of the whole capacity of the sheet-rolling industry in Britain on one of the greatest rush jobs of the war. Night and day, 280 factories were engaged on the task, for when the final plans were complete there was available only a quarter of the time necessary to do the work under normal conditions.

Furthermore the raw material situation was in a constant state of flux. There was first of all the progressive cutting off by enemy action of most of the normal oversea sources, the various stages in the position of American imports dictated by their own production programme, and always the limiting factor of transport capacity—internal and seaborne. On the railways particularly heavy burdens were placed because increased quantities of home ore had to be carried long hauls—from the Midlands, perhaps, to a Scottish steel works which had formerly drawn its supplies from a port near by. Three thousand 20-ton trucks were built for the carriage of iron ore, 450 or more special iron-ore trains were run every week to carry 250,000 tons of material for the iron and steel works.

To maintain steel output and meet the changing demand therefore meant a constant juggling with four major problems—changes in methods of manufacture; research to secure suitable substitutes; provision of steels with maximum economy for new jobs; and distribution.

Before the war there was a period during which the steel industry, knowing itself to be as vulnerable as it is essential, sought to prepare against eventualities, and in the face of official discouragement succeeded at least in increasing its critical stocks appreciably.

From the outbreak of war to the unloosing of the German attack on Norway was a phase of preparation and organization. With the nation only half at war, the demands of the munition industries were much lighter than they became later, and most oversea sources of supply remained open. The end of this period saw the inauguration of the distribution scheme—the chief step in establishing steel as a precious war commodity to be used for nothing that was not essential. These early months saw the purchase, through existing contacts, of valuable supplies of steel from oversea.

The next phase embraced Dunkirk and the all of France, and may be said to have ended when "cash and carry" gave place to "lend-lease." In it an altogether new urgency of demand coincided with an accumulation of difficulties. The acceleration of every war industry to meet the emergency came at a moment when most normal sources of raw materials had been lost, when U-boat warfare threatened our remaining imports, when the country was under first the shadow, then the reality, of air attack, and when the export drive was still needed to obtain the foreign exchange we must have to buy abroad. The distribution scheme came into effect and played an important part in helping the industry to meet its commitments. It produced at first a cut in civilian consumption greater than the rise in war demand, and therefore increased the quantities of steel at works and stockyards by 1,000,000 tons—an invaluable reserve.

The period that followed falls between the introduction of lend-lease and the point in 1942 at which the Minister of Production could say that Britain was at least within sight of full production. It included the entry of America into the war and the progressive rationalization of the steel industries of the two countries. While there had been time to devise alternatives, fresh raw material difficulties were created by the Japanese conquests in the East, and in particular by the loss of vitally important tungsten supplies from Burma and China. The Pacific war again involved changes in the nature of demand, while intensified submarine attacks further stretched shipping resources.

The last phase was a period in which the British arms industry attained full production, in which the basic equipment of our forces was completed but in which at the same time the change-over to the offensive meant alterations in demand. These years included, for example, special emphasis at different times on the construction of escort vessels and anti-submarine equipment, aircraft production, aerodrome construction and equipment for American forces in Britain, landing craft and other necessities for the offensive. Internal transport problems were latterly further complicated by the added strain of invasion preparations. This phase was characterized, in fact, by the need for a measure of adaptability even greater than before, by the realization of earlier researches in the production of new weapons and machines—rocket guns, for example, and jet-propelled aeroplanes—and by the completion of the whole industry's adjustment to the purposes of war.

36

ELECTRICAL INDUSTRY'S EXPANSION

THE First World War showed how important the effective supply of electricity and the provision of the necessary equipment to use it were for the successful prosecution of the war itself. Even then, the dependence of the entire war machine on electricity was understood, and first among the post-war reconstruction schemes was one which aimed above all at providing a reasonably safe national supply.

The second war meant an immense expansion of electrical service, so much so that at almost every phase the struggle in the actual conduct of hostilities, so far as it depended on science and the provision of the necessary technical equipment, was one between the British and German electrical industries. The 40,000 million units of 1944 compared with the 2,500 million units generated in 1914 are only a slight indication of the immense increase in range and responsibility of the electrical supply and manufacturing industries. A bare list of specially designed equipments would fill several pages and still afford no real indication of enterprise and achievement. Still less would it illustrate the invention and resource of the manufacturers themselves when confronted with what appeared to be insoluble problems or the speed with which they reacted to new developments worked out by a cunning and resolute enemy.

In the game of chess on which so much depended for the successful outcome of the war the Government, aided by research scientists and engineers, made few false or belated moves, and it is a remarkable fact that preparation for this contest began not in 1939, but as long ago as 1934. For the electrical manufacturers the war lasted not six but 11 years, and the greater part of their contribution falls within the period 1934-40.

The industry had an equipment of research laboratories and development shops not only adequate for its own purposes, but able to absorb additional tasks imposed on it by the Government. The great laboratories at Trafford Park, under the control of a man of genius, and at Wembley and at Rugby linked up intimately with a vast manufacturing complex, were supplemented by laboratories and test departments

The electrical industry has been responsible for the supply of new equipment for use in the factories and power stations in U.S.S.R. This picture shows work in progress on a 10,000 kv.a. transformer for the Soviet.

Erecting electro-hydraulic control gear for anti-aircraft guns in a factory in Scotland.

owned by specialist firms, as at Hollinwood and Edinburgh, and the entire system was brought into play and kept constantly active before and during the war.

It is necessary to emphasize this point, since the special research executive evolved by the Government, where technical experts from the Services handed over their problems to the manufacturers for solution, could not have worked without it. The answer to German war expedients and inventions, from magnetic mine to V2 bomb, was invariably and immediately found. The further process of translating research data into commercial and large-scale manufacture was a simple matter of selection of individual firms or groups of firms. Occasionally specifications, such as that of the radio-directed automatic tank, were not capable of easy realization in the workshop, at least within the time indicated, but the Government showed wisdom in allowing firms to keep their research experts and the Services were not over-selfish in collecting scientist and specialist engineers from the firms. Cooperation between Government departments and individual firms was, on the whole, extremely successful.

One can divide the war effort of the electrical manufacturers into possibly five divisions :—

(1) Maintenance of the economic effort of the country apart from war production.
(2) Increasing the war industrial potential.
(3) Direct war activity and the supply of material.
(4) Improvement of the technique of war.
(5) Assistance to allies in all four phases mentioned above.

While it is true that at the highest concentration something like 70 per cent. of the national production was devoted entirely to war production, the remaining 30 per cent. had to be efficiently and adequately supplied with electrical energy. The great public utilities and services had to be kept going. This meant that the requirements of the Grid in generating plant, transformers, switchgear, and control equipment generally had to be met with the minimum of delay, the great reserve pool of machinery and equipment had to be stocked so that transforming and switching stations could be repaired at once and destruction of power plants made good. We know now that concentration of power production in a few big stations had to give way to a policy of diffusion over a much larger number, private industrial plants were brought into the system, and a considerable duplication of transmission and distribution systems carried out. In addition, provision of standard generating units and the actual equipment of new stations, as at Reading, had to be met. During the worst time of the blitz electrical service had sufficient material to make good destruction and maintain supply. One firm supplied 1,833,000 kilowatts of generating plant and 2,352,000 h.p. of electric motors.

On the other hand, the manufacture of consumers' apparatus such as electric lamps, fires, cookers, boiling plates, radio sets, refrigerators, and vacuum cleaners had to be severely restricted and to all intents and purposes abandoned. Even so, the physical existence of a very large number of electric fires reduced to manageable proportions the hardship imposed by

fuel shortage on the civilian population. Small engines required for direct drive or for local electricity generation had to be produced in immense quantities to aid in the dispersal of industrial production.

It is, however, in the second and third categories that the great achievement of the industry stands out. The terrific problem of decentralizing war industries was quite insoluble without the Grid system and the manufacturing resources of the electrical firms. The creation of subsidiaries to Woolwich Arsenal in South Wales, Lancashire, North-East England, and Scotland, of no less importance than the present institution, the designing and construction of shadow factories, principally in 1937 and 1938, the elaboration of new munitions factories over an immense area from London to South Wales and South and East Scotland with amenity buildings, hostels, canteens, and houses, and the rapid expansion of the chemical and explosives industries (one electrical firm supplied over 140,000 h.p. of machinery to one group alone), brought into play every element in heavy and light electrical engineering—not merely the complete installation of independent power plants, the supply of control apparatus to link up with the Grid, or extensive consumers' material for lighting, cooking, and heating, but also a wide range of motors activating machine tools and following out complicated industrial processes. Induction heating and dielectric heating were developed to an astonishing degree, the latter in the making of moulded products, the manufacture of aeroplane propellers out of resin-bound ply-wood and, experimentally, in the drying of textile yarn, the drying and sterilization of grain.

Essential industries inconceivable without low-cost electricity and enormously powerful electric heating furnaces came into existence—above all, magnesium, light alloys, and aluminium, special heat-treated steels. The mechanization of coal-mining, open-cast working both in coal and iron ore, the maintenance and extension of services on electrified railways, the provision of Diesel-electric locomotives on new railways in conquered areas, extensive dock-handling equipment, not least on new ports in the south of Scotland and on the shores of Normandy, brought new tasks to materials handling and transport departments.

In the third category it is not easy to sort out purely electrical from non-electrical contributions. All electrical firms were alike in not confining their work to purely electrical products. They not only provided the wiring and other electrical gear for aeroplanes, but assembled the complete unit. One firm in Manchester erected a new factory for this purpose in the spring and summer of 1939 and by the end of 1944 had passed more than 1,000 heavy bombers through it; a second firm was responsible for an even greater number as well as the manufacture of engines for high-speed fighters. A fair estimate would credit to the industry half of the heavy bomber output of the country and a high proportion of medium bombers. A similar contribution can be found in tanks, rolling-stock, and transport vehicles, but the most original example came from an Edinburgh firm, which supplied dead on time the pier pontoons or "Whales" required for the Mulberry prefabricated harbours at Arromanches.

In another chapter the story of the invention and supply of radio-location equipment is told, but it should not be forgotten that from the first sets elaborated in 1937 at Trafford Park to the immense production of the new factories at Manchester, Peterborough, Northampton, and Leicester Radar was associated with the electrical engineering industry and still remains its most spectacular achievement. The evolution of the jet-propelled aeroplane from 1936 onwards must be credited largely to a Rugby firm.

There was not a single detail of major equipment in the wide range of aeroplanes evolved during the war which was not manufactured in bulk, developed or actually invented by the industry. A single quotation from the list prepared by a firm at Rugby may suffice :—

> 65,000 sets of parts for assembly of major aircraft magnetos, 84,000 auto-timing devices, 24,000 aircraft motors and generators, 50,000 engine-driven air compressors, 18,000 regulator valves, 1,400 aircraft cameras (a second firm at Hollinwood was responsible for practically all camera control units), 50,000 bomb slips.

The same group supplied 1,250 Radar equipments, including 700 for the Army, while an associated group manufactured, in addition to prototypes, an even greater number. The latter specialized also in the design of automatic pilots. One can select from a bewildering variety such things as turn indicators, distant reading compasses, gyro gun-sights for fighter aircraft, mean altitude measuring apparatus and sirens for screaming bombs.

Aerodromes and anti-aircraft defence generally brought into play the varied resources of the

industry : from generating plants, mobile searchlights, special lighting schemes to the most delicate control mechanism on the A.A. guns themselves. The spectacular claims made in connexion with the use of infra-red rays by Germany could be transferred to British firms. The study of sound location carried out at Trafford Park during the first world war was carried to such a standard of perfection that the location, elevation, and direction of suspected aircraft would be established by means of locators supplied to the army as early as 1936 ; aeroplanes could be aware of submarines charging batteries at night literally hundreds of miles away and the coordination of fire control and sound location with other methods of detection ensured the destruction of the Italian fleet, for example, at Matapan, without the British or Italian fleets seeing each other.

The neutralization of the acoustic mine (as, no doubt, later, the acoustic torpedo) involved the use of an apparatus sending out high frequency acoustic waves sufficient to explode the mine well in advance of the ship. The early development of searchlights for the Army, of signalling lights and fighting searchlights for the Navy was supplemental by the use of Radar as a kind of radio searchlight used to discover enemy ships and aircraft. One firm developed a searchlight of 1,000 million candle-power.

The Navy was supplied in many other ways—not merely with heavy machinery for propulsion and electricity generation, but also an immense range of detailed apparatus requiring the most delicate adjustments. One electrical firm supplied all the lifts installed in aircraft carriers, a second specialized in submarine torpedo detectors, a third concentrated on submarine motors. Some idea of the range of product can be derived from production by one group :—

Two hundred electric torpedoes, 10,000 mines for aircraft laying, 17,000 mine mechanism plates, and 6,000 hydron switches, 800 Duplex pistols for torpedoes, 550 special depth charge cylinders, 800 oscillators for protection against acoustic mines.

An Edinburgh firm manufactured thousands of compass corrector coils to offse the errors created by de-gaussing equipment for neutralizing magnetic mines, paravanes, broken floats, and Dan buoys, for minesweeping operations. A Manchester factory, among other things, made gyros for torpedo control and H.E. anti-aircraft projectiles incorporating parachutes and other gear to form a barrage ready to be exploded by enemy aircraft.

The story of valve design from immensely powerful tubes to the most minute incorporated in fuses belongs elsewhere as well as that of the millions of shells, igniters, electric rammers, gun-sights, range finders, gun mounts, and elevating gear supplied direct to the Army and Navy. The conversion of 18-pounder guns to 25-pounders as early as 1937 allowed the Army to deal with the heavier German tanks in the North African campaign. At every stage the war became more and more completely mechanized in terms of electricity :- gun-sighting and firing became an exact science with automatic electric control substituted for human fallibility.

In the last category of all—namely, assistance to allies—the electrical industry supplied new equipment for the mines and factories in the Don Basin, generators and transformers for Stalingrad, and a large number of mobile power stations moved along the railways. One Trafford Park firm supplied more than 50 such stations with capacities ranging from 1,000 to 5,000 kilowatts and a second firm large motor generator sets for chemical purposes. Through them the Soviet could make good the destruction of local power supplies.

The lesson of the war reinforced without changing the lessons of the peace. Summarized, they may be stated :—

(1) The higher the state of organization of an industry the more easily it lends itself to the demands of the State at war as well as the State at peace. Government departments, staffed by experts who know their business, can get out of industry all that they desire, provided they enlist the finest research ability and administrative capacity employed by industry. It is no coincidence that the electrical manufacturing industry, on its record, one of our best conducted, should not only have met the ordinary demands laid on it, should not only have doubled its manufacturing capacity to deal with highly complicated electrical equipment necessary for the conduct of war, but should have undertaken other lines of manufacture as well.

(2) Without the great research departments in the industry, the industry and the State would have been helpless. The war was fought out in the research laboratories and British intelligence won. The transition from the findings of pure research to the fabrication of prototypes, the development of test products, the segmentation of those products into mass production elements, the organization of groups of firms supplying

those elements, and the erection of great assembly factories were miracles of organization which should be continued in peace. The spread of organization from one industry to another, exemplified at Trafford Park, at Rugby, and Coventry, so that a complete range of apparatus could be supplied at high speed is one which should be studied.

(3) Increased labour efficiency was achieved not merely by the establishment of joint production consultative and advisory committees but by the most exact study of individual outputs and examination of social and psychological factors. In other words, labour was treated with care as an essential to good production—not as a commodity or a piece of machinery. Working conditions were not worsened but improved. The experience at Willesden, where the increase in output was achieved by a 10 per cent. expansion in factory area, 18 per cent. expansion in personnel, and 25 per cent. increase in working hours, gives an indication of method and results. Two groups of firms had in 1938 about 4,000,000 square feet of workshops and in 1945 just over 7,000,000 square feet, but effective use of area was so great that outputs were considerably more than doubled. There was no labour difficulty of any kind.

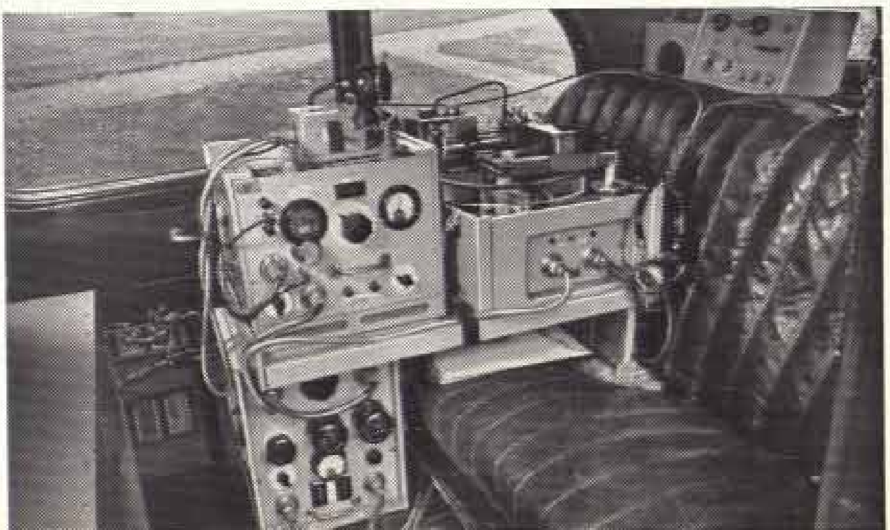
(4) The technique by which an immense factory was erected at Trafford Park within seven weeks is one which merits examination even more than that of the fabrication of the Mulberry ports in Normandy. We know now that excessive delays in the latter almost jeopardized invasion, but the former was a straight piece of construction, with no complications of a bureaucratic nature. Examination of what happened in the electrical industry should be valuable for the solution of the housing problem.

(5) The capacity of industrial firms to recover from bombing is one of the minor wonders of the war. In the Coventry area, under the control of a Local Reconstruction Panel, 63 per cent. of several hundred casualty firms in the panel area, nearly 80 square miles, were able to resume full production within two days of the incident. At no time was war production seriously interrupted by bombing attacks.

(6) It is difficult at this stage to determine which of the war inventions or industries have a future in peace. The potentialities of Radar, of infra-red and other forms of light penetration, of jet propulsion, and air supercharging remain to be studied by the light of further research. One development can already be seen. The provision of mobile power-stations has shown once and for all that the cumbrous and generally exceedingly ugly and vulnerable structures housing generating plant are an anachronism. The waste of capital and effort involved in such erections should be avoided in the future with an improvement in efficiency and cost and less violation of natural amenities.

(7) The last and most important conclusion is surely that the lack of preparation for war should not be attributed to firms of the calibre of those in the electrical industry. The main scientific and technical discoveries necessary for success in the war were made and worked out over the period 1934-40; no major advance took place after the autumn of 1940.

The scientific and technical war was won four years before it was fought out on the battlefield. There is no space available here to give details, but together they provide a complete answer to any claim that only after 1940 was the war prosecuted with energy and efficiency. The electrical industry, within its range, did evolve and design the tools in good time. Their production in immense volume was a matter for State policy and State organization.



A B.B.C. saloon car recording equipment showing the amplifier, the power supply unit, and the single turntable recorder. Recorded items have become an important feature of wireless programmes.

37

UNSEEN VICTORIES OF RADIO

MR. CHURCHILL described radio as "the heart of our war effort" when, in 1942, he invited Sir Stafford Cripps to become chairman of the War Cabinet's Radio Board.

In peace-time, however, even the most knowledgeable people, including those few who knew of our early work on radiolocation, did not foresee the leading role that radio was to play: and when the war began the radio and television industry, an infant compared with the other armament industries, did not immediately feel any pronounced growing pains. Television, in fact, came to a stop so far as the public consumer was concerned. There were increased service radio needs, of course, but the war was more than a year old before the violent growth of these demands, coupled with the loss of raw materials and components from oversea, became suddenly apparent.

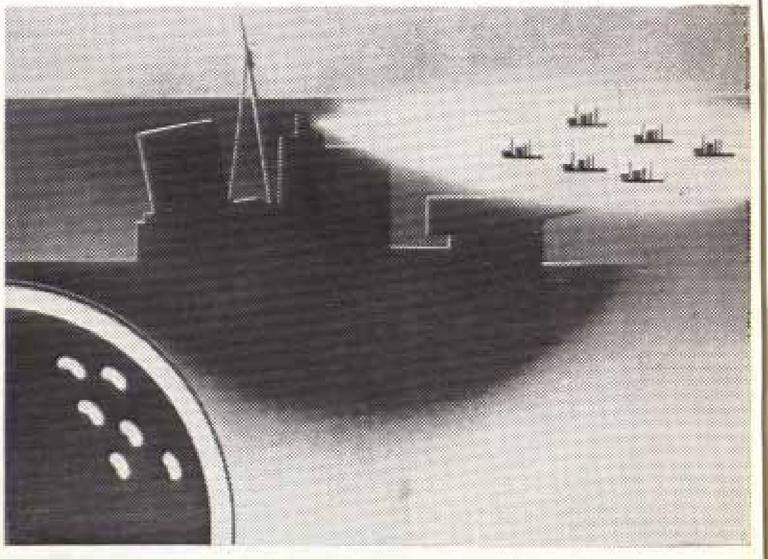
From then on every device was used to increase the output of valves, components, and complete sets for the radio and radar war of wits; and at the end of the five years and eight months of war in Europe the United Kingdom's radio industry had grown to five times its pre-war size, measured simply in the number of people it employed.

That growth was accomplished in the face of a special difficulty which no other industry experienced in the same degree: the necessity for secrecy about the actual articles produced, and particularly about the entire production of radar equipment.

To the public, and so inevitably to the enemy, it was apparent that such industries as tank production, the manufacture of explosives, and shipbuilding were enlarged and active for war; and the location of those industries could not entirely be concealed. The radio industry, however, had huge and unknown tasks to perform at pressure, as development rapidly followed on research, and production on development, without the whole picture being unnecessarily disclosed even to those engaged in design and manufacture.

These tasks were accomplished partly by general dispersal of the industry, partly by separating factories producing related parts of the same secret equipments, and partly by improvisation which led both to the transfer of workers from unessential industries and to the adaptation of factories which had been engaged on strangely different types of work—mills, garages, and even private houses and huts.

In all, the industry produced, it is officially calculated, 12,000,000 separate radio equipment



Among the uses of radiolocation to the Navy was that of directing fire on to the enemy's ships and U-boats. The picture on the left shows gunnery radar in a British cruiser. By this means the range is transmitted automatically to the guns. Right: A diagram illustrating how the position of enemy vessels is located and indicated on a screen.

units for war purposes; it was manufacturing 38,000,000 valves a year at the peak period, compared with an annual 10,000,000 before the war; and the production of components, which are reckoned to number a rough average of 20 to every valve needed, accordingly reached astronomical figures.

The general development of the radio and television industry can best be summarized by saying that it had to serve science at war by producing in industrial quantities apparatus which would have been of laboratory standard a few years before, and that this applied both to the newly developed science of electronics and to more normal electrical techniques. The continual trend in radar, for instance, hastened and really made feasible by the invention of the magnetron valve by a research team at Birmingham University during the war, was towards the transmission of greater pulse power at ever shorter wavelengths.

Parallel development of communications radio, and particularly of very high frequency radio-telephony, used as a basis of a control system by fighter aircraft in the Battle of Britain and subsequently for other purposes, was similarly exploring the handling of shorter radio wavelengths; in the V.H.F. system push-button methods of "channel" switching were used by the fighter pilots, who already literally had both hands too full to undertake elaborate retuning.

Work on extremely short waves both for radar and for wireless communications was therefore the principal field in which the radio industry underwent considerable change. New techniques involved hollow wave-guides to direct radio-frequency power, in place of normal metal conductors, and tuned circuits so small and apparently simple that a mere slit in a metal plate could now be the equivalent of the elaborate condensers and solenoid coils necessary for the longer wavelengths of previous years.

Apart from the experience gained by the industry in making components and assembling sets to handle these higher frequencies and greater powers, the outstanding advance was undoubtedly in valve manufacture. Standardization has never been a strong feature of British valve manufacture; though, in fairness, it should be remarked that this very diversity may possibly have made our equipments—and particularly our experimental equipments—less susceptible to enemy prediction, interception, or jamming during the war. At the end of the war, moreover, in spite of continuous effort to classify and compare the characteristics of different makers' types, the valve field was greater than ever: there were 600 different types being manufactured in the United Kingdom for Service requirements at the time of Germany's defeat. They varied in size from the foot-long, weighty affairs used in the ground radiolocation transmitters round our coasts to the tiny "acorn" types which have no separate bases or pins: and in complexity from the magnetron and other types, which contain so many ancillary circuits that they almost cease to be valves, to the ordinary diode.

It is worth remembering that a tiny valve is essential to the location of an enemy land-mine, and that many tanks carry three equipments using valves, while warships and aircraft fairly bristle with equipment depending on valves. Small wonder, then, that the output of normal valves for the civilian pleasures and duties of war-time broadcast reception had to be left at a maintenance level from 1941 onwards while all these other types in greater numbers than ever before were being produced in both permanent and makeshift factories.

Nor must it be forgotten that cathode ray tube consumption in radar equipment for the three services additionally necessitated an output of 360,000 a year. Before the war the oscilloscope, as it was then more generally known, was produced in comparatively humble numbers, in spite of the leading position held by British industry in the television world.

The total contribution of the radio industry to victory in Europe cannot easily be over-assessed, particularly since even now the full part played by radar has not been disclosed. It is accepted fact that, considering one aspect of radar alone, the U-boat menace was neutralized by electronic devices, both airborne and seaborne; that in direct consequence the invasion of Europe was possible by June last year; and that we as an island were accordingly delivered by the Allied Armies just in time from the impending blows of enemy rocket and other multiple artillery, which Mr. Churchill described subsequently in Parliament.

Plainly the part played by radio, and so by the industry which fought continually to keep design and production abreast of the scientists' and the services' demands, went even deeper than that. It was the radiolocation chain, secretly assembled before the war and coupled with V.H.F. control, which gave us tactical supremacy in the Battle of Britain, and developments from that chain which made night raiding too costly

for the Luftwaffe. It was radar aerial navigation and blind-bombing aids, including systems both depending on ground stations, such as "Gee," "Gee-H," and "Oboe," and independent of them, such as "H2S," which made it possible for us to strike back decisively and accurately at Germany even before we invaded Europe. Equally it was radar which gave our coastal batteries and light naval forces warning of the approach of E-boats or mine-laying aircraft, and made it possible for a sea action between large warships to be fought as accurately in pitch darkness as in daylight.

If these achievements alone seem major contributions to victory, it must also be remembered that more orthodox radio equipment was used as well in greater amounts than ever before to supply ships, aircraft, and soldiers with radar and other information, to make direction-finding possible, to carry teleprinter messages, and to provide a communication link from mobile stations even in the heat of battle over distances which could not be spanned in any other way.

It is to the credit of the radio industry that these essential communication sets for telegraphy, telephony, D.F., and so on, each subject to improved and new techniques as the war went on, were produced in huge quantities without interfering with the vast radar production programme occasioned by research, development, and enemy attempts at counter-measures.

It is known now that Germany was not aware that radiolocation was, in fact, so developed in this country that our entire air defence strategy was based on it, although she had sufficient inkling of the existence of coastal stations to try to detect them with the aid of receivers carried in the Graf Zeppelin. Nor, naturally, was she prepared for the airborne developments which were to upset her undersea campaign, as Hitler complained in a public speech in 1943.

It has been the radio industry's part to accomplish these unseen victories, often without knowing any more of the overall radio campaign than the individual platoon commander can know of the entire front line. As time passes the radio industry as a whole will no doubt learn of still further uses to which its products were put; already it is obvious that radio was the core of almost every major operation, involving its own tactics and separate preparation although at the time its successes could not be publicly recorded.

The first two problems of the many encountered by the industry in helping to wage this war were the necessity for absolute secrecy in peace-time, when the absence of special security precautions normally makes this especially difficult, and, once the war had really begun and France and the Low Countries had been overrun, the cessation of supplies of raw materials and components from abroad almost exactly at the time when the magnitude of the Services' demands was becoming apparent.

The necessity for secrecy was such that, when contracts were first placed in 1937 for the radiolocation chain sets, only two men in the industry were given complete information about both transmitters and receivers; their colleagues in the first firms selected were told about only the transmitter or the receiver, according to which firm employed them. Naturally more people knew about the chain as time went on and as development of the valves and other apparatus became necessary, but the secrets were kept during peace and war; from the start separate assembly shops were used by each firm so that the whole of any factory should not know what was happening.

The loss of components from the Continent was a great blow. A third of our supplies came from France, Germany, Holland, and Belgium, and no less than 80 per cent. of the ceramics used was from these sources. The loss was made good and more than compensated eventually by diverting material (for example, work such as cigarette-paper manufacture was changed to the production of paper insulation for condensers), and there was considerable dispersal of the components factories over provincial areas where new workers were taken in and taught the unknown techniques.

Other branches of the industry had to adjust themselves to the use of labour unacquainted with their special requirements: in many parts of the country the local women were initiated into the 24-hour processes necessary in valve-making, for instance, which required special nimbleness of fingers. Yet there were instances of the processes being eventually so well organized that unskilled women could produce certain valves faster than a larger number of skilled men in earlier days.

Perhaps the greatest problems, however, were those associated with the necessity for keeping

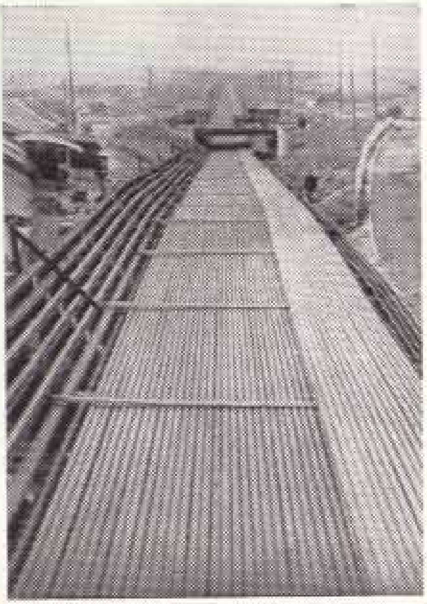
The application of radar to anti-aircraft gunnery is illustrated in these two pictures. Left : The fire control equipment which indicates aircraft on a screen and transmits the range, bearing, and height to the predictor. Right : A radar-aided 3.7 A.A. gun. The shell, which is untouched by hand, is seen entering the breech.

pace with research by means of "crash programmes," as the emergency production of new equipments to a severe schedule were generally known ; with the allotment of priorities between different equipments and services ; and with enemy action, particularly where the valve industry was concerned, since three-quarters of the production was unavoidably concentrated in and around London.

The first-mentioned two problems were controllable. Special benches for crash programmes, reserved all the time, as well as industrial development sections which identified themselves in mind and spirit with the services they were arming, presented the answer to the first : at the same time the development sections worked willingly under the watchful eye of the country's research scientists, whose ideas were born principally at the Ministry of Aircraft Production's Telecommunications Research Establishment at Malvern and at other laboratories.

Similar cooperation solved the difficult question of priorities ; from the first there were inter-service arrangements which avoided some of the supply pitfalls experienced in the last war, but the ultimate step of forming a Radio Production Executive in 1943, with day-to-day powers over the radio production sections of the various Whitehall service departments, without belonging strictly to any of them, was the complete solution. The R.P.E. had in effect the control of the quarter million workers who now served the radio industry in the United Kingdom, and also overall responsibility for the allotment of priorities.

As a result of the wars both in Europe and in Eastern Asia the radio and television industry has not only learned many new techniques, as already indicated, but has acquired a deep-rooted importance to the country which its pre-war status in the world of broadcast entertainment and certain home and oversea communications did not suggest. It submitted voluntarily to a control—that of the Radio Production Executive—which was not at any time compulsorily forced on it from outside. In short, it has taken on a stature which it will not lose when its physical size necessarily decreases to meet the less hectic requirements of peace. Radar navigation by sea and air has come to stay, and there is a great field of other electronic controls and devices which will become inseparable from the production of radio and television sets for the home and communications services for daily life.



Hamel pipes for carrying oil across the Channel stored in three-quarter-mile lengths ready for winding on the floating drums.

38

WORLD-WIDE CABLE LINKS

THE early electrical pioneers used insulated wires and cables made by themselves; Faraday, for example, made up his own cotton-covered wires for his experiments in electro-magnetism about the year 1831.

The first commercially made electric cable was a copper wire insulated with tarred yarn, and such cables were used by Professor Wheatstone in 1837 in the course of his experiments.

That first yarn-insulated cable marked the birth of a great British industry, an industry which during the course of its evolution has kept pace with every electrical requirement of science and commerce. From small house-wires to cables operating at 200 kilovolts or more and capable of transmitting the whole output of a fairly large modern power station, from bell wires to the ultra high-frequency cables required in television and radio-communications, from an instrument wire which when insulated with six coats of enamel scarcely equals the diameter of a human hair to the largest power cable nearly five inches in diameter, the modern British cable-making industry is able to meet every need.

A policy of continuous technical advancement based on systematic research has made these things possible. Although the materials used in cable-making have been more or less stabilized for many years, the quality of those materials, especially insulants, has been constantly improved. Where new conditions arise which cannot be met to full satisfaction by materials already in use the research resources of the industry are able to find new materials which will suit. For example, new materials had to be sought and have been found for the insulation of cables to carry the high-frequency currents of short-wave radio-communications circuits; again, when the Japanese overran and occupied the rubber-growing districts of the Far East, the industry was prepared with alternative materials to meet the rubber shortage.

The industry was confronted with enormous demands for new types of cables when war was declared in 1939. Never in any previous war has electrical science had so prominent a role to play. The establishment by the Royal Navy and other services of specialized electrical ranks and ratings is a recognition of the pre-eminence of the application of electricity in war. An idea of the magnitude of the advance in the use of electricity in warships is conveyed by comparing the 950kw. of generating machinery installed in the largest battleship of the last war, H.M.S. Royal Sovereign, with the 4,000kw. of Britain's largest and latest battleship, H.M.S. Vanguard.

Many entirely new types of war vessels have been introduced during this war; corvettes, escort aircraft-carriers, tank landing craft, to mention a few, all of which require electric cables. More than 800 different types have been used by the Admiralty.

The cable-making industry figured prominently in combating Hitler's secret weapon, the magnetic mine. In an extremely short time ships were being de-magnetized by cables fitted round their hulls as a passive defence. For this purpose the industry produced 1,000 miles of cable a week for a year during the early period of the magnetic mine menace.

For the purpose of direct attack upon the magnetic mine buoyant cables were designed and manufactured by the industry. These cables, which floated on the surface of the sea, were towed by minesweepers and produced moving

magnetic fields which exploded and destroyed the magnetic mines. Inshore waters were continuously covered by such operations and the buoyant cable achieved its purpose well.

The Army established the Corps of Royal Electrical and Mechanical Engineers, embracing 63 specialized classes of tradesmen in its various branches, to maintain and repair something like 1,000 different types of electrical equipment, every one of which required a product of the cable-making industry in the form of one type or another of insulated wire or cable.

By March, 1945, the Royal Corps of Signals had required from the cable-making industry more than 3,440,000 miles of cable for the maintenance of military communications—enough to encircle the Equator more than 130 times.

For the supply of fuel oil across the English Channel, known as Operation "Pluto," the Service Chiefs required a series of pipelines to be laid under the sea to meet the enormous demands of the invading armies after D Day.

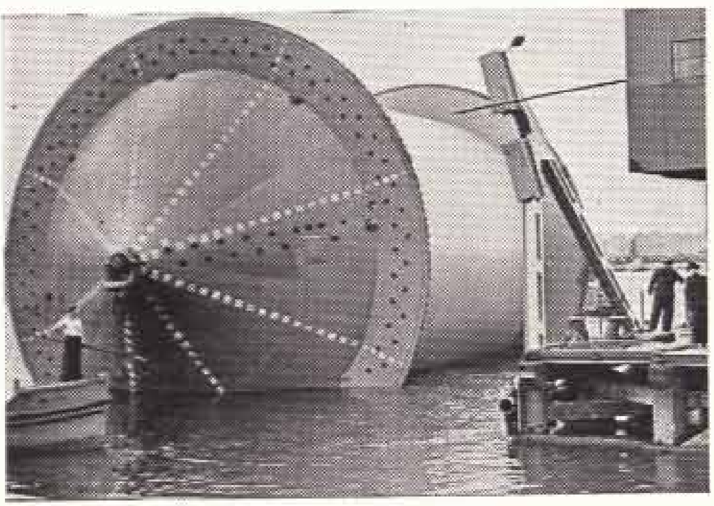
The British cable-making industry provided an answer by designing and constructing cables consisting of a hollow lead tube reinforced with steel tapes and armoured. Those cables had internal bores of 2in. and 3in., and operated at hydrostatic pressures up to 1,200lb. per sq. in.; they were made in continuous lengths up to 40 miles, weighing 1,000 and 2,000 tons approximately. Between 800 and 900 kilometres of such hollow cables were provided. At a later stage they were supplemented by more than 450 kilometres of steel tubing, and by means of these connecting links between England and France fuel supplies were pumped from the Mersey to the Continent at the rate of 1,000,000 gallons a day.

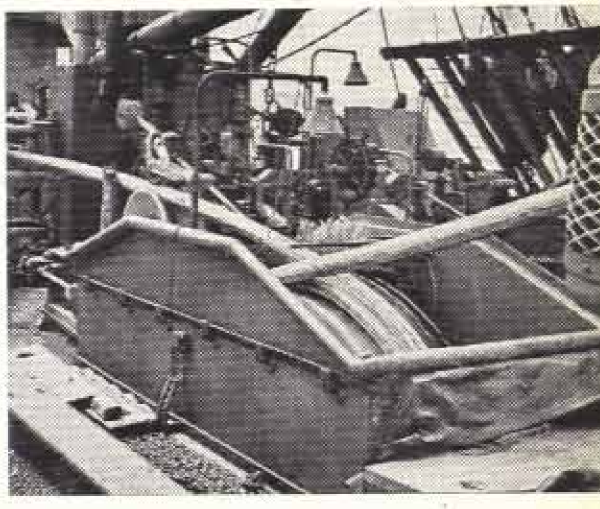
The provision of communication cables also called for intensive effort. Two days after D-Day, the Prime Minister was able to telephone from Downing Street direct to the Normandy beaches *via* a submarine telephone cable, which had been specially manufactured and laid in spite of determined enemy air attacks during the laying operations.

Electric cables were installed in readiness to ignite the flame defences which had been provided on the English coast as a protection against invasion.

The Ministry of Aircraft Production had an enormous appetite for electric cables. In the five and a half years of the war the British cable-making industry provided 114,000 miles of different types annually. The wiring of every Lancaster bomber requires four and a half miles of cables. A Rolls-Royce Merlin engine, when assembled for mounting in a fighter or bomber, alone embodies 76 core yards of cable.

To enable Britain's prodigious air fleet to operate 200 existing airfields had to be reconstructed, while a further 500 new airfields had to be provided. Every airfield required many thousands of yards of electric cables to





"Operation Pluto." Pictures illustrating the remarkable engineering feat of laying an oil pipe-line across the Channel to the Continent. Two methods were used, one by means of special steel pipes, while in the second, cables were adopted for the purpose. Left: One of the huge floating drums ready for winding on the steel pipe. Right: A Hais pipe passing round the cable drum for controlling the speed in laying.

maintain its normal power, lighting, and communication services. The ignition of thousands of gallons of petrol in burners placed along airfield runways for the fog dispersal scheme known as " Fido " also demanded cables.

The British cable-making industry had for some years nurtured the science of thermoplastics and its research organizations were well abreast of developments in that field; Radar—that wizard of intelligence which enabled the R.A.F. to foretell the position, course, height, speed, and approximate strength of approaching German air fleets far out over the North Sea, and which did so much in the Battle of Britain to turn the scales in our favour—owes much of its success to the realization by the cable-making industry of the potentialities of thermoplastics.

To meet the unprecedented expansion of munitions production large numbers of entirely new industrial plants had to be erected and large numbers of existing plants had to be extended. No machine could turn over, no electric furnace could produce the essential high-grade steels, and no ship or tank could be fabricated by electric welding without electric cables. During the war years electricity consumption increased by 11,038.5 millions of units—practically all of this being used by industry, an increase of 65 per cent. above the total 1939 consumption. Cables were needed to convey power from the generating stations to the factory sites, to distribute the power within the factories, and to feed individual machines and producing units. The cable-making industry met those needs.

During the war years the Post Office laid cables providing 5,000,000 miles of underground telephone circuits to maintain communications for the fighting services and other essential services. This is a third of the total which had previously been laid throughout the whole period of development of the telephone and telegraph system of the G.P.O.

Scarcely any single type of cable sufficed for even one particular war service; the conditions which had to be met were much too variable for that. Cables had to be capable of withstanding the extremes of cold in the Arctic regions in order to enable ships and aircraft to keep open the transatlantic and northern European sea routes. At the opposite extreme, the cables had to withstand the fetid atmosphere of the jungle, the ravages of white ants, and the deleterious action of swamps in order to enable our forces to maintain their communications and airfields in the war against Japan. The North African desert campaign imposed stringent conditions on cables, especially those for tanks and communications, and large variations of temperature and the attrition of sand had to be withstood. British cables have stood the tests of all these conditions and fulfilled their purposes well.

The British cable-making industry is proud of its contribution towards winning the war, and, enriched by the knowledge gained during the war years, it is ready to meet demands all over the world in the services of peace and in the great era of reconstruction which lies ahead.

Seamen painting a non-magnetic girdle fitted to their ship as a counter to magnetic mines. This device proved most effective.

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MACHINE TOOLS AND SMALL TOOLS

IN peace or war the machine tool and small tool industries hold the key to all production; whether it be the plough or field-gun, spinning machine or aero engine, the simple yard-stick or radio-locator, all derive their being from the products of these industries.

During the peace years the important role

played by them and their intimate contact with all spheres of manufacturing activity was inclined to be accepted but never fully appreciated; only when responding to the paramount needs of war requirements did they come into the full limelight.

At the outset war exigencies made it imperative that a rigid control of demand, supply, and allocation should be in force to ensure that machine tools and allied equipment were available at the right times, in the right places, and in the right numbers and types, and it was only the close harmonious working of the industry with the Machine Tool Control that enabled such remarkable success in this direction to be achieved.

Advisory panels set up by the Machine Tool Control played an important part and closely associated with this effort must also be mentioned the valuable cooperation of the Machine Tool Trades Association, the Gauge and Tool Makers' Association, and the National Federation of Engineers and Tool Manufacturers, as well as the correlated activities of other bodies, together with the various Government departments involved in the production of war material.

The various advisory committees set up by the Machine Tool Control contributed their share of the harmonious cooperation of Ministry and manufacturer. Hundreds of firms sank their individualities and banded together into different groups run under the aegis of the Machine Tool Control for the distribution of such items as twist drills and screw gauges to those quarters most urgently requiring them, this work being controlled from allocation centres in different parts of the country.

In order that makers and users of machine tools, small tools and ancillary equipment should be kept informed of developments and processes of general interest, the Machine Tool Control has published booklets, leaflets and posters from time to time for distribution to the industry.

The information given is the result of careful study of modern production methods and has been compiled by experts with practical knowledge of present-day problems arising from such factors as shortage of tungsten for high-speed steel, the necessity of tooling economy, the need for intelligent production planning, &c. The latest production was a comprehensive survey of recent developments and practice in the application of negative rake milling.

In coping with the many difficulties involved the Machine Tool Control endeavoured to see that (*a*) each manufacturer produced the types of machines he could best make to fit in with the war programme, (*b*) as much standardization and simplicity as possible was secured, bearing in mind the immense variety of types and the complication of the industry, and (*c*) production agreements were placed with manufacturers to cover any actual or possible gap in the flow of firm orders.

To this end a rationalization scheme was readily accepted by the trade as a method of increasing output of individual sizes; extensive use was also made of sub-contracting, approximately 25 per cent. of the total requirements being produced by this means under the wing of the main contractors.

Bearing in mind that manufacturers in these industries tend to be relatively small, specialist, and highly individualistic firms, the fact is of significant importance that of the total war demand 75 per cent. of the machine tools required, 90 per cent. of the cutting tools, about 80 per cent. of the fine measuring tools, and practically all the gauging equipment were supplied by the British machine-tool and small-tool industries; these figures include certain types not previously manufactured in this country.

When one considers the dearth of skilled engineers for a war-time programme, particularly after endeavouring to meet the needs of the mechanical branches of the armed forces, the expansion of the tool-making industries to approximately eight times their 1939 size is all the more remarkable. In this connexion tribute must be paid to the industry, which, in collaboration with the Ministry of Labour and National Service, accepted and trained a much larger proportion of female and dilutee labour than was possible on a peace-time production basis.

One of the many joint activities of the Machine Tool Control and the industries is worthy of particular mention. This is the Emergency Machine Tool Armament Corps, or EMTAC for short, a body of men recruited from the industry and highly skilled in the use of all types of machine tools who, from the summer of 1941, boldly tackled managements' most urgent problems in the training of unskilled labour on unconventional lines.

In spite of firms' own training schools and the useful flow of trainees from Government Training Centres many bottlenecks in production had to

be cleared where the labour situation was particularly acute or the job itself was more difficult than the average. Any firm on work of national importance and requiring assistance was able to call on their services until the difficulties were ironed out, and EMTAC's success was due in no small measure to the helpful cooperation of the works staff, from the management downwards.

Very valuable voluntary service was provided by the trade in the matter of speedy investigation and assistance in overcoming the effects of air-raid damage of machine tools and ancillary equipment. In each important manufacturing centre a voluntary committee was set up, the members of which, immediately upon the report of air-raid damage being received at headquarters of the Machine Tool Control, proceeded to the scene of the incident and made such immediate arrangements as were possible to deal with the situation. A pool of machines was reserved to provide immediate small scale replacements, and a repair organization was built up to deal with both short and long term repairs.

Another outstanding achievement in the drive for more production was brought about early in the war by the inauguration of the Mutual Aid Scheme, which came into being in connexion with a nation-wide survey of cutting tools instituted by the Controller-General of Machine Tools and carried out by men lent by the trade.

Following a proposal and trial in the Midland Region of a voluntary survey organization carried out by members of the trade, a number of mutual aid exchanges were set up and firms were invited to attend meetings held in different districts of the region and to present at these meetings details of their immediate and most urgent shortages, also giving details of tools and equipment which they were prepared to lend or sell to any other firm who might be in urgent need of them.

The meetings were presided over by a chairman, who called on each member in turn, and something like 80 per cent. of the demands put forward were satisfied then and there. The two parties to the transfer were put into direct contact and apart from a note of the transaction no official paper work was involved.

The scheme was an immediate success and the organization of these mutual aid exchanges was gradually extended over the whole country. Within a few months more than 100 of these exchange centres met at regular intervals and several million tools were exchanged to relieve immediate production bottlenecks.

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FABRICATION OF ALUMINIUM

IT is fitting that aluminium has reached its centenary in 1945, and that victory in Europe coincided with the 100th anniversary of the production by Wöhler of the first malleable bead of the metal.

Britain has taken the lead in aluminium fabrication; the commercial production dates from 1858, when the first aluminium works was established in this country at Battersea by F. W. Gerhard. Although Nature has not provided us with high-quality bauxite, and our water-power supplies are severely limited, British light alloys played an outstanding part in the aircraft industry's contribution to victory.

The fabricating industry has built great new plants in record time, completely reorganized technique and methods, developed new materials for special purposes, successfully undertaken the huge job of training unskilled labour to perform highly skilled jobs; and in tune with this national effort there is the great part played by the secondary metal refiners.

Light alloys of every type are an integral part of aircraft fabrication, and during the war the light alloy industry has seen how productivity can be increased by long-range planning and by the enthusiastic cooperation of management and labour in pursuit of a clear-cut objective. The very efficient factories which we have organized and equipped will now rank as important capital assets in our national economy. Some accurate notion of the expansion can be gained when it is recalled that in 1936 the total average annual production of magnesium castings was only 400 tons. Yet at one stage of the war we were producing die-cast incendiary bombs at a peak rate of 4,327,000 castings a month. Castings other than bomb castings were produced at the rate of 700 tons a month. If the weight of a bomb casting be taken as 18oz. the total weight of 4,327,000 castings is about 2,200 tons a month. With other castings this gives a total of 2,900 tons a month, or production peak rate of 34,800 tons a year.

The first and most important task facing the light alloys industry was to increase output when war began and to keep on increasing it. This involved great extensions to existing plants and

Stockpiles of 84,500 metric tons of aluminium ingots, covering about 13 acres, at a factory in Canada, the source of a large part of the aluminium for the British light alloys manufacturers. The aluminium industry expanded sevenfold during the war. Its products played an important part in aircraft production and in various new fields.

the building of new plants in widely separated parts of the country—the necessity for dispersal being an important factor, adding to the many difficulties of managements. Parallel with this great expansion of plant there was carried out a great training programme. Shop assistants, salesmen, housewives received intensive training in all branches of the industry—in moulding, coremaking, press and drop-stamp operations, inspection, and even die-sinking. Jobs which had formerly been carried out only by highly skilled men after many years of apprenticeship were performed by boys direct from school; and all this was achieved partly by training, partly by careful instruction and close supervision by the skilled craftsmen (who became, overnight, key men of the industry), by the great attention given to mechanical handling, and by the breaking down of each intricate operation into several simpler ones.

Within the industry itself there were colourful changes. "The first sight of one of these great new plants comes as something of a shock to one who knew the industry in its less prosperous days before the war," says Mr. W. C. Devereux, F.R.Ae.S., vice-president of the Royal Aeronautical Society, "and who knew the smoky, sweltering atmosphere of the dark old foundries, the black coating of soot and oil and the acrid fumes of the pre-war forge, and the magnificent skill of the real craftsman metal-worker, kneading hot metal into fine and beautiful shapes, oblivious of the inferno around him.

"His first impression now is of lofty, light and airy shops, of brightly coloured machinery, of an almost complete substitution of human by mechanical power; only the noise now remains to remind him of the old days. Even more surprising to him is the sight of girls in brightly coloured blouses and slacks tapping the great new furnaces and pouring the shining metal from large electrically operated ladles into orderly rows of ingot moulds.

"In the forge more shocks confront him; teams of semiskilled workers, among them boys in their 'teens stamping out the largest aircraft engine components under massive 25-ton drop hammers, operating 3,000-ton hydraulic presses, doing jobs in fact which before the war were entrusted only to men who had spent many years in the forge shops of the Midlands. He sees row upon row of presses operated by women, who but a few months previously had never heard of such machines. He sees youths and old men hewing dies from great blocks of alloy steel, and in the control laboratories girls, who never worked

before, carrying out the precise operations of spectrographic and chemical analysis, tensile-testing, and X-ray inspection."

All through the period of rapidly expanding light alloys output the same high standard of quality, for which the British aluminium industry is famed, had to be maintained, and was maintained by fine team-work and give-and-take collaboration between planning and production engineers and metallurgists. Great changes had to be made in manufacturing methods, procedures based on years of cautiously acquired experiences were altered overnight in the race for production—there was little time for experiment. That quality did not suffer, that few projects met with failure, is proof of the great fund of metallurgical knowledge and experience built up in the light alloys industry by its long adherence to its policy of scientific research and control.

Then as production got into its stride there was superimposed the demand for even high-quality alloys, and for increased strength at elevated temperatures to enable higher performances to be achieved from fighting aircraft. The industry, still in the throes of production and expansion, intensified its research activities; without affecting production, alloy compositions were modified, new alloys were developed, and improved methods of casting, working, heat-treatment, and control were evolved.

One of the light alloys industry's great achievements of the expansion period was the revolutionary change in the policy of utilization of secondary material. Financial risks had been taken early in the war by the secondary-metal refiners in building up stocks of material which became such a vital factor in the supply of aluminium to the fabricating industry.

Users of light alloys undertook the segregation of their scrap according to specification, thus removing much of the tedious work of sorting and blending for remelting; the secondary manufacturers multiplied their plant and instituted the closest control at all stages in their refining processes; the light alloys founders and fabricators studied the effects of increasing proportions of "secondary," and eventually evolved limits not only for their output generally but for individual processes and components. To-day the amount of material wasted has been reduced to a trifling figure, and almost a third of the nation's requirements for aluminium alloy is supplied from secondary metal.

In spite of labour shortage, bombing, priorities, and heavy demands on its limited numbers of experienced executives and technicians, the light alloys industry was able to provide experts first to organize and then to operate the Light Alloy Controls, whose excellent work, which won the admiration of British and American executives, played a most important part in securing the smooth supply of raw materials into industry and the proper allocation of its output.

As a practical example of the efficiency of the industry, one may take the highly stressed crankcase casting of the Rolls-Royce Merlin engine; its performance and reliability have been put to the very hardest test in all parts of the world. Yet a large proportion of these crankcases has been produced in a foundry built for full-scale mass production during the first stage of the war, and the casting is produced very largely by girls.

Production was at the rate of 500 of these complicated castings each week. When aluminium was at a controlled price of 11.8d. per pound (£110 per ton) this casting was produced for 2s. 5d. per lb. With the present ruling price of £85 per ton the casting is being made for below 2s. 3d. per lb.—and it must be emphasized that it is a very complicated casting made in a high-duty, heat-treated alloy. These figures refer to castings made from primary materials, but we must also take into account the important development of secondary alloys from scrap already mentioned. Secondary aluminium of high quality can be made to very close composition tolerances for less than £45 per ton, or 4.8d. per lb. This means that such a casting as the Merlin crankcase can be made from secondary material for less than 1s. 7d. per lb.

These are but a few of the contributions which the light alloys industry made to the war effort. That it succeeded through the Ministry of Aircraft Production in supplying the nation's largest war industry with all its requirements, while still improving the quality for which it was famed before the war, is evidenced by the ever-growing might and high technical efficiency of Royal Air Force equipment.

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NON-FERROUS METALS

COPPER, zinc, lead, tin and nickel—the major non-ferrous metals other than aluminium—are vital sinews of war, as well as being of fundamental importance to industry in peace-time. In peace-time these metals are widely used in the electrical industry, in building, motor-cars, general engineering, factory and household equipment, chemical plant, food processing and canning, and in a great variety of smaller applications.

In war-time there is a large demand for brass (copper and zinc) for shell cases and fuses; copper wire and cables are needed for military communications, and there is a large indirect military demand for the wiring of war factories and aerodromes; zinc alloy diecastings are used for fuses, zinc sheets for battery cans, and zinc oxide and zinc dust for smoke mixtures for concealment of military operations; lead is primarily needed for cable sheathing and for batteries for naval craft and military vehicles, and there is also some demand for lead for ammunition purposes, although this has been much smaller than in the war of 1914-18 owing to the replacement of shrapnel by high explosive; nickel goes primarily into alloy steels, though it is of great importance in Radar equipment and aircraft in particular; and tin is required for food canning for military stores and for bearing metals, bronzes, and solder.

In general, therefore, there was at the outbreak of war the prospect of a large war demand for the above metals, superimposed on an already large peace-time demand. The following figures compare the extent of the United Kingdom consumption of the metals pre-war and during the war:—

—	Tons per annum	
	Average Pre-War 1936-38	Average War Years 1940-43
Copper	270,000	456,000
Zinc	200,000	249,000
Lead	345,000	223,000
Tin	22,000	27,500
Nickel	11,500	21,500

Against such large requirements the United Kingdom mine output of the metals is negligible, so that practically the whole of the tonnages which have been needed have had to be imported. The central problem was, therefore, to ensure sufficient supplies for war needs and essential civilian purposes, but, at the same time, to reduce so far as possible the demand on shipping and on our resources of foreign exchange. The utmost economy in the use of the metals was, therefore, of paramount importance.

Copper, zinc, and lead came under statutory control in the United Kingdom immediately at the beginning of the war, and tin and nickel after the United States entered the war. These metals, and also cadmium, antimony, and cobalt, were placed under the Non-Ferrous Metals Control of the Ministry of Supply.

To ensure adequate supplies of copper, zinc, and lead, long-term contracts were arranged between the British Government and producers in Empire countries. These contracts had been discussed in the months before the war, and their main lines had been settled when war broke out. They represent an outstanding achievement of Empire cooperation on the part of the copper producers in Canada, Northern Rhodesia, and South Africa, and the lead and zinc producers in Canada, Australia, and Burma. The producers agreed to sell their exportable surplus at f.o.b. basis prices, which were closely in line with the level of prices existing just before the outbreak of war, and were to be reimbursed for subsequent increases in their costs of production.

The scale of the Empire contribution is illustrated by the fact that during the five years and four months from September, 1939, to December, 1944, Canada, Australia, and Northern Rhodesia together supplied to his Majesty's Government 5,000,000 tons of copper, zinc, zinc concentrates, and lead.

In the United Kingdom the main problem was to confine the use of the metals to strictly essential purposes. It was fairly easy to eliminate obviously inessential uses and luxury articles; it was far less easy to reach decisions that, for example, the use of copper and lead pipe and sheet for plumbing and roofing purposes should be virtually stopped, that tinplate could no longer be available for a large variety of canned goods, or that the release of zinc oxide as an ingredient in paint must be severely limited.

Service requirements needed no less careful scrutiny, and for a large range of requirements (for example, ammunition box linings, fuse covers, caps and components, military equipment,

fittings and badges, buttons and fasteners, ships' fittings) the use of non-ferrous metals was substantially cut down and replaced by the use of materials such as cast iron, steel, and plastics which were in better relative supply.

These are only a few instances of the detailed examination and curtailment of the use of non-ferrous metals which was applied to all branches of civilian (both home and export) and service demand. Applicants for licences to acquire virgin and scrap metals had to furnish supporting schedules giving details of all the orders which they had to fulfil. For example, for copper and copper alloys alone, the orders submitted totalled between 2,000 and 4,000 a day.

Metal was released only for orders approved by the Control, and the Control in their decisions were guided by a staff of technical experts and maintained close cooperation with the manufacturers or Government department concerned

Members of the Women's Land Army using a mechanical excavator for making a drainage ditch in a field in Hertfordshire.

and with technical bodies such as the British Standards Institution. The contemplated use of substitute materials might often involve increased difficulties in respect of labour, machining, and wear and tear of tools, and such considerations had to be given full weight before finally deciding whether to release or refuse non-ferrous metals for a particular purpose.

Most of the restrictions which were imposed were frankly recognized by the Control as achieving short-term economies only, to be removed as soon as conditions permitted. Consequently, as the metal position in general grew easier from 1943 onwards, restrictions were lessened or removed so far as possible and in agreement with the United States. For example, in November, 1944, all restrictions on the release of copper, zinc, and lead for building work were removed, so that house builders and repairers could be free once more to use these metals for waterpipes, roofing, and other purposes.

The restrictive side of the Control has been shown above. In several directions, however, the Control had to take action to foster the output of various non-ferrous metal products which were vital for war purposes. This was more especially the function of the Brass and Zinc Alloy Diecastings Sections of the Control, which had to arrange for the organization and enlargement of productive capacity to meet the very high call for brass strip and rod copper tube and zinc alloy diecastings for ammunition purposes. In particular, four steel mills were converted for the production of brass strip. Peak output in the United Kingdom was reached in the last quarter of 1942 and the first quarter of 1943, and during this six-monthly period output of brass strip was at the rate of 471,000 tons per annum, against a pre-war rate of under 100,000 tons; output of brass rods and sections reached 253,000 tons per annum, against 100,000 tons pre-war, and output of copper tubes 41,000 tons per annum, against 20,000 tons pre-war. In this task of planning and augmenting output the Control received invaluable assistance from the advisory panels of manufacturers in the various branches of the industry.

Finally the non-ferrous metals trade had the benefit of stable prices over long periods of the war. There were only two major changes from the statutory maximum prices of copper, zinc, and lead which were imposed at the beginning of the war. The first was in December, 1939; the second was not until June, 1945, and the latter affected only lead and zinc, copper prices remaining unchanged. Moreover, prices of all three metals in this war were kept substantially below the peak levels which were reached in the war of 1914-18.

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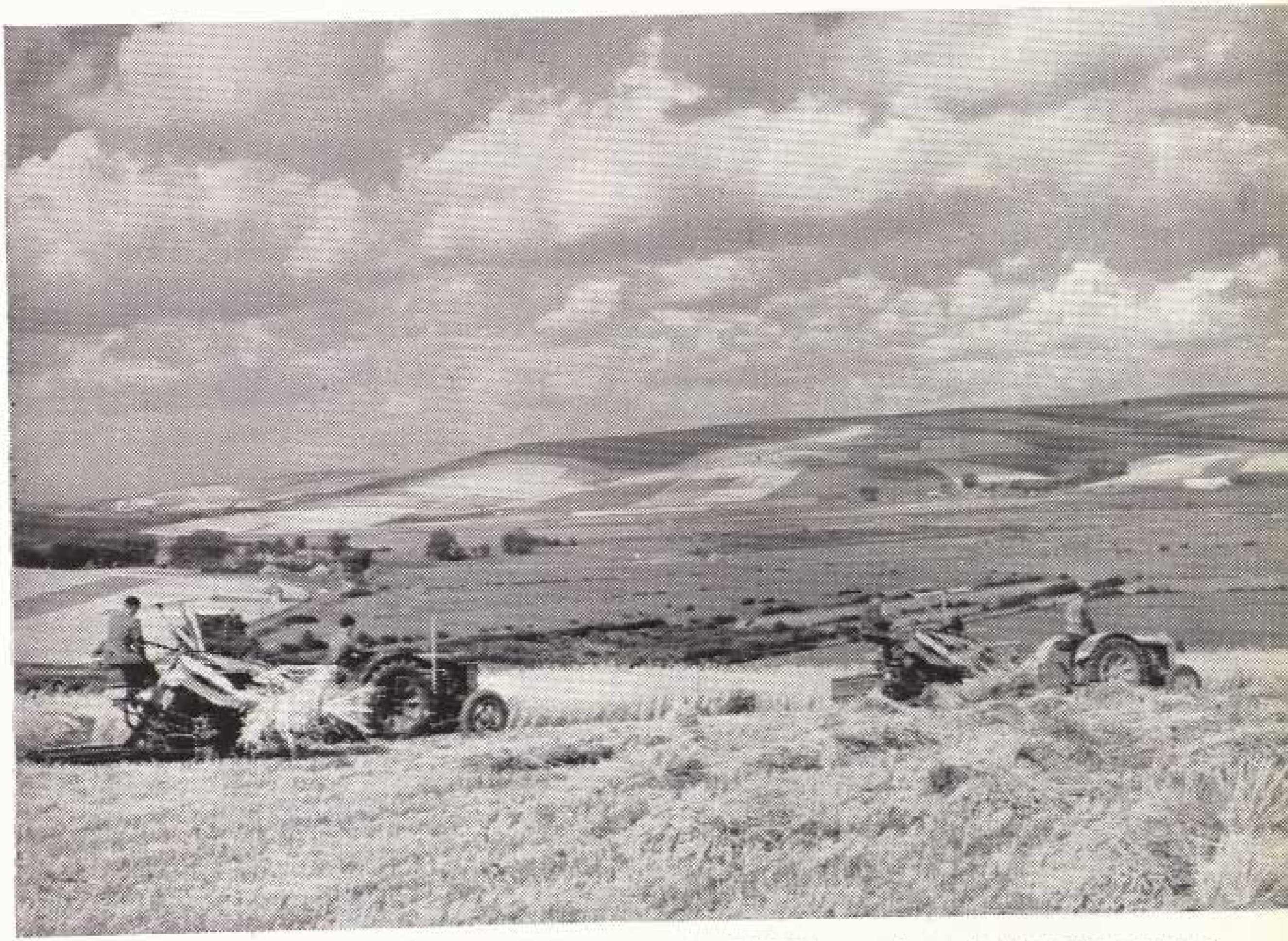
FOOD PRODUCTION AT HOME

BRITISH agriculture's task in this world war, as in the last, was clear. This time the Ministry of Agriculture and farmers got a flying start. Our land had to produce as much food as possible and as quickly as possible, so as to release shipping for the vital purposes of war. Hitler knew well enough that Britain's dependence on imported food was a weak link in her armour. Before the war we produced only 40 per cent. of our food needs, relying for the rest on Canada, Australia, New Zealand, South America, and the western European countries. We could not hope to become completely self-supporting if our 45,000,000 people were to have an adequate diet which would keep them fit for the strenuous tasks which total war imposes on all, but home production now meets 70 per cent. of the nation's needs. We have had to be content with bare necessities and a diet balanced on scientific standards, with little regard for the preferences of the consumer. The war-time diet has been dull, but it has been adequate. Indeed, a good many people in this country are living on a sounder diet to-day than they did before the war.

The United Kingdom is naturally a grass country. That is to say, grass grows readily in our climate, and when there is no great



Harvesting in progress on the Sussex Downs near Newhaven. Over 7,000,000 acres of grass land have been converted into arable land for the growing of crops.

pressure to produce food to the maximum grazing cattle and sheep are the mainstay on many farms. This was the state of affairs before the war. The grazing cattle were largely dairy cows, because milk production offered a regular and steady income at a time when other prices were low and uncertain. We had big pig and poultry industries, mainly on specialized lines, which depended to a great extent on imported feeding stuffs, as indeed did the dairy cows.

For some time before the outbreak of war the Government had plans prepared for a big increase in the production of cereals, potatoes, and other tillage crops which would cut down bulky imports. There was no doubt about the policy to be pursued. An acre of permanent grass feeds only one to two persons; that acre ploughed up and sown with wheat feeds 20, and planted with potatoes feeds 40. Nor could there be any doubt about the scope for increased output on these lines. The arable area had fallen as low as 13,000,000 acres, out of a total area of crops and grass of 32,000,000. The ploughed area was the lowest ever recorded, being 2,000,000 acres less than at the start of the 1914 war.

As early as May, 1939, the Minister of Agriculture offered farmers a grant of £2 an acre towards the cost of ploughing up permanent grass land. Steps were also taken then to increase the home manufacture of tractors and farm machinery. In the weeks from May to the outbreak of war in September, 350,000 acres of grass were ploughed and added to the acreage ready for growing bread grains. This was a good start, but matters could not be left entirely to the patriotism and business sense of farmers. Some direction must be given to the food production campaign if the country was to rely on home production for definite amounts of wheat, barley, oats, potatoes, and sugar beet.

At the same time the production of milk had to be sustained and more vegetables grown to keep the right balance in the national diet. Inevitably there would be some conflict between milk production, which requires grazing, and ploughing up for corn growing. Some central direction in policy matters had to be given, but the Ministry of Agriculture was reluctant to take on itself the detailed control of the campaign in the counties.

Immediately on the outbreak of war the Minister set up War Agricultural Executive Committees in each of the 61 counties in England and Wales. The members of these committees were appointed direct by the Minister to act as his local agents. They in turn divided the work between district committees. In some counties there are six or seven district committees, in others a dozen or more. Most of the committee members are farmers. They do not receive any payment beyond out-of-pocket expenses. To assist them they have technical staffs, some of whom are qualified to advise farmers on the reclamation, manuring, and cultivation of land, the management of dairy herds, and such technical problems. Others are engaged in supervising the supplementary labour controlled by the committees, such as prisoners of war, Women's Land Army, and Irishmen. Others administer the rationing of feeding stuffs and the allocation of machinery.

Thanks to the work of these committees, who know their districts intimately and the capacity of each farm and farmer, over 7,000,000 acres of grassland have been converted into arable and in the main good crops have been grown. The home production of food has been increased by 70 per cent. Some farmers have not responded to the advice given them by the committees and have failed to carry out cropping directions served on them. In the most obdurate cases the committees have power to recommend the Minister to dispossess the farmers. This extreme power has not been used widely. The Minister stated a few months ago in the House of Commons that 2,353 farmers had been required to leave their farms and homes. This represents 0.63 per cent. of the total number of holdings.

The War Agricultural Committees have also been concerned to increase the milk supply, particularly during the winter months. The extension of the National Milk Scheme, providing milk free or at reduced cost to mothers and children, has made heavy calls on the milk supply, necessitating the strict rationing of ordinary consumers in the winter. Considering the difficulties which farmers have had to overcome in providing adequate winter rations for their cows and maintaining sufficient labour for regular milking, this result is most satisfactory.

The labour problem is now acute on many dairy farms. Land Girls have been brought in as milkers and have given most excellent service, but as cows have to be milked twice a day for seven days a week the job is not popular, especially since the introduction of P.A.Y.E., which reduces

A striking view taken at a British factory showing a line of tractors ready for work on the land. The mechanization of farming was essential to meet the demands for more home-grown food, and the output of agricultural machinery was greatly increased.

the amount of overtime money going into the worker's pocket. Minimum wages, averaging under 35s. a week for men before the war, have been raised to a national minimum figure of 70s. a week. The total labour strength of agriculture in England and Wales increased during the war from 607,100 in 1939 to 740,500 in 1944. There were fewer regular male workers, some of the younger men having been drafted into the Army at 18 or 19, but agriculture was able to draw on some supplementary help, notably through volunteer land clubs and holiday harvest camps for schoolboys and also adults.

An important factor in securing increased home production was the Government's guarantee of markets and prices. Farmers were able to count on satisfactory returns for cereals, potatoes, and also for milk. Recently there has been a change of emphasis in Government policy favouring livestock production. Siege conditions are past, but dairy products, meat and eggs are scarce in the world, and Britain will need all the home production she can get for some years to come. More sheep, more pigs, and more hens, as well as more cattle, are wanted. The Minister has stated the targets which the Government hope to see achieved this year and next year. No limit is set to home production, and as farmers know the prices guaranteed for 18 months ahead there is every reason to expect a satisfactory response, provided that the additional feeding-stuffs needed for an extension of pig and poultry production are found either by increased imports or by setting aside some home-grown cereals for stock feeding.

The achievements of British farming in the war years have shown that this country still has some of the best farmers and farm workers in the world. Americans and Canadians who have come here to see for themselves have been loud in their praises. Crop yields generally have been remarkably good, thanks to fuller mechanization, which has enabled cultivations, even on the greatly increased arable area, to be done at the right time, and thanks also to the largely increased use of fertilizers, notably nitrogen and phosphates, in which many soils prove deficient when brought under the plough.

To-day the lessons of science are being put into practice on the great majority of British farms. Technical advice is indeed now becoming the main function of the War Agricultural Committees, and its ready acceptance by the general body of farmers is a good augury for future standards of farming in this country.

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TIMBER AND WOODWORKING

THE war has brought home to the public in terms of deprivation and inconvenience, if not of statistics, the importance of timber in the national economy. Over 95 per cent. of our timber was imported. Imports of softwood alone were the heaviest import item, being even greater than those of iron ore or wheat. In terms of value our oversea purchases of timber were by far the most important of our raw material imports.

Since timber was always plentiful in supply the public did not realize its importance as a war material, and Sir Arthur Salter's plea in the House of Commons before the war that an emergency purchase should be made to relieve shipping if a crisis should occur brought no response from members. Even after the Munich crisis our softwood stocks fell so that when war broke out they were well below the normal level.

The published statistics relating to the war effort reveal the extent to which shipping difficulties, and in particular the Battle of the Atlantic, endangered our essential supplies and threw a strain on the timber-using trades. No other raw material of magnitude shows anything like the same fall of imports, nor indeed was any other bulk material replaced by home production to the same degree as timber. The bulk of our softwood used to come from Russia, Scandinavia, and the Baltic countries, while we received large quantities of pit props from France, but the course of the war cut us off from all these supplies. In 1942, at the height of the Battle of the Atlantic, our normal imports of 9,750,000 tons fell to less than one-fifth of their normal level, and in 1943 were only 1,750,000 tons.

Quite apart from considerations of exchange and price, this situation alone would have made it necessary for the Government to make or control all oversea purchases, and except for certain specialized woods which the various trades handled under licence, imports have been purchased by the Timber Control on National Account. As private pre-war stocks were used up, the bulk of the timber in the country thus came to be national timber handled by wharfingers as agents of the Minister of Supply. The task of the Timber Controller has not been easy. Except for useful but small quantities of Russian timber, we had to look to Canada for the bulk of our imported softwoods. Great as this Canadian productive effort was even these supplies were not free of difficulty, since the scarcity of tonnage made it necessary to rail across Canada from the west coast no less than 2,250,000 tons.

These supplies, vital as they were, left us with the problem of running our economy, including war production, on an import one-fifth of the normal level. One contribution to the solution was home production. Britain is not a heavily forested area, its lumbering industry was on a small scale, the business unit small, and the labour force, particularly the number of skilled men, also limited. The policy of the Home Timber Production Department was to rely upon the maximum of trade production, and to help this out by the Department's own production as a balancing factor to work the less accessible stands or to take up some special type of production urgently required.

In 1943 home production at 3,800,000 tons was eight times larger than pre-war, a growth to which no other bulk material can show a parallel. Instead of providing only 4 per cent. of our total supplies, in 1943 it contributed one-half. Among its more striking achievements was the almost complete replacement of an annual import of 2,500,000 tons of mining timber, including pit props, by home production. The labour force was raised from 10,000 to 70,000 by the use of 7,000 men in Canadian, Australian, and New Zealand military forestry units, of 2,000 men from Newfoundland, and others from British Honduras, as well as over 6,000 girls of the Women's Timber Corps.

The Women's Timber Corps, which was established in 1942, worked largely out of the public eye, and has therefore received less public recognition than it deserves, yet these girls, drawn from a great variety of unlikely occupations, for they included shop assistants, milliners, typists, and teachers within their ranks, substituted for men over a wide range of processes from measuring to light felling, tractor-driving, and work on the saw bench.

The third line of attack on the problem was economy in the use of timber, and this had to be secured without endangering the war effort. This was accomplished through the machinery of the Timber Control Area Offices, which covered the whole country, and the insistence that

no timber could be used or obtained without a licence specifying the amount released for each individual job. This involved dealing with 600,000 to 700,000 licences a year, and in view of the drastic economies enforced on the applicants it speaks well both of the Control and the consumers that the volume of real complaint has been so small.

By January, 1940, even consumers' private stocks were brought within the system of licence. As war needs expanded and timber supplies declined acute questions of priority arose, and it became necessary to supplement the licensing system by giving each Government Department a timber ration or account. Out of this it had to provide for the programmes for which it was responsible by issuing " timber cheques " to its contractors and consumers.

The public has gradually learned the severity with which Timber Control has been compelled to use the licensing system to carry out its economy functions. Some uses of timber were prohibited altogether—namely, for pianos, garden furniture, dog kennels, &c. The manufacture of furniture was first limited and then prohibited altogether for a period, and long before the system of building licences began Timber Control stopped the release of timber for private building completely. In other cases the amount of timber released was greatly reduced.

Thus the loss of imported finished matches and the reduction of imports of wood for matches was only partly replaced from home sources, so that total match consumption was reduced by one-third. In other cases redesign to secure a reduction in timber content was suggested and enforced. For wartime houses only a fifth or less of the usual amount of timber was allowed, and even coffins were slimmed in thickness to yield a saving of 500,000 cubic feet per annum. Nor were the services and Supply Departments free from scrutiny. Thousands of War Office specifications were overhauled in the early stages of the war, and in the later stages timber specifications were worked out in advance with Timber Control.

The substitution of home-grown for imported timber, or hardwood for softwood where technically possible, and of plywood for solid wood was demanded from manufacturers and departments alike. The railways accepted very large quantities of home-grown wood for sleepers and wagon building, while the Post Office relaxed the stringency of its specifications for telegraph poles. Even slabs and off-cuts and 200,000 tons of reconditioned timber salved from bombed houses and second-hand crates were pressed into service. About a quarter of our softwood goes to make packing cases and boxes of various kinds. Great economies were secured by making the release of timber conditional upon arrangements for a high degree of returnability, while the endless types of agricultural packing were reduced to eight, and those of fish boxes were brought down to three or four economically designed sizes.

It was by such measures as these that we were able to provide for the great war programme, as well as to reduce total consumption to one-half and softwood consumption to less than one-third of the pre-war level. The provision of thousands of army huts, miles of flooring for Bailey bridges, thousands of tons of shuttering for Mulberry, chestnut pale fencing for trackways, heavy piling timber for dock construction, millions of bunks for A.R.P. shelters, and hundreds of thousands of tons for beach-head and Pacific packing was thus made possible. The production of a high grade of aircraft plywood made from imported birch, &c., the search for Balsa, and the development of the all-wood Mosquito are a story in themselves.

These results were secured only at a price. The cut of our limited woodlands was far more severe than that in many countries occupied by the enemy, so that not only is there the task of restoring depleted national resources, but there is a difficult adjustment in front of the home-grown trade, which now finds itself with most of its accessible raw material gone. Importers also have a new situation to face. Although before the war timber-producing countries were beginning to take concerted action in their own interests, as a great importing country our buying strength was a sound bargaining counter. But the devastation in Europe, together with the fact that timber is the great emergency material, means that we now face a seller's market. It may be that for some time softwood purchasing will still have to be on Government account.

The trade is also troubled lest the enforced substitutions for timber should become permanent. There is no doubt that we have learned to use timber more scientifically, though how far these new practices will be retained when supplies are more plentiful is a matter of some controversy. The various wood-working and fabricating trades have also got their troubles. Owing to the pressure of urgent war demands these trades have been provided with machine tools on a

large scale, and the capacity of the industry is considerably greater than before the war. At the same time the different trades have crossed one another's boundaries, for furniture firms made airframes and packing cases and boxes, while wood-working firms which had never made furniture before have had contracts for Government furniture and stores of all kinds.

The settlement of these problems would be easier if the supplies were plentiful, but it is not going to be easy to raise depleted stocks from their present hand-to-mouth level to pre-war figures, as well as overtake the enormous arrears of furniture, house-building and repairs, industrial re-equipment, and even packing case manufacture. The timber trades have hitherto paid little attention to the statistics of their industry. The basis of policy should be knowledge, and it is all to the good that steps are being taken to remedy this defect. The timber and wood-working trades have perforce had to make severe adjustments during the war, and aided by the widened experience of those of its members who during the war have gained practical knowledge of the national aspects of timber policy, they will no doubt be able to surmount the immediate difficulties that lie ahead of them.

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BRITISH PLASTICS AT WAR

FOR security reasons, little publicity has been given to the part played by plastics during the war. The developments made and the components in which plastic materials have found application have necessarily been suppressed, but a comprehensive survey is now possible.

In 1939 the Government set up a technical service to act as a link between the services and the industry and to ensure that the Government had efficient advice on the subject of plastics.

It became obvious after a year that control and allocation of plastic materials were essential and a Plastics Controller was therefore appointed by the Raw Materials Department of the Ministry of Supply. Development of specifications for plastic materials was undertaken by technical committees of the British Plastics Federation with the assistance of the British Standards Institution, and liaison was maintained with the supply departments. Close contact was kept

Plastics are widely used in the manufacture of aircraft windows. Above are two photographs taken during the construction of a Perspex hood for a Spitfire aircraft. Left : Placing the heated Perspex over the hood before shaping. Right : Trimming off superfluous material with a bandsaw.

with the Dominions and other countries through the Scientific Liaison Offices and by interchange of visits by experts.

One of the most important of plastic materials is the phenolic resin. Moulded phenolic plastics are probably most familiar to the layman in the form of telephone instruments and other domestic fittings. Phenolic materials are made from phenol and formaldehyde, reinforced usually with a fibrous material such as wood flour. The properties of the materials can be varied widely by changing the resin or filler, or both. The use of a cotton filler increases mechanical impact strength; asbestos increases heat resistance; mica improves electrical properties, and so on.

Urea resins have been used mainly for cements and adhesives, and in these instances much progress has been made, particularly in the development of waterproof plywood for the aircraft industry. Melamine, on the other hand, with its greater hot water resistance, high temperature stability, and good anti-cracking properties, has found numerous uses which will be advantageous for post-war development.

The biggest developments on the material side have taken place in thermoplastics. Before the war, almost the only thermoplastic materials made in the country were nitrocellulose and cellulose acetate; there was, however, some methylmethacrylate, polyvinyl chloride, polystyrene (very small scale), and polythene (polyethylene) just coming into production. But there was no manufacture of polyamides (nylon).

The demands of the aircraft industry for cellulose acetate and polymethyl-methacrylate sheet have resulted in the large-scale production of these materials. At the same time there has been a corresponding development in knowledge of the fabrication of these materials which should lead to many new developments in post-war applications.

With the overrunning of the rubber plantations in the East by the Japanese the cable makers found themselves short of rubber at the very time when the services and industry were making ever-increasing demands for their products. The answer was found by the use of polyvinyl chloride (P.V.C.). This has proved to be a good insulator, and it can be extruded as a casing round wires without undue difficulty. New plants were erected to meet the demand and though at first a quantity was imported under lend-lease, practically all our requirements are now met by our own production. This should be a great benefit to the industry, since the material can be moulded, extruded, and produced in sheet form. Its peace-time applications cover various uses, from floor coverings to wrist-watch straps and curtains.

Nylon is now made in this country and has provided the bristles for tooth brushes and hair brushes for the forces and medical sutures in place of gut for the medical services. It has also been woven into ropes for gliders. But the outstanding development has been the production of the new all-British plastic material polythene. This was just coming into production in 1938. Its production now is 2,000 times the pre-war output.

It so happens that Radar equipment required an insulating material with minimum power loss combined with flexibility. Polythene provided the answer. It is also a versatile material which can be cold drawn, extruded, injection-moulded, and produced as foil.

Cellulose acetate film was made here before the war. The production of first-grade film for photographic purposes demands special precautions, but satisfactory film has been produced in large quantities for the R.A.F. It is also used for X-ray purposes, which was of special significance in the treatment of the wounded and the development of mass-radiography for attacking tuberculosis.

When the war came, the service Ministries soon called for huge quantities of mouldings and specified the kind of tolerances more appropriate to mass production in metal than in plastics. Thus all the previously unused skill and a good deal more was in demand. Many special grades of phenolic moulded plastics developed before the war were immediately required. Materials were also developed which were compatible with explosives and with the various chemicals employed in chemical warfare. Plastic containers played a not inconsiderable part in our preparations for gas warfare.

The contribution of these materials to the war effort was marked by their wide adaptability and steady improvement in quality and fabricating technique rather than by sensational applications or developments.

Typical applications were shell nose caps, hand grenades (many millions of these two items alone were produced), gas valves for barrage balloons, obturator pad containers for guns, rocket and shell components, telephone line insulators, and streamlined aerial loop housings for aircraft. A particularly fine example of improved moulding

technique developed in the later days of the war is an aircraft petrol pump impeller, a deep, thin spiral which was moulded to very fine limits in one operation, whereas previously it had been laboriously machined from metal. It not only provided a corrosion resistant component but resulted in considerable saving of man and machine hours.

In addition to use in service equipment, phenolic mouldings were widely used in ordnance factories for such items as filling trays where the danger of sparks precludes the use of metals.

One of the first big jobs was the famous 69 hand grenade, which was coming off the presses of five different moulding works at the rate of hundreds of thousands a week during 1940. Shell fuse caps and shell plugs were soon in large-scale production and English moulders were working " flat out " to limits finer than they would have believed possible.

In consequence of this rapid development, when, after Pearl Harbour, we began to welcome to our works representatives of the American plastics industry, these technical experts expressed their surprise at the immense use which we were making of plastics moulding for war equipment and we were able to provide them with much detailed information. Soon the 69 hand grenade and many other ordnance stores with which we had long been familiar were pouring out from moulding works in the United States.

One of the main uses for ürea mouldings under war conditions was for lighting fittings, ranging from special designs standardized on all his Majesty's ships because of their resistance to shock of gunfire, to the immense numbers of industrial fittings for the equipment of Britain's new factories, aerodromes, and military installations. In addition to high light transmission with excellent diffusion, light weight and absence of hazard from splinters are important advantages. Tableware for the Navy, buttons for all services, containers of many kinds, and various essential items of equipment, such as chronometer cases, dials, and pointers for radio and electrical equipment, were other uses.

Although the plastic material melamine has been manufactured in England since 1939, the output has not reached very large tonnages because of the shortage of raw material. Melamine resins made from it have been used primarily for the manufacture of British high-strength plywood, but some has also been employed as a base for coating resins, for the manufacture of high wet strength paper and for certain very important mouldings. Every ounce of melamine has been used solely for the highest priority service requirements. Mineral-filled melamine mouldings have established new standards of performance in the ignition equipment of aero engines while mouldings have been made for several years from a special unfilled melamine for some Admiralty equipment which is still highly secret.

One of the most spectacular uses for plastics during the war was the wide use of acrylics for aircraft windows where large curved panels are required. Owing to its remarkable transparency and lightness it is excellent for the purpose. Acrylic resins have also been used for internal lenses of scientific instruments and also in the surgical field. Complete plastic binoculars have been supplied to the Navy, with plastic lenses and plastic outer case.

The outstanding uses of celluloid were as an interlayer for safety glass for bullet-proof panels on aircraft and for tank visors, as well as interleaving material for service respirator eyepieces. Another use was for map cases.

Vast numbers of cartridge containers were made and an interesting use was the production of incendiary leaves, which comprise small pieces of celluloid two inches square which were sandwiched in pairs on either side of phosphorus. These leaves were transported in water tanks by air and dropped over Germany to fire crops and forests.

There has been an ever-increasing demand for cellulose acetate plastic, and it has been used for transparent glazing and also for component parts in the inside of aircraft. Transparent wire-reinforced material was used most successfully as a replacement for glass in buildings before the war, where its use eliminated all risks of accidents due to glass splinters. During the war it was also used very largely for windows of Army lorries.

Several hundred millions of cellulose acetate eyeshields were made. This simply designed and practical eyeshield is one of the neatest jobs the plastics industry has turned out during the war.

Another plastic, polystyrene, with its excellent electrical properties, has been in much demand for radio sets and radar equipment. An outstanding development in the manufacture of co-axial cables was the use of polystyrene separators.

P.V.C. cable covering has been extensively used in aircraft, as it is able to withstand the

special fluids used in the hydraulic systems. Its abrasion resistance is remarkable, and it has been found that it is an excellent material for the curtains of shot-blasting cabinets.

It is well known that petrol is a solvent for rubber, but extruded tubes of this rubber-like material, P.V.C., have been successfully used as petrol feed pipes in aircraft, thus overcoming the danger from fracture due to vibration fatigue of metal petrol pipes. It has also been used for medical tubing and irrigation bags for giving continuous saline baths in case of extensive burns on limbs. Paratroopers were supplied with small water bags made from P.V.C. which roll up into a small space when not required.

Large quantities of laminated sheet were used in peace-time for electrical insulation—particularly for telephone and radio equipment. In modern warfare speed and reliability of communication may frequently determine whether battles are won or lost, and where radio played such a large and important part—not only in communication, but in detection also—phenolic laminated materials fulfilled a vital role.

Fabric-reinforced material is increasingly used for mechanical components of aircraft where light weight (laminated plastics are little more than half the weight of aluminium) and strength are valuable features. Many different components of the Mosquito, including such an important part as the piston in the undercarriage system, are made from phenolic laminated plastics.

In the early part of the war a reinforcing material was required for wooden aircraft. Laminated plastics were thought to be suitable, but aircraft manufacturers experienced difficulty in gluing the material to the wooden parts of the aircraft. Faced with this problem, the plastic manufacturers produced a laminated material with a wood facing, thus enabling the aeroplane manufacturers to take full advantage of the laminated plastics while employing wood-working technique.

Non-magnetic materials were in demand, both for the manufacture of mines and for mine detectors. Detectors rather like giant sweeping brushes without bristles, which became familiar through pictures of land mine clearance in the North African desert, are made entirely of phenolic laminated plastics.

Special types of instrument cases which would normally be made of wood were made of laminated plastics, which are not affected by tropical conditions of heat and humidity to the same extent as is wood. Because of their self-lubricating properties laminated plastics have also been used for bearings for tanks.

The partnership between wood and plastics developed enormously during the war. The invention of a melamine hardener, with boiling water resistance, for urea resin-bonded plywood, made it possible to produce aircraft plywood in low temperature veneering presses. The use of plywood and laminated construction with

A war-time application of the use of plastics was for nose caps of shells. One of the processes in manufacture is seen in this picture.

cold-set gap-filling glues allowed the construction of the highest performance aircraft in furniture factories; and the world's fastest bomber, the Mosquito, and the world's biggest glider, the Hamilcar, were the result.

Another example of the partnership between wood and the plastic resins is the material known first as " improved wood "—very thin veneers of wood alternated with sheets of resinous film or liquid resin glue. Under heat and pressure the resin impregnates the wood and the whole is bonded into a compact material which possesses properties derived from both wood and plastics. They have great strength, good electrical properties, resistance to chemicals, dimensional stability, and excellent machinability. Electrical switch-

gear, battery boxes, press tools and jigs, water lubricated bearings may be cited as examples of the wide range of articles made from this material.

Plastics have played an all-important part in the wooden airscrew. The wood laminates are cemented together with urea formaldehyde glue, the root end is made of compregnated wood, and the entire blade is covered in thermoplastic sheeting. With this plastic skin the blade is impervious to weather conditions, and it has protection from flying stones and particles of grit when the aircraft is taking off. These materials were in large-scale production throughout the war, and in fact many of the fighters which won the Battle of Britain were already equipped with airscrews made from them.

It is not possible in a short article to give a complete survey of the great part the British plastics industry played in the war, but enough has perhaps been said to show that the skill of British workmen in producing very high-grade moulds and the skilled technique of the moulder and fabricator, whose main occupation in peacetime was to produce highly decorative articles, made a great contribution to the national war effort.

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DRUGS AND PHARMACEUTICALS

AS far back as 1936 Government Departments were engaged on plans designed to safeguard supplies of essential drugs and medical products in the event of war with Germany. Estimates of requirements of essential drugs were prepared and, later, action was taken through the appropriate Supply Committee to augment stocks and to supplement the stocks of certain important crude drugs in the hands of private traders by the setting up of Government reserves. These reserves included opium from Turkey, ipecacuanha from Brazil, and ergot from Spain and Portugal.

After the outbreak of war the supply position of certain important vegetable drugs was further strengthened by an increase in production on the part of British commercial growers and through

The large-scale production of penicillin was one of the most important war-time efforts of the chemical industry. These photographs show two stages in its production. Top : Emptying the mould from bottles. Below : The mould developing in an incubator.

a scheme of private collection organized by County Herb Committees on behalf of the Vegetable Drugs Committee established by the Ministry of Health. Among the important crude drugs grown commercially on an increased scale or collected under the scheme were digitalis, belladonna, hyoscyamus, and male fern. Rose hips contain Vitamin "C," and through the County Herb Committees large quantities were collected and provided a valuable addition to the none too plentiful supplies of that important vitamin.

While at no time was there a serious shortage of any vital drug owing to the measures taken, it became evident during the early part of the war that, in order to conserve supplies and to deal adequately with the difficult supply position that seemed likely to arise during a long war, co-ordination of the various activities was necessary, and accordingly in 1941 the Directorate of Medical Supplies was established in the Ministry of Supply. Since then all aspects of medical supplies have been dealt with by the Directorate in the closest cooperation with the United States, including production, controls, imports, exports, and the provision of supplies for the Dominions, colonies, allies, Unrra, and liberated countries.

In the field of synthetic drugs, one of the most difficult problems facing the pharmaceutical industry at the outbreak of war was the production of a British equivalent for every foreign proprietary product considered to be essential. The high percentage coming from Germany was cut off the moment hostilities began, and the collapse of France reduced the available range still farther.

As early as the Munich crisis in 1938 the British drug industry laid its plans. As a result of conferences between representatives of the Manufacturers' Association and the Medical Research Council a list of 17 vitally urgent products was prepared. Experts consulted the relevant patent literature and thus prepared the way for rapid work should war break out.

When war was declared no time was wasted. Enemy patents lost their protective power, and research, as distinct from organizational work, was started at once. Many practical problems had to be overcome. It was soon found that the description of manufacturing processes given in many patents tended rather to hide than to disclose facts. Every product therefore presented a threefold problem. Its theoretical basis had first to be established in the laboratory. Next, pilot-plant manufacture had to be organized. Finally came mass production, in which engineers and chemists combined their knowledge.

These diverse obstacles were all surmounted. The following list gives examples of the products formerly obtained from abroad and now available from British sources :—

Use	Products
Anaesthetics (to produce local or general unconsciousness)	Bromethol, hexobarbitone soluble, benzocain, orthocain, ethocaine hydrochloride (hexobarbitone soluble is often preferred to chloroform and ether)
Analgesics (to ease pain)	Pethidine hydrochloride, phemitone, phenylsemicarbazide
Anthelmintics (to cure internal worms)	Diphenan
Anti-epileptics (to prevent or ease fits)	Phemitone
Anti-malarials (to prevent or cure malaria)	Mepacrine hydrochloride, mepacrine methane sulphonate, pamaquin
Cardiac and respiratory stimulants (to stimulate the heart or lung)	Pholedrine, nikethamide, leptazol, hexazole (leptazol is used in shock treatment of stubborn psychological illness)
Cardiac repressants (to slow excessive heart-beat rate)	Carbachol
Diagnostic adjuvants (to aid diagnosis or enable it to be made)	Diodone, iodoxyl, pheniodo (pheniodol is used in radiographic examination of the gall bladder to obtain a superior shadow)
Skin diseases	Dithranol, mesulphen
Hypnotics (to calm "nerves" or produce sleep)	Allobarbitone (this barbiturate produces sleep without leaving a sensation of drowsiness on waking)

To these can be added various veterinary preparations, such as pirevan and sulphacetamide.

A heavy increase of output had to be organized by the British chemotherapeutic industry, in spite of enemy air attacks, man-power difficulties, and scarcity of raw materials. Yet the required additional production has always been forthcoming. In the hormone field there were increased demands for testosterone, progesterone, stilboestrol, hexoestrol, and derivatives such as methyl testosterone and testosterone propionate, as well as adrenalin.

Much more could be written regarding the steps which had been taken to ensure adequate supplies during war-time for which there is no space, but mention may be made of one or two special items.

At the outbreak of war little was being done in this country in the manufacture of the newer sulphonamides such as sulphathiazole and sulphaquanidine, the latter of which has been invaluable in the treatment of bacillary dysentery, and has been required in very large quantities by the services. Production was established in this country after the outbreak of war, and the output of each of these two drugs is now in the neighbourhood of 80 tons per annum.

Before the entry of Japan into the war the world relied on quinine for the treatment of malaria (a disease which is probably the biggest single cause of death). The fall of Java, which produced 95 per cent. of the world's quinine, was therefore a matter of the gravest concern, especially since active operations were likely to take place in malarial zones.

In consultation with the United States steps were taken to conserve such stocks of quinine as then existed and to restrict them to the treatment of malaria. Simultaneously, joint steps were taken to explore the possibilities of obtaining cinchona bark (from which quinine is extracted) from other sources, mainly South America. Joint plans were also made for the manufacture of an alternative drug of German origin known as atebrin, but now manufactured in Britain under the name of mepacrine. This drug had not been extensively tried out as an alternative treatment and was being made only in very small quantities, either in the United States or in this country. There was, however, sufficient faith in its efficacy to warrant making provision on an extensive scale. These steps have been fully justified, with the result that the drug is proving to be in some respects even better than quinine both therapeutically and prophylactically, and the present joint output of the United States and Great Britain is equal to many times the previous world production of quinine.

One of the most important war-time demands which the fine chemical industry had to meet was for penicillin, which reached the practical stage in 1938-39. The story of its development by British scientists from Sir Alexander Fleming's discovery in 1929 to its large-scale production as a therapeutic agent both in Britain, under direction of the Minister of Supply, and the United States, under the direction of the War Production Board, during the war is now well known.

The academic workers collaborated with commercial manufacturers in an alliance regarded as a good augury for the future, and enough penicillin was produced for clinical tests on which the most effective dosage and the best method of treatment were worked out.

In 1942 Professor Florey went to the United States and placed at the disposal of experts there all the theoretical and practical knowledge that he and his co-workers had accumulated. Descendants of Fleming's mould, which hitherto were the source of the world's entire supply, were taken to America and laid the foundation of manufacture there. In 1943 Sir Howard Florey, with Brigadier H. Cairns, carried out in North Africa an investigation into the use of penicillin in war wounds. Later the information resulting from the interchange of experience between British and American investigators was placed at the disposal of Russian scientists.

46

INDUSTRIAL ALCOHOL

THE outbreak of hostilities in 1939 placed a heavy burden on the manufacturers of industrial alcohol and solvents, as these materials enter very largely into war production. The list of usages of industrial alcohol and its derivatives, such as acetone, butyl alcohol, and acetic acid, is formidable and covers, among many others, the manufacture of propellants, war gases, liquid coolants for aircraft engines, air-screw de-icing, parachute fabric, hydraulic fluids for power-operated gear for aircraft and armoured fighting vehicles, and plastic materials and finishes of all kinds.

While the pre-war capacity for producing industrial alcohol was sufficient to meet all requirements for the above purposes, the greatly increased demand for acetone and butanol was such that the industry was asked to instal considerable additional equipment.

The principal raw material from which industrial alcohol is manufactured in this country is molasses, which is a by-product of sugar manufacture and is produced wherever cane sugar

and sugar beet are grown or refined. Molasses itself has other uses, such as the manufacture of compound cake for cattle feed and as a raw material for baker's yeast ; both of these products use a very considerable tonnage.

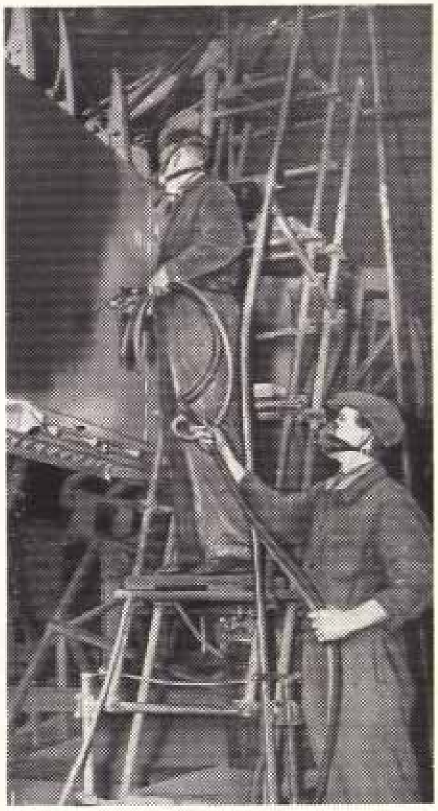
Before the war a large emergency stock of molasses had been built up in this country through the initiative of the molasses and distilling industries, and this stock, which was taken over by the Ministry of Supply in September, 1939, was of the greatest value in the early years of hostilities. In addition to becoming the sole owner of all molasses stocks in this country and of British-owned stocks oversea, early in the war the Ministry of Supply made arrangements to purchase on public account the United Kingdom stocks and production of industrial alcohol, acetone, butanol, and acetic acid. These industries have thus been subject to the direction of the Ministry and, in all, molasses, alcohol, and over 50 derivatives have been brought under statutory or voluntary control.

In view of the importance of these products for service requirements, it was necessary to restrict supplies to essential demands and, in many cases, to prohibit less important usage. This became more necessary as the shipping position deteriorated ; indeed, in some instances, there was no alternative but to cease or reduce manufacture in the United Kingdom and to import the finished article from the United States. As an instance of some of the difficulties which had to be overcome, in the summer of 1940 it was decided that too great a hazard was involved in discharging tankers at east coast ports. Equipment was therefore transferred to areas where molasses could be imported with less risk, and this transfer was accomplished by the industry with commendable expedition. As a result, alcohol and solvent capacity was maintained at a level adequate to process all the available material.

In 1941 the tanker position had become so acute that in order to make greater use of the available vessels, arrangements were made to obtain bulk cargoes of alcohol and acetone from the United States, and during the war large quantities have been imported, production of alcohol and solvents in this country being correspondingly reduced.

The position in respect of molasses supplies was also eased by the erection in this country of a plant designed to produce industrial alcohol and acetone from oil specially cracked for this purpose. This development, which was of considerable technical interest, was also supplemented by other projects utilizing alternative raw materials to molasses.

Such changes in normal trade operations as are outlined above, involving the curtailment or complete cessation of production in the case of individual works, required very close cooperation between the industry and the Ministry of Supply. It stands to the credit of all concerned that their relations were most cordial and helpful throughout this difficult period.



Spraying the wing of a bomber with a protective finish. Among the uses of industrial alcohol and its derivatives are finishes of many kinds.

With the termination of the war and the easing of the shipping position, the difficulties referred to will gradually cease, and ample supplies should soon become available to meet post-war demands.

47

THE COTTON INDUSTRY

THE result of the war upon the fortunes and prospects of the British cotton industry has been to improve them. In 1939 the affairs of the industry were not in a very promising condition. The late nineteen-twenties and the nineteen-thirties had been years of retreat so far as the vast export trade in cotton textiles was concerned. These exports had been one of the wonders of the world, if only by their sheer magnitude, before the first German war—7,000,000,000 yards per annum. By 1938 they were down below 2,000,000,000 yards.

Half the loss was due to competition from Japan, based on incredibly low standards of living and currency depreciation, coupled with a performance in policy and operation which commanded respect. The other half was caused by high protection in countries which had determined to run their own textile industry whatever the price to be paid. The British cotton industry had passed through anxious years of searching for the right adjustments to these new conditions, impeded all the time by falling volume and losses of capital. In the summer before the war it had united to seek a Bill in Parliament to give it a new centralized organization to direct the necessary adjustments. The Act was passed in July, but along with other measures passed in the last few weeks of peace, it was put into cold storage when war broke out.

The outbreak of war therefore caught the industry at a moment of some confusion. In the course of the war the industry had to endure more than most others in the way of unavoidable and compulsory changes. First it was told to export everything possible to gain vitally needed dollars and hard currencies. Then commercial exports were entirely shut off. In the black days of 1941 one-third of its mills were closed down, so that their workers might be transferred body and soul to munitions production. Then it gradually became increasingly evident that cotton goods were going to be among the crucial needs of the new kind of war. The cry from London to the sadly denuded industry was for more and more production, and the unhappy lemon had to be squeezed and squashed by planning and more planning.

Through all these experiences the Lancashire men plodded on—a trifle dazed by the shifts of policy, grumbling a little at the impossibilities required of them, but doing a fine job of work and incidentally learning a lot of things which many now believe will turn out to be the answers to those complex problems of 1939. The justification of these hopes will be seen by any thoughtful student of the industry's war-time experiences.

To begin the story it may be convenient to the reader to have a brief recital of the bare facts from the production angle.

As already stated, the cotton industry was concentrated to between one-third and one-half of its pre-war level. This reduction in output, combined with heavy additional demands for military purposes, brought the output of the industry under a strict rationing system for the allocation of the available supplies among the principal users. This system was operated at the highest level by the Raw Materials Division of the Production Executive—later the Ministry of Production—and yarn allocations were made to some 20 Government Departments as well as to industrial groups.

Over one-third of production was allocated to military uses, and it may be estimated that some 300,000,000lb. of yarn and 600,000,000 yards of woven fabric were produced annually for this purpose.

About one-fifth of production was directed to civilian clothing and approximately the same amount to essential exports to Dominions and allied countries. The reduction in civilian trade was to about one-third and of exports to about one-quarter of pre-war levels. The remainder of production was directed to essential industries in this country.

The reduction in home and export supplies led to further rationing schemes—*i.e.*, the Utility programme and the allocation of exports through the Combined Production and Resources Board in Washington. The Utility scheme was designed to produce supplies of good quality materials at reasonable prices, and it had also the effect of increasing productivity by concentrating production on a relatively small number of styles. The international allocation of exports was designed to relieve the shortages in oversea markets and enable these countries to plan their own civilian requirements.

Obviously all this needed elaborate organisms of control and direction; equally obviously these would have achieved but little without loyal, intelligent and resourceful cooperation, which in fact they received in the fullest measure.

The Cotton Control, a branch of the Ministry of Supply, has been responsible for supplies of the raw material—at times a very anxious question—and for planning production up to the loom state cloth. Side by side with the Cotton Control there has been since March, 1940, the Cotton Board. This body was established initially at the outbreak of war and was given a statutory basis in March, 1940. In composition it was designed to resemble the Board envisaged by the Act of 1939, the operation of which had been postponed. But its terms of reference were purposely left quite vague and general. It was to be representative of the industry, except for its chairman, who was to be independent and impartial. It was to be responsible to the Board of Trade. The openness of this mandate coupled with the sequence of events has led the Cotton Board to assume a wide and varied range of duties. It has been specially concerned with the distributive side of the industry's activities, if only because this was beyond the point where the domain of the Cotton Control ended. In its work during the war the Cotton Board has acquired much factual information and experience which cannot fail to be of immense value now.

The war has shown the importance of coordination between the horizontal sections of the industry—spinning, weaving, finishing, and distribution. Production planning by the Cotton Control was necessary to ensure the availability of the right types of cloth in the right quantities at the right time for essential purposes. The Cotton Board has administered a scheme for producing utility fabrics of both cotton and rayon for the purposes of the system of utility clothing created by the Board of Trade to supply the minimum requirements of the civilian populatio with thoroughly satisfactory goods at controlled prices. The Cotton Board has also conducted a plan of allocated exports for destinations the supply of which was considered by the allied authorities as essential to the war effort. The Cotton Board has administered care and maintenance funds, supported by contributions from running firms and disbursed to the mills closed under the concentration of industry policy.

On the technical side the pressure of war-time needs was a powerful stimulus to rapid technical progress. Cotton happens to be the most vital textile for war purposes, its uses for service requirements being far more diverse as well as more extensive than those of any other textile fibre. Its contributions to the services indeed are now so many and varied that it is hard to know where to begin an illustrative list of them. Some of the uses are, of course, well known, and represent no new development—webbing equipment, for instance, surgical dressings, various articles of clothing, working uniforms, overalls, and so on. It is natural also to find such products as sandfly netting and camouflage fabrics made of cotton. But modern warfare makes new demands, and now the uniforms of tank crews and the Army dispatch-rider's coat are to be found made of stout fire-proofed cotton, while the crash helmets of both frequently have a cotton base. Airmen have wind-proof flying suits made of fine cotton gabardine and flame-resisting waistcoats of fine cotton poplin. Their parachute harness is of cotton, and so

Cotton is used in the making of flying-suits, parachute harness, flame-resisting waistcoats, and "Mae West" jackets. This picture shows Spitfire pilots wearing typical flying clothing.

is their " Mae West " jacket. Dinghies used by bomber and fighter plane crews when they have to bale out over the sea are of rubberized cotton, and barrage balloons are made of cotton suitably proofed. Many of the component parts of aeroplanes themselves are made from a plastic material consisting of compressed layers of cotton cloth impregnated with synthetic resins. The Navy, too, uses large quantities of cotton, in many instances now as a substitute for flax.

A large number of these specialized uses have been developed only as a result of intense research. The industry is fortunate in possessing in the British Cotton Industry Research Association (popularly known as the Shirley Institute) in Manchester the finest as well as much the largest textile research organization in the world. A great deal of war-time research work has been undertaken by this body, and the success it has achieved is certain to have more far-reaching consequences than might at first appear probable, for though its prestige has always stood high, its recent work and the results it has produced are making the whole industry more " research conscious," more ready to experiment and try new methods, than ever before. Now that the war is over the institute can be relied upon to keep the British cotton industry in the van of technical progress.

The story of the Colour, Design, and Style Centre set up by the Cotton Board illustrates the strange way in which an initiative evoked by war bids fair to prove invaluable afterwards. The Centre was inaugurated in 1940 as part of the export drive. It then hoped to increase exports by raising still higher the already notable achievements of the industry in colour, design, and style. It also hoped to indulge in a certain amount of " telling the world " about the prowess of Lancashire in these fields. Fortunately the Board found a brilliant man to become director of the Centre. He has made its beautiful exhibition hall a veritable Mecca for the artist in design and for the energetic manufacturer. Altogether 23 exhibitions have been staged at the Centre up to the present date.

The stimulus to creative work and to prestige thus evoked has been remarkable. The Centre has come to stay. Perhaps the highest compliment paid to it is a decision by the British Government to establish in London a Council for Industrial Design, of which a principal object is to encourage other industries to establish similar design centres. In Manchester they remark with a chuckle in this connexion that it seems there is still some validity in the old tag about what Manchester says to-day London says to-morrow. The best thing about the Centre is its immense vitality. The enthusiasm it fosters, especially among the young, augurs well for the standard of design of Lancashire textiles in the next twenty years. Foreign buyers are already alert to it and even during the war a surprising number of experts have contrived to see the Centre. All have come in curiosity and left in admiration. The Centre will prove a magnet for Manchester in years to come.

Another Cotton Board development of great significance is its Recruitment and Training Department. As things stand the cotton industry in England as in other countries consists of relatively small units. Even where amalgamations exist, the unit of production is never large, as in certain engineering and other industries. Great concerns nowadays apply modern principles to recruitment and training, and place in charge of these activities specially qualified and well-paid personnel. This latter is not practical politics for the small unit and so the Cotton Board stepped in to provide at the headquarters of the industry an expert staff which can and does perform for the individual mill what the personnel directorate performs for the large industrial undertaking. The ultimate results are clearly foreshadowed by present achievements. A highly significant advance in methods of recruitment and training is confidently anticipated. With this will go improvements in amenities and mill conditions. A separate article would be required to do justice to the work of the Cotton Board in this field.

It is generally agreed in Lancashire that there will have to be well-considered alterations in the wages structure, which is governed by old-standing agreements with the trade unions, in deployment of workers to the machines, especially having regard to increased mechanization, and in mill practices generally. The Cotton Board has obtained the cooperation of employers and trade unions in launching concrete experiments and tests in these matters. At the Wye Mill—and later on at other mills—experts are devising new methods. Both sides in the industry have agreed to permit departures from agreed practices. A faithful record is to be kept of costs, wages, production, &c., before the experimental changes are introduced and after. On the records thus made available the two sides will evolve a modernized practice by the usual methods of industrial negotiation. Thus, in an orderly

manner, the industry will facilitate rapid adjustment to new conditions without sacrificing that stability to which the trade union movement naturally and rightly attaches so much importance.

This particular plan of action grew out of a report of a mission to the United States known as the Platt Report. The mission's terms of reference were limited to production per man-hour. It went to America at a time when increased production was of critical importance to the war effort. It found, as was already known, that production per man-hour was much greater in the United States than in Britain. The resultant publicity was to a considerable extent misleading to the inexpert. In the cotton industry it is always possible to increase production per operative by using better and more expensive grades of cotton and by a high degree of mechanization, which increases capital charges. It is a matter for calculation how far these policies can and do cheapen selling prices There is no doubt that the Platt Report, sticking to its terms of reference, left many outside observers with an incorrect impression of the relative commercial efficiency of the American and British industries On the other hand, no competent expert in Lancashire questions for a moment that in years to come, owing to population trends and social conditions generally, the industry will have to concentrate on increased production per man-hour. The Platt Report, with its unreserved concentration on this theme, did good service even if it temporarily reflected somewhat excessively on the British industry's alleged weaknesses. The Wye Mill experiments and other developments will open the way to significant changes in the rate per man-hour.

The cotton industry knows that it will have thirsty markets in the period immediately following the war. Some of the competition it met before the war will not figure in the scene as it then did. The shelves of the world are indeed bare. Lancashire will use the benefits of a period of high demand to set her house in order. New machinery, new practices, new personnel, the application to peace requirements of a great deal of scientific research already at a well-advanced stage, the intensive development of colour and design—all these are on the way. There will be also the old virtues, the old assets. Customers oversea may confidently look for the best service in quality, reliability, and styling. While supplies are short there will be fairness and consideration in rationing. The inherited skill and judgment will be apparent in the Lancashire of to-morrow. Tested and tried by the adversities of war and pre-war, the British cotton industry has the means and the spirit to stage an impressive renaissance.

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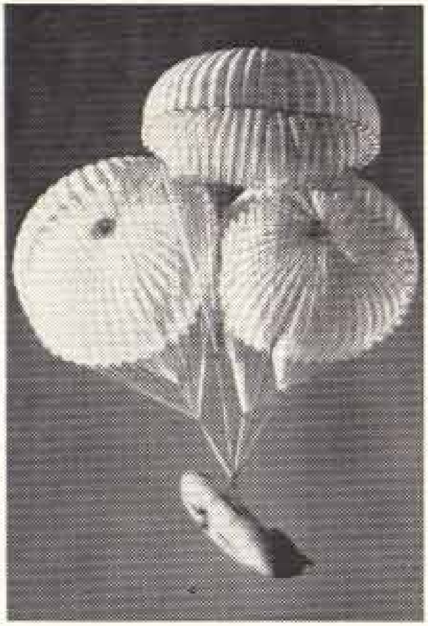
SILK, RAYON, AND NYLON

SILK, rayon, and nylon have all played an important part in the war effort in meeting service and essential home demands. It was inevitable, however, that as the war progressed and supplies became short, silk should decline in importance and the emphasis move to the synthetic fibres. The history of this transition, with the solution of technical difficulties and processing problems, forms yet another example of the adaptability and technical skill with which British industry faced the loss of familiar raw materials and the necessity for producing the same (and sometimes even better) results with less known alternatives.

Before the outbreak of war and during the early war years, between 80 and 90 per cent. of the raw silk imported into the United Kingdom came from Japan, which country produced about 80 per cent. of the total world supplies. At that time, silk was the approved raw material for many important service and essential uses, the most important being parachutes (fabric, cordage, and sewings), insulation fabric and thread for fine wire covering for electrical apparatus, cartridge bag fabric, bolting cloth for use in sieving flour and similar materials, and in addition there were a number of minor uses of a similar type where tensile strength was needed, combined with fineness and small bulk.

The entry of Japan into the war, therefore, in depriving the United Nations of supplies of raw



One of the many uses to which nylon yarn has been put is the manufacture of parachutes. These three are carrying a lifeboat.

silk, presented them with a problem of considerable magnitude, particularly as it coincided with the beginning of a rapid expansion of requirements in almost all fields of utilization. Steps were taken immediately to conserve silk supplies in the United Kingdom by the application of additional measures of control. The Silk Control under the Ministry of Supply became the sole purchaser of raw and waste silk abroad; stocks were taken over from the trade and the licensing of use was strictly enforced. The control involved also the elimination of non-essential use and the careful planning of production. Considerable developmental work was done in finding and encouraging production in alternative sources of supply, particularly in the Middle East and India.

It was, however, apparent that these measures would suffice to cover only a small proportion of the United Kingdom's essential requirements and concurrently the development of substitutes for silk was vigorously pursued. The most pressing need was for use in parachute production, where the lives of airmen and paratroops depended on the finding of the right answer. Exacting standards were necessarily laid down, involving long and detailed experiments and tests.

The textile fibre finally approved as a substitute for silk for fabric and cordage for man-carrying parachutes was nylon yarn. This yarn is only one of a group of new materials with a chemical base for which "Nylon" is the generic name. The basic raw material is chemical, and the ultimate product can be made up into various forms and utilized as plastics, in brushes as a substitute for bristles, &c. In the United States the peace-time uses of nylon yarn had to some extent been tested, particularly in the hosiery industry, but nylon came as an almost entirely unfamiliar raw material to the United Kingdom silk industry, which was entrusted with developing the use of this substitute for raw silk.

The industry achieved a high degree of voluntary cooperation in handling this important piece of research and essential production. The processing (twisting and winding), weaving and finishing and dyeing all presented problems, particularly as the new yarn showed marked characteristics not shared by the more familiar natural textile fabrics. Later, nylon yarn was also processed by the rayon-weaving section of the cotton industry.

Production of the yarn itself was undertaken in the United Kingdom, the manufacturers working in close touch both with the service departments and with the industry which had to produce the goods. A large part of the United Kingdom supplies has, however, been imported from the United States and Canada, with which countries there has also been close technical cooperation. Cordage production also from nylon yarn replaced the silk cords of the parachute harness, and the spun-silk industry developed yarns made from waste silk to replace the raw silk sewings.

The use of rayon for direct service needs, apart from clothing and similar items, has been largely in the field of high tenacity yarns which have served a number of valuable purposes. Parachutes for dropping supplies were originally designed in silk, and the first substitute approved for this purpose was high tenacity rayon. In addition, these yarns in fine deniers have to some extent replaced silk for such uses as electrical insulation and bolting cloth, though there remains a

hard-core of demand for which silk only is suitable. In coarser deniers the major development in the use of this type of yarn has been in tyre production, where large quantities are being taken up. This development, which has been carried to considerably greater lengths in the United States, was connected in the first instance with the use of synthetic rubber after the loss of natural rubber supplies. Later, it became the opinion of some experts that tyres made with rayon fabric have extra strength and wearing qualities, which may lead to the continuation of the use of rayon on its own merits. Nylon yarn is in early stages of development in tyre production in this country, particularly for aero tyres.

Rayon yarn production other than the high tenacity types has fallen very heavily since the early war years on account of a withdrawal of much of the industry's labour force for the services and for the direct munition industries. The nucleus remaining has, however, been responsible for the provision of an important element in civilian textile requirements at home and has provided yarn and finished goods for Empire and allied countries suffering from the world textile shortage following the cessation of supplies from enemy and enemy-occupied countries. The industry is now planning an ambitious post-war programme with the object of expanding production both for the home market and for export as quickly as the labour and other difficulties can be overcome.

Much of the technical progress in the use of synthetic fibres has been achieved during the war under the stress of immediate necessity, but there is no indication that the whole story has yet been told.

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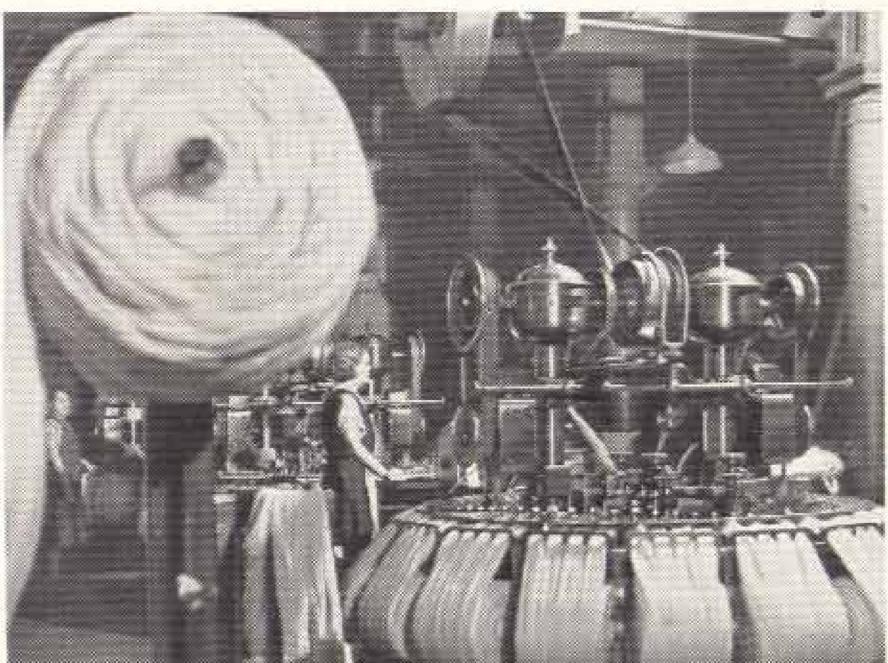
WOOL TEXTILES

PREPARATIONS had been made well in advance of the outbreak of war for the control of the wool textile industry, and during the first week of September, 1939, the Ministry of Supply issued an order which brought into being the Wool Control with Sir Harry Shackleton as Controller.

As a result of a series of subsequent Orders the Wool Control became the sole importer and supplier of wools and tops (combed wool) to the industry. A system of rationing was introduced and the Controller was given power to direct production of yarns and fabrics into the desired channels. The requirements of the services formed the first priority, and in the early war years export trade came next and home civilian needs last. In the later war years, when circumstances changed, the order of priorities was altered and the requirements of the utility clothing scheme were put in front of production for export.

The first essential was an adequate supply of raw material, and from this point of view the British Government was in a favourable position. The five principal wool-exporting countries are Australia, New Zealand, South Africa, Argentina, and Uruguay, and the average production in



This picture, taken in a woollen mill, shows a machine separating the long and short fibres of the yarn in preparation for the spinning of the finer cloths.

recent years has been about 2,135,000,000lb. per annum, three-fourths of which came from the three British Empire countries.

The British Government bought the entire wool clips of Australia, New Zealand, and South Africa for the duration of the war and up to one season after the end of the war with Japan. Some idea of the magnitude of these operations may be gathered from the fact that for the 1943-44 season the purchase price for the three clips was over £100,000,000. In addition, the wool production of the United Kingdom has been bought each year by the Government.

The Wool Control has therefore had at command an abundance of wool. The only problem in the early years was transport. There were times when stocks in the United Kingdom were adversely affected by shortage of shipping space. It was convenient at one stage to ship large quantities of wool to the United States as return cargo in vessels which had conveyed troops and war materials to the Pacific war zone, and it was kept in store there as a strategic reserve owned by the British Government.

Before the war the world consumption of wool was about 3,400,000,000lb. per annum, of which about 1,400,000,000lb. was absorbed on the Continent of Europe. That part of the world was virtually cut off from oversea supplies during the war and in consequence there was a huge accumulation of wool at the sources of supply, estimated to amount to about 4,000,000,000lb. or about 13,000,000 bales. The recent Empire Wool Conference held in London was convened for the purpose of making plans for the disposal of this surplus, concurrently with the incoming new clips, during the next few years. There is a great world hunger for wool and wool goods, but the speed with which the surplus can be disposed of will largely depend on how long it takes to restore the numerous mills on the Continent of Europe to their normal activity.

One of the most satisfactory phases of the Wool Control administration has been the stability of prices. Wool and tops have been supplied to the industry by the Control at fixed issue prices. After a period of adjustment during the first year of the war a price level for home civilian trade was fixed in November, 1940, and it remained unchanged over a period of five years. Prices of yarns are governed by an official list of maximum prices and margins of profit on cloths for the utility clothing scheme are controlled by a series of Orders.

This stability has been achieved in spite of the fact that in 1942 the purchase price to the Dominion wool growers was increased by fifteen per cent. and that since 1940 there have been two advances in the prices paid to British farmers. In July, 1942, issue prices for wool and tops required for the production of yarns and fabrics for export trade was increased by 20 per cent. above the home civil issue prices, but there was a modification of this increase in October, 1944, which left export prices from 5 to 10 per cent. above home prices.

The fact that issue prices were not raised for the home trade was largely due to the Government policy of avoiding so far as possible an increase in the cost of clothing. There is indeed

Pressing battledress. In one year, 1943, 10,325,000 blouses or trousers were produced by the wool textile industry.

Cutting cloth for Army uniforms.

a considerable element of subsidy in the comparatively low controlled prices for utility wool clothing. The increased cost of wool has not been passed on to the home consumer. Moreover, the increase in the cost of cotton used in wool-and-cotton union cloths was refunded to manufacturers by the Wool Control, and when the cost of tailoring increased the clothiers were compensated by reductions in the prices of their cloths. The cloth manufacturers in this case also were compensated by the Wool Control for the reductions they had been ordered to make.

In the early war years there were enormous demands on the industry for wool clothing for the fighting services and for the Women's Auxiliary Services. In pre-war years the average annual consumption of wool in the United Kingdom was about 650,000,000lb. During the peak period of war production it is believed that the consumption increased to about 900,000,000lb. per annum. Some facts with regard to quantities produced for the Army were given in the Government publication "Statistics Relating to the War Effort." Here are a few extracts :—

—	1940	1941	1942	1943
		(In thousands)		
Battledress : (Blouses or trousers) . .	17,550	16,976	9,566	10,325
Shirts or vests	16,558	8,953	7,582	9,387
Greatcoats . .	3,681	3,056	1,004	1,719

No statistics have been published with regard to supplies for the Royal Navy or the Royal Air Force, but it can be said that all the requirements of the Services have been adequately met.

During the first two years of the war the full labour force of the woollen and worsted industries, numbering about 240,000, was employed to the limit and overtime was the rule rather than the exception.

During the period before the enactment of lend-lease legislation in the United States there was a big export drive in order to obtain foreign currency to pay for necessary imports. The National Wool Textile Export Corporation was formed and, together with its companion organization, the Export Group of the National Wool Textile Executive, directed an export campaign with great vigour. In spite of the huge demands on the industry for the Services, there was sufficient production for export to permit of shipments amounting to about 86,000,000 sq. yds. in one year. This was not far short of the shipments during the years immediately before the war.

Subsequently there were two factors which caused a reversal of export policy. First, the lend-lease plan modified the need for exports to pay for imports, and, secondly, the withdrawal of man- and woman-power from the industry for the services and for munitions work seriously curtailed its productive capacity. The available labour force dropped from 240,000 to about 140,000, and it became very difficult to provide adequate supplies for the home population, with a reasonable margin for export orders. Oversea trade declined because the goods could not be produced in adequate quantities, and shipments declined until they were only about a third of the pre-war volume. They were in fact restricted to the essential needs of Empire markets and to some of the oversea territories of allied Governments, with a moderate allocation for the United States and Latin-American countries. For a period of about 16 months there was no allocation for the United States or Latin America.

A number of mills were closed down under a concentration scheme and premises were taken over by other Government departments. When the war came to an end the textile industry was working under the handicap of a seriously depleted labour force. So much so that it was not possible to satisfy all the demands upon it for home and oversea trade.

Shelves were empty and wardrobes bare, and there was an insistent demand from all markets for British wool textiles. The extent to which the industry will be able to deliver the goods in the coming months depends upon the speed with which former wool workers return to the mills and upon the change-over from services to civilian production.

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FLAX, HEMP, AND JUTE

FLAX, hemp, and jute have all been in urgent demand for essential service purposes, while in spite of stringent rationing there also remained a hard core of requirements which had to be met in order to ensure the maintenance of the life of the community. Supplies, utilization, and processing all presented problems varying in intensity and emphasis. In no case was the way easy and ingenuity and skill were demanded from the industries by way of adaptation and substitution and general measures of economy in utilization.

Flax

Flax is the raw material for linen, the manufacturing industry being centred in Northern Ireland and Scotland. Before the war some 90 per cent. of the flax used in this country came from oversea, chiefly from the Low Countries, the Baltic States, and Russia. A Flax Control was set up by the Ministry of Supply at the outbreak of war, which became the sole purchaser of flax, controlled its use and sale, and took an active part in planning production of service requirements. With the loss of Continental sources of supply it was necessary to eliminate (except for a few essential items) the export trade, which had been most valuable, and to restrict manufacture to essential needs of the United Nations for which no suitable substitute could be found. Such uses included aeroplane fabric, parachute harness and cordage, hose-pipes, linen thread, and tarpaulins and canvases.

The main task was therefore the provision of raw material rather than the use of substitutes, and with the active cooperation of the Dominions and agricultural interests in this country difficulties were overcome and essential needs met.

In Northern Ireland the flax acreage sown was increased from 20,000 to five times that figure, while Eire also contributed larger quantities. In Great Britain an acreage of 60,000 was reached from a pre-war area of only a few hundred acres. Production here, which was the direct responsibility of the Home Flax Department of the Ministry of Supply, was chiefly of green or " natural " flax, thus avoiding the process of retting, for which both the facilities and experience were lacking. Under this scheme valuable pedigree seed was also produced which played a major part in augmenting acreages elsewhere. The Empire also came to our assistance and there was large-scale introduction and expansion of flax production in Canada, Australia, New Zealand, and Kenya, while larger supplies were obtained from Egypt.

As was to be expected, not all flax produced was of the quality and type to which flax spinners were accustomed, while the use of green flax was an innovation, but the industry tackled these difficulties with adaptability and skill and to a large extent overcame them. How far these new sources of supply can continue to contribute to world requirements of flax once pre-war sources become available is problematical and depends largely on economic factors such as cost of production, &c.

Hemp

All supplies of hemp, which is required for a wide range of cordage and netting items, came

from oversea. So far as was possible, all non-essential uses were eliminated at an early stage, but here also no suitable substitute could be found, and the problems facing the industry were again largely those of supply and adaptation. There are two main types of hemp—hard and soft. Of the hard hemps the most important was manila, which, as the name suggests, was produced almost entirely in the Philippine Islands. The loss of these islands therefore presented a major supply problem to the United Nations and necessitated large-scale substitution by other types.

The type chiefly available was sisal, the chief sources of which were British East Africa and Mexico, as the other main sisal-growing area, the Netherlands East Indies, was also lost. Thus, as compared with a pre-war availability of about 160,000 tons of manila and 270,000 tons of sisal there remained for the use of the United Nations some 122,000 tons of sisal from East Africa, 85,000 tons from Mexico, 27,000 tons from Portuguese East Africa, and relatively unimportant quantities of sisal and other types of hard hemp from smaller sources of supply.

These supplies were allocated by combined planning among the various consuming nations, the chief uses being for binder twine, without which essential food crops would have been lost, and the many types of cordage and rope required for service and essential civil needs where strength and durability were essential factors. Marine cordage was the use for which existing stocks of manila had to be chiefly allocated, where risk of life of personnel or safety of ships were involved.

There are two main types of soft hemps—those coming chiefly from Continental sources (Russia, Italy, and the Balkans) and Indian hemp. These hemps were required for the manufacture of ropes, cords, and twines, for purposes where strength combined with flexibility was required, such as fishing lines and nets. Indian hemp, which was not so strong as the European variety, was used for cheaper types of cords and twines and also for the manufacture of various kinds of paper for the electrical industry, for insulation, and in the manufacture of cigarette paper. Supply here did not present the same difficulty, but the field of usage remained relatively limited owing to its lack of strength, and existing stocks of European hemp, chiefly of the Italian variety, needed strict rationing and careful planning, though supplemented by supplies from Chile. As soon as Italy was liberated active steps were taken to obtain supplies from the south.

Jute

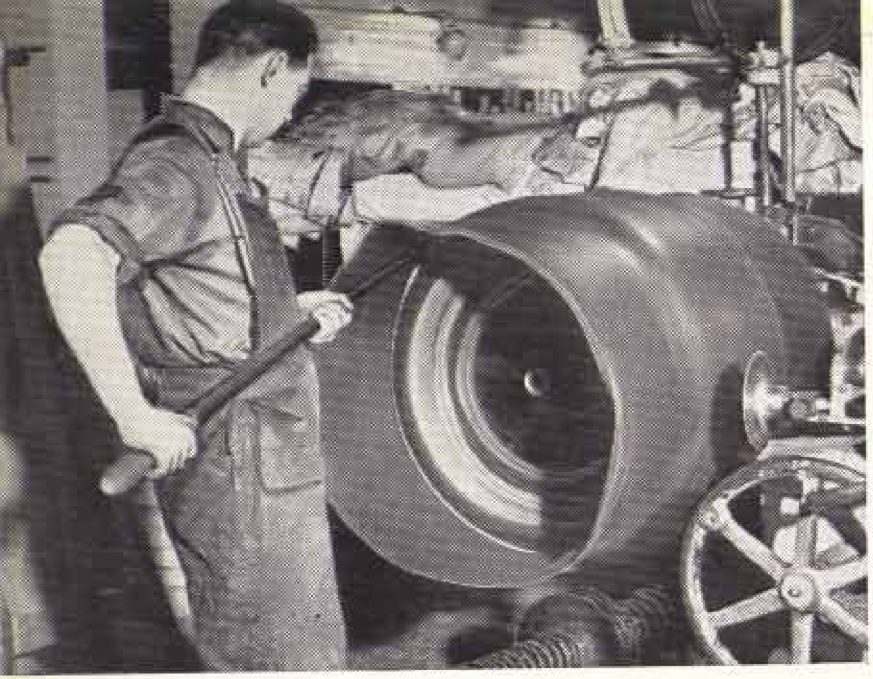
Jute is a fibre produced almost entirely in India, and is used mainly to produce a coarse cloth which provides the principal bagging material of the world for carrying food supplies, fertilizers, and a wide range of vital commodities. It is also used for certain types of cordage where great strength is not essential, for backing carpets and linoleums, and for meeting other industrial purposes. India has a large manufacturing industry and provides the greater part of the world's needs of bagging material or finished bags. The United Kingdom imports both raw jute and finished cloth and bags from India.

During the war there was an increased usage of bags in the United Kingdom, in view of the abnormal food movements and for food storage. In addition there was an increased use of jute for cordage to relieve hemp and of jute cloth to relieve flax. Other war-time demands included cloth for sandbags, for garnishing camouflage nets, and as the basic material for bitumenized cloth for aerodrome runways.

There have always been large variations in the size of the annual crops in India. During the early years of the war there was no shortage of raw jute, but with the loss of Burmese rice to India jute lands had to be turned over to rice, and for a time the overall raw jute supply was difficult. This position has eased and the main problem in India is now the shortage of production due mainly to coal difficulties.

From almost the outset of the war shipping considerations limited United Kingdom supplies and a control of import was instituted. The usage for relatively non-essential purposes, such as carpets and linoleums, was gradually reduced and finally eliminated. Every effort was made to obtain the maximum use of second-hand bags. Owing to labour considerations a greatly increased percentage of total consumption was met in Indian-made goods and production in the United Kingdom fell to below 50 per cent. of its pre-war level.

Certain relaxations in the use of jute for carpets and linoleums have recently been possible, but the increase of supplies to those industries will be dependent not only upon the rate of expansion of the United Kingdom jute industry, but also upon the extent to which the United Kingdom will have to increase its own production for bagging purposes in view of the shortage of production in India and heavy world demands, and on the extent to which jute will have to continue to be used in substitution for sisal and flax.



Vast quantities of new plant had to be installed in factories for the purpose of turning out rubber tyres required for military purposes. Here is a tyre being built up on a flat drum.

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THE RUBBER INDUSTRY

IN the period between the two world wars technological development of the rubber industry was very rapid. Engineers and technicians in other industries learned to appreciate more fully the possibilities of rubber as a material having important properties—adaptability to moulding into complicated shapes, lightness, resilience, comparative chemical inertness, stability, ability to withstand abrasive wear and to endure without fatigue stresses repeated hundreds of millions of times. Simultaneously, the technicians within the rubber industry made great advances in the quality of their products, in design, in process of manufacture. At the outbreak of war in 1939 rubber consumption was at a record high level in the British industry.

It was not surprising, therefore, that when preparations for war began seriously, about 1937-38, rubber found many and vital applications to munitions of war. The urgent stress of war itself produced a great acceleration in these applications, and in the space available in this article it is impossible to do more than mention a few of the more important items among those not still regarded as " secret."

All the well-known implements of war contain rubber in vital parts. Aeroplanes must have rubber tyres, and the industry was called upon for enormous numbers at short notice. But, in addition, rubber is used in the aircraft's gun-firing mechanism, in its electric cables, oil seals, and engine-mountings, fuel tank coverings, and many other parts. Military tanks contain large quantities of rubber in tyres on bogie wheels, in suspension parts, engines, &c. All classes of ships require rubber in great quantities. Amphibious vehicles, road transport vehicles, gun carriages, are among the greatest consumers of rubber.

The rubber industry, mainly through the direct contact of individual companies with the Services and the Production Departments, has originated, or developed at the suggestion of Service or Ministry personnel, a great many ingenious and useful devices. A typical case in point is the well-known airman's " G " suit, which was brought to the attention of one of the largest companies, and which was soon transformed into a practical and easily produced type. Other examples of developments of which the original idea emanated from the Services and the heavy task of adaptation and production fell upon the industry, are rubber wave-breakers, pneumatic lifts for damaged aircraft, enabling crashed aeroplanes to be removed quickly from runways, degaussing equipment in ships, swim-suits for under-water wear, barrage balloons, meteorological balloons, rubber dinghies.

The outbreak of war had great effects on the rubber factories quite apart from these special demands. Staple peace-time lines of production—tyres, belting, hose, footwear—were radically changed in form. For example, in 1942, the production of tyres for passenger cars, including

all military and Government requirements, was only 2.5 per cent. of total tyre production expressed as weight. In 1938 it had been about 40 per cent. Factories had to be laid out afresh with vast quantities of new plant for heavy tyres. Similarly, hose, belting, and footwear underwent great changes in form, to suit the new demand of heavy industry and of the services.

Even in the sphere of large tyre production itself, the types demanded by the services, for bullet resistance, for cross-country and for desert work, differed in important respects from civilian types. They required, in general, more plant, heavier plant, more labour, and more material, even when of similar size.

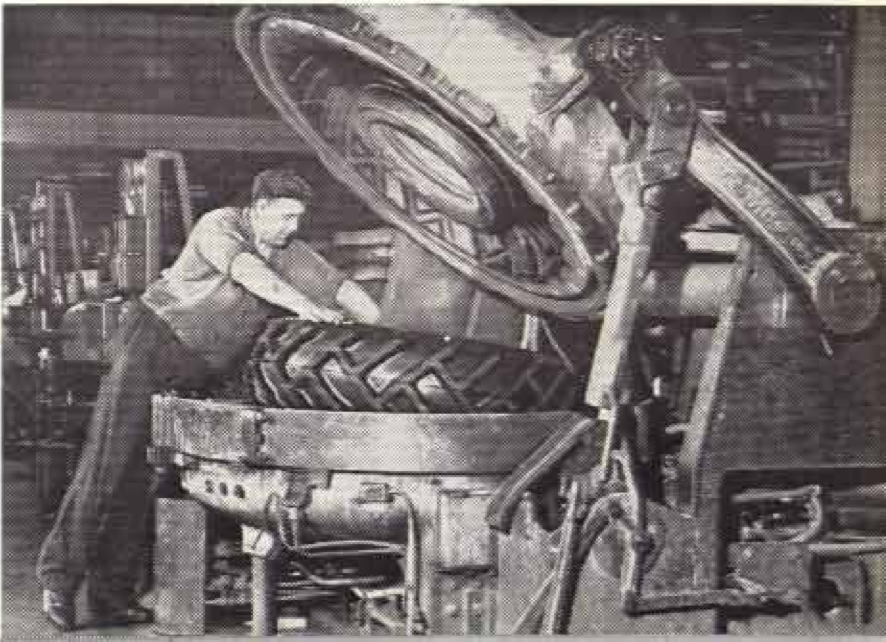
At the beginning of 1942 the industry was faced with the loss of the major part of its crude material producing areas, and immediate reductions in the consumption of rubber had to be made. Very quick decisions were necessarily taken; many goods which up to that time had been manufactured for export, and for the maintenance of the essential life of the community, were discontinued. For example, golf ball and tennis ball manufacture, which had been mainly for export and for the services, and had already been drastically curtailed in 1940 and 1941, was stopped altogether in 1942. Hot-water bottles were restricted to very small quantities for hospital use. Rubber footwear, which had been manufactured on a large scale for industrial, agricultural, and service training purposes, was drastically reduced and production concentrated in one or two factories.

The manufacture of a great many articles previously made with rubber in various forms was prohibited, and in other cases prohibited except under licence. The use of rubber latex for sponge-rubber upholstery, mattresses, elastic thread, and footwear was forbidden except under very restricted licence. Personnel in tanks and aircraft had to dispense with foamed latex protective pads, and less satisfactory substitutes had to be used. The production of tyres was severely curtailed, and in the early months of 1942 the rubber tyre industry lost some 25 to 30 per cent. of its labour force. Towards the end of the year it became apparent that the cuts had been somewhat too heavy, and from that time on special—but largely ineffective—measures were taken to re-man the industry.

The outlook for the rubber industry at that time was indeed very depressing. Supplies of synthetic rubber from the United States were in view, but distantly, and could not be expected until late 1943.

While it is easy to look back and to consider the measures taken in 1942 to have been too drastic it has to be admitted that no crippling effects resulted either on the war effort or on the life of the community.

From the critical days of early 1942 until the spring of 1944, when synthetic rubber began to enter largely into the production of rubber goods in the United Kingdom, the rubber industry tried to maintain production by making use of reclaimed rubber, and by restricting the volume of rubber used in such articles as tyres and conveyor belts. These measures were essential in order to conserve crude rubber supplies, but were stopgap methods and could not have been justified except to bridge the wide gap between the running out of stocks of natural rubber and the arrival in bulk of synthetic rubber. It is well known that the United Nations won through with nothing to spare.



Removing a tractor tyre from the mould in a British factory. Special types of tyre were constructed to resist bullets, and for cross-country and desert work.

Rubber goods, including tyres, gave shorter service but were not unreliable, that is, not subject to accidental failure and sudden collapse. By the provision of more tyres of a lower quality the essential wheels of transport and of industry were kept turning, and it can be said that there was in general no serious effect either on the transport services or on military operations.

The use of synthetic rubber in the rubber factories created a great upheaval. Synthetic rubber differs from the natural product in many important particulars. The type in most general use, made from butadiene and styrene, requires considerably more electric power, more plant of heavy type, and more labour than does natural rubber, to produce the same quantity of finished goods. In many of the more important applications, including tyres and conveyor belts, the "general" type of synthetic rubber is markedly inferior to the natural product. In these goods, under severe conditions, natural rubber itself is strained to the limit.

The use of synthetic rubber in tyres accelerated a development which had been going on gradually for some years before the war—namely, the use of rayon instead of cotton in tyre casings. Rayon, by virtue of its greater tensile strength and its greater resistance to the effects of heat, as compared with cotton, has proved to be essential in large tyres subject to severe conditions of use. The rubber factories, therefore, had not only to change their principal raw material, but also to adapt their processes to the use of rayon in large sizes of tyres.

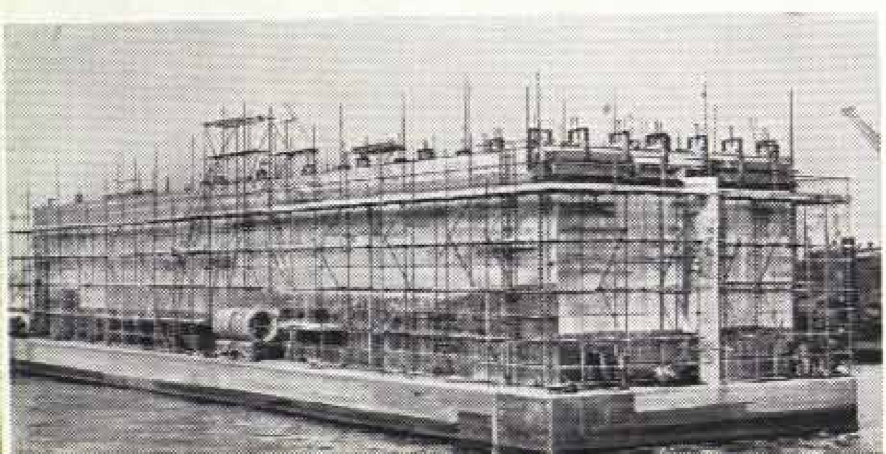
All this had to be done during a period when many important classes of goods were in dangerously short supply. The various units of the industry pooled their information on these problems, and rapid progress was made. In the United States the manufacturers had faced the same problems some months earlier. The industry over there had pooled its information, and it was made available to British industry.

The percentage of synthetic rubber used by the British industry is now 70 per cent. This is lower than the percentage in the United States (85 per cent.), chiefly because of the different constitution of the manufacturing programme. In like products there is very little difference between the two countries' consumption of synthetic rubber.

It is opportune, in reviewing the upheavals and the technical developments of the industry during the war, to consider their probable effects in post-war years.

These effects are, on a broad view, not very remarkable. The new techniques discovered, the new products manufactured, while of immediate and enormous advantage to the job in hand for the war effort, represent no epoch-making change. It is possible to state the case that even more rapid development would have been made towards satisfying the needs of the users of rubber products in an equal period of highly competitive peace-time conditions. Materials available to the rubber industry show no important forward development, except in the case of synthetic rubber of very special types for certain limited uses—*e.g.*, oil resistance.

As in many industries, war conditions have led to certain inefficiencies, due to inexperienced and unsuitable personnel, to black-out conditions, to restrictions in raw materials, and so forth. After a return to peace-time conditions, it will be possible to make up the leeway lost during the war, and those engaged in the industry look forward to the day when they will be free to do their best for the consuming public and for the welfare of the nation as a whole.



The concrete caissons, one of the main elements in the Mulberry Harbours prefabricated for D Day, were among the outstanding war achievements of the building and civil engineering industries. The picture shows one of the caissons under construction.

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ASBESTOS IN WAR-TIME

THE asbestos industry played an important part in the war. From the outset the call-up of millions of men and women for the services necessitated the construction of hundreds of camps. In many of these asbestos-cement provided the roofing, cladding, and soil drainage equipment. Millions of corrugated and flat sheets were turned out by factories scattered throughout the United Kingdom, together with a multitude of fitments and pipes of all sizes. The black-out also caused a heavy demand for these sheets.

With the blitz came a further huge demand for asbestos sheeting and equipment for anti-aircraft gun sites, hospitals, and for various purposes in place of glass and timber. For the development of over 300 aerodrome sites, 20 ordnance factories, and a number of industrial estates the "quaker grey" of the natural asbestos-cement product had to be camouflaged and the industry was required to work to maximum capacity and to maintain this output throughout the war. There was the constant need of industrial hutments and buildings for miscellaneous purposes, of which no fewer than 58,344 are known to have been erected and covered with asbestos-cement. In fact, many of them were constructed entirely of this material, either by using curved sheets or by constructing roof principals, rafters, and purlins from asbestos-cement pressure pipes.

Nursery schools, colliery canteens, and British Restaurants used up large quantities of asbestos-cement, and vast stacks of flat and corrugated sheets were located all over the country in a co-ordinated emergency scheme for the temporary repair of blitzed factories, shops, and houses.

To all these demands the workers in the industry responded nobly, as well as to many others put upon them as the war progressed and new applications of asbestos-cement were developed. Thousands of asbestos-cement pressure pipes were used to carry water during the advance from Alamein to Tunis. These non-magnetic pipes were also used for the housing of delicate electrical instruments which had to be sunk into the ground. The National Fire Service used large quantities of such pipes in their fight against incendiary bombs. Carried about in large and specially constructed vehicles they were rushed to incidents, coupled and pegged to the ground; several hundreds of yards of piping could be assembled in a short space of time, even in the black-out, and much valuable property was saved by their means, especially in rural areas. Asbestos-cement tanks, too, were used for storage of static water. Asbestos wood also gave great help to the provision of furniture, especially such items as cabinets and lockers, where its fire-proof quality proved valuable. Miles of asbestos-cement shelves and thousands of lockers hold the wares in various classes of trade buildings all over the country, including in at least one instance the parts of motor-cars that had to be surrendered temporarily to the police.

One of the uses for asbestos textiles has been for R.A.F. fire-fighting suits, as seen in this picture. This material is also used for parachute flare hoods, aero-engine muffs, &c.

Special black-out ventilators for air-raid shelters; bafflers and cowls for gas stoves; large hoppers weighing nearly 15cwt. and moulded in one piece for placing over the funnels of locomotives when starting up in engine-sheds; door fascias and moulded canopies for bay windows and doors—these are some of the many uses to

which asbestos-cement has been put in war-time, and the industry has had the opportunity of research and application in a far wider field than would have been possible in peace.

Factories concerned with asbestos textiles, engine packings, jointings, belting, and brake and clutch linings were almost entirely occupied on production directly connected with the war effort.

In the case of naval equipment, there were many vital uses for asbestos, such as the extensive employment of asbestos cloth as a covering for all kinds of boiler insulation, and its use in connexion with splinter protection for warships and merchantmen. Asbestos fibre was used for special insulation both in the Arctic and the tropics. In the Arctic it made the living conditions of our naval and merchant seamen tolerable by the exclusion of excessive cold. In tropical seas it proved valuable not only in tempering excessive heat transmitted by metal surfaces, but also in arresting condensation. Moreover, being of inorganic substance, asbestos is inert and repellant to the attack of bacteria and other incursions which, if encouraged, would rapidly attack equipment, bedding, food, and other stores. Another quite distinct use of asbestos on the marine side of the war effort derives from the extensive use of electric welding in ship construction, which has made great demands on asbestos-covered electrodes.

Typical uses of asbestos textiles in air warfare were R.A.F. fire-fighting suits, parachute flare hoods for Pathfinder planes, aero-engine muffs and cover linings, and the insulation of aeroplane bulkheads.

In Army equipment there were many technical uses for asbestos, of which the most obvious is its employment in brake and clutch linings for tanks, armoured vehicles, and cars of all descriptions. Accumulated experience and research work provided an immediate solution to many problems which arose as new weapons of war were developed. For D Day, for example, brake linings were required which would operate successfully in sea water as well as on land. One firm supplied vast quantities of these in less than three weeks from the first intimation of the problem by the Ministry of Supply.

Special asbestos plastic mouldings were also supplied for various purposes, especially in the form of non-metallic bushes or bearings for the springing of gun-carriages or amphibious vehicles, and in the mountings of aircraft engines or power-operated gun-turrets. Similar bearings facilitated the manufacture of penicillin.

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CEMENT FOR WAR PURPOSES

IN order to present in a few words a picture of the cement industry's contribution to the war effort it is necessary to indicate briefly some features peculiar to the manufacture, distribution, and use of cement, and the policy pursued by the industry in pre-war days which alone made possible its ability to fulfil all demands made upon it during the war.

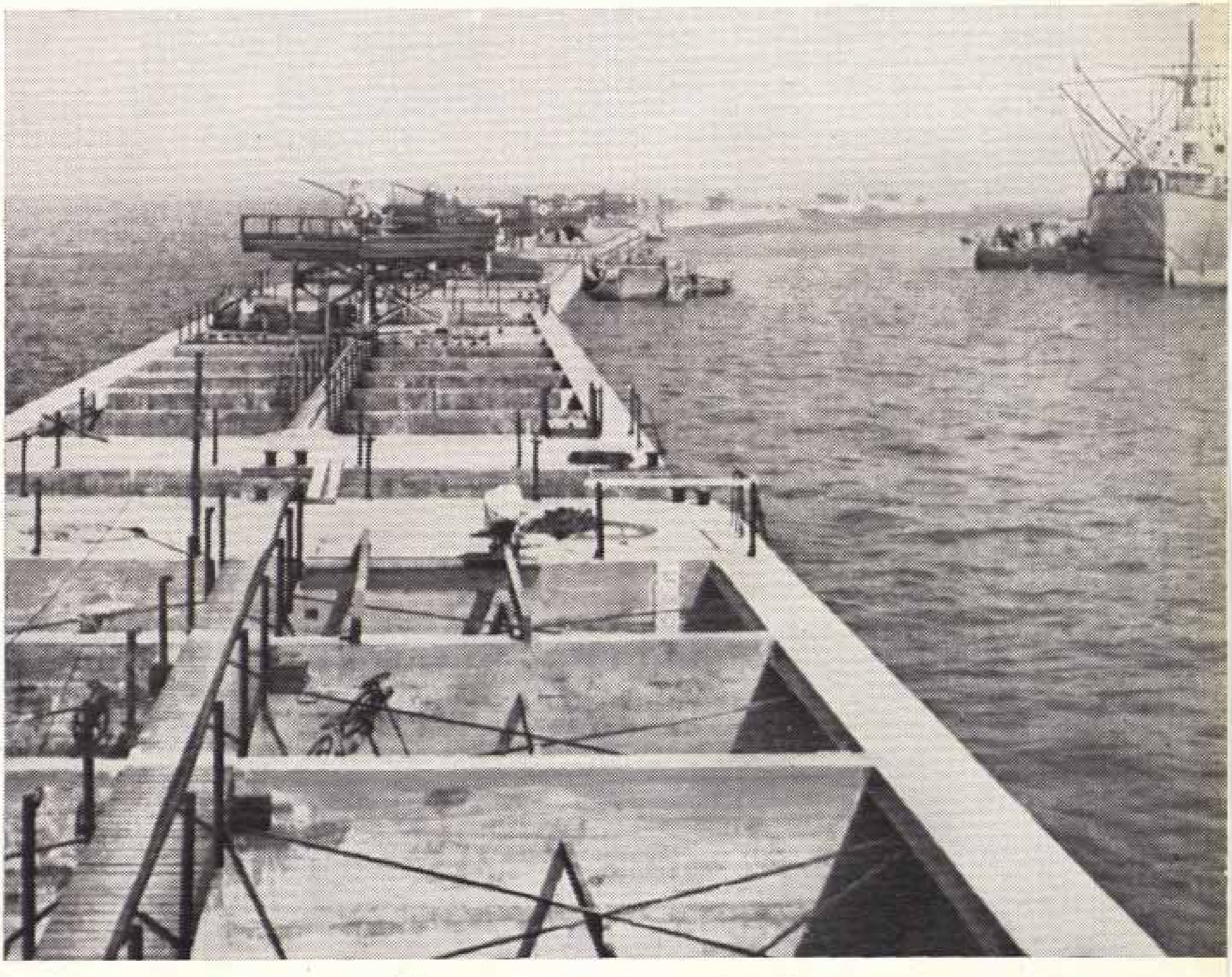
Cement is manufactured by large and expensive units of continuous process plant, from which it follows that the prosperity of the industry is largely dependent on the extent to which this plant can be kept fully employed. It must be appreciated also that while cement plays an essential part in practically all forms of building and constructional work it represents a very small proportion indeed of the cost of any such work, and it has the peculiarity of being virtually useless by itself, being in effect used only in conjunction with other materials to form concrete.

The cement industry has for many years been organized within the Cement Makers' Federation, which since 1934 has represented the entire industry in this country. In order that everything possible might be done to enhance efficiency, to achieve the utmost economy in production, marketing, and distribution, to increase the use and uses of cement, and, above all, to ensure as far as possible that the resultant concrete should be used to the best possible advantage physically, mechanically, and aesthetically, the industry in 1934 set up the Cement and Concrete Association as a non-profit-making body with a large staff of experts to advise on all aspects of the proper use of cement and concrete, and to undertake research and propaganda.

Being thus organized, the industry was able to follow in the pre-war years a clearly defined policy of keeping capacity always ahead of demand, of increasing production, of improving the quality of the product, of reducing costs, and of passing on such reductions to the consumer, relying for its profit on greater manufacturing efficiency and on a small margin per ton on the increasing tonnage. During this period wages and conditions of labour were materially and steadily improved, while at the same time a satisfactory return was made on the capital involved. Perhaps the most important and

significant feature of the five years before the war was the scrapping of obsolete and uneconomic plants with an annual capacity of less than 125,000 tons, and the replacement thereof by efficient modern plants with a capacity of no less than 2,250,000 tons. As a result of this policy 1939 found the cement industry in a highly efficient state, with a man-hour production at least equal to, if not in excess of, that of any other country in the world.

In one sense the cement industry's war effort can be said to have started in 1938, when the armament shadow factories and other defence works were being rapidly constructed. As soon as the war broke out, the industry appointed a small War Executive Committee of three to act for it in every way in which it could cooperate with the Government, and the committee's first act was to inform the Government that no matter what the demand for cement might be it was not the desire nor the intention of the industry to increase its pre-war profits so long as the war lasted. The cement industry was operated throughout the war period in con-



Big concrete caissons forming a main deep-water breakwater for one of the artificial ports on the French coast that solved the enormous problem of providing vital supplies for the forces in the invasion of Europe. Some 20,000 workers were mobilized for the construction of these caissons alone.

junction with the Government by means of a voluntary control, and was able fully to meet every demand made upon it and to maintain in addition a moderate export trade. A large part of the expert staff of the Cement and Concrete Association was lent to the Research and Experiments Department of the Ministry of Home Security.

After Dunkirk many measures had of necessity to be taken to safeguard the position, since nearly half the entire cement industry is located in the Thames and Medway area. Plans were made to ensure that distribution could be maintained in the event of works in that area being put out of action. Happily, however, the damage done to cement works during the war was comparatively small. At no time was there a shortage of cement and in all the circumstances there was surprisingly little delay in distribution even at the worst periods.

Many special problems arose from time to time and many things had to be done and unusual costs incurred in the interest of the nation and under the direction of the Government, which would be neither necessary nor economic under peace-time conditions. The well-planned organization of the industry enabled it readily to agree to the suggestion of the Ministry of Works that these exceptional war costs should be spread over the industry as a whole by means of a scheme which, while giving effect to the limitation of profits referred to above, would pool such excess costs on an equitable basis, and enable a normal economic level of prices throughout the country to be maintained.

Cement naturally played its part in every form of construction, both in defence and attack, from the early shadow factories to the great airfield runways and the mighty floating harbours used for the invasion of Normandy. It is a story of which the cement industry is proud. It now stands ready to deal with all peace-time demands.

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PAINT, VARNISH, COLOURS, AND COATINGS

THE key to an understanding of the problems of the British paint industry is that materials are the largest item in the cost of its product, and that most of these materials have to be imported. As much as 70 per cent. of production cost and 50 per cent. of selling price is represented by materials.

Dependence on foreign materials led to a concentration of the industry round ports, and particularly in East London. These factors were the danger points of the situation which

confronted the industry in 1940. Enemy submarines threatened to cut off the trade's imported materials; enemy bombers threatened to make London and the great ports untenable for production.

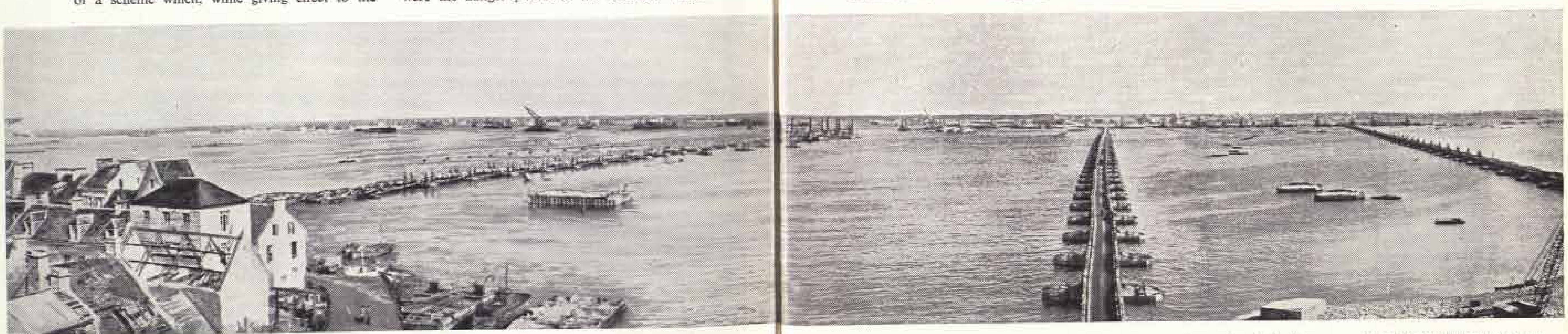
The German blockade never completely cut off supplies of materials, which dribbled in from the four corners of the earth; but no paint manufacturer knew from one month to another just what he was going to get. While production managers kept the machines running under roofs being repaired after the previous night's raid and stimulated workers tired after nights in the shelter, the chemists, just as tired from the same cause, had to work against time to adapt their formulations to constantly changing materials.

The Ministry of Supply, being largely reponsible for raw materials, formed groups of manufacturers to make certain products, with a view to dispersal of the units of the groups as a protection against damage from air raids and to the most efficient use of the raw materials available.

The war has at any rate taught the British paint industry the importance of the chemist and of research. There will be no return to the salary-level of pre-war days, when the value placed by many manufacturers on their chemists might be gathered from advertisements of posts carrying as little as £300 a year. To-day a competent paint chemist can command a salary around £800, and it is not grudged. A deficiency of good chemists is the paint industry's chief present problem. During the war it has lost too many to Government departments and other industries. So well persuaded is the industry of the importance of the chemist in any scheme for its expansion that in the middle of the war the professional body—the Oil and Colour Chemists' Association—formulated proposals for training the new generation of chemists.

The industry is equally convinced of the need for intensifying its research. Any paint manufacturer will admit that the American industry has, in technical development, made good use of its advantages during the past few years. From a close study made of these developments the trade has presented a memorandum to the Government departments concerned, asking for early facilities to import experimental and manufacturing quantities of the synthetics introduced in the United States during the last few years. Long before the world's immediate need of paint products nears satisfaction British chemists ought to have been able to learn all that America can teach.

Research in paint technology was not forgone during the war, but it had to be channelled into directions immediately useful to the war effort, and it had also to be kept secret. Most of this work was done either in the laboratories of the largest paint firms or by the Paint Research Station at Teddington, which is collectively financed,



"MULBERRY"—The prefabricated port at Arromanches, Normandy, one of the most imaginative pieces of war engineering in history. Pier roadways are seen running out to pierheads forming a wharf; in the centre distance is a breakwater of caissons and blockships; and in the distance on the left and right are caisson breakwaters. The two ports, each as big as Gibraltar, were manufactured in Britain in sections and towed across the Channel. The worst June gale experienced for 40 years caught the harbours at the half-way stage. The American harbour suffered most severely and work on it had to be discontinued. The British harbour, seen above, suffered less damage, and was completed. By means of it hundreds of thousands of tons of vital supplies were landed.

with the aid of a Government grant, by a large part of the industry. A new programme—a long and most specific document—has been drawn up by the association responsible for the work of this station and, on the strength of it, the annual income of the station has been raised to £40,000.

It is still not possible to disclose all the achievements of the British paint industry during the war. One or two developments only can be mentioned.

Special paints were developed to camouflage land surrounding airfields to simulate ploughed fields, roads and hedges. At first a low-pigmented emulsion of light fuel oil was used, but this was later replaced by a pigmented aqueous ammonium oleate solution.

The formulation of aircraft finishes is typical of the problems the technical side of the industry has been faced with in the last few years. The finish has to withstand sea-water spray and desert sand. It is at one moment in tropical heat and an hour or two later covered with ice; it may be at 10,000ft. or 30,000ft. up. It must not weigh more than a given weight per square foot so as not to over-load the machine; it must " stay put " at over 400 miles an hour. Its surface must be such as to present the least friction to the air. The surface may make a difference of 10 miles an hour in speed—sometimes a matter of life and death.

New aircraft finishes demanding the very highest qualities of materials, grinding, and finish have been evolved, and it is for this purpose that the urea- and melamine-formaldehyde type of finish has been so largely developed. But one of the chief uses of urea-formaldehyde has been for the manufacture of petrol-resistant red-oxide coatings for the interiors of jerricans.

Modified phenolic resins—home-produced synthetic resins—have replaced very satisfactorily for many purposes the tung oil once imported from China.

Oils " tailored " for specific industrial purposes have been derived from fractions of natural oils, such as linseed oil, by fractionation processes designed to produce many oils of specific nature and purpose from a single general-purpose oil.

Fluorescent dye markers have been supplied to pilots who are forced to bale out over sea. The dye spreads a patch of yellow on the surface of the sea visible from a great distance by searching patrol craft. The same dye was pumped in solution through the Pluto cross-Channel pipeline to enable breaks and leaks to be detected.

These, however, are only a few, and not the most important, of the technical war-time achievements of the industry at a time when the erratic supply of even the commonest materials of the industry made every month's formulations a challenge to innovation and ingenuity.

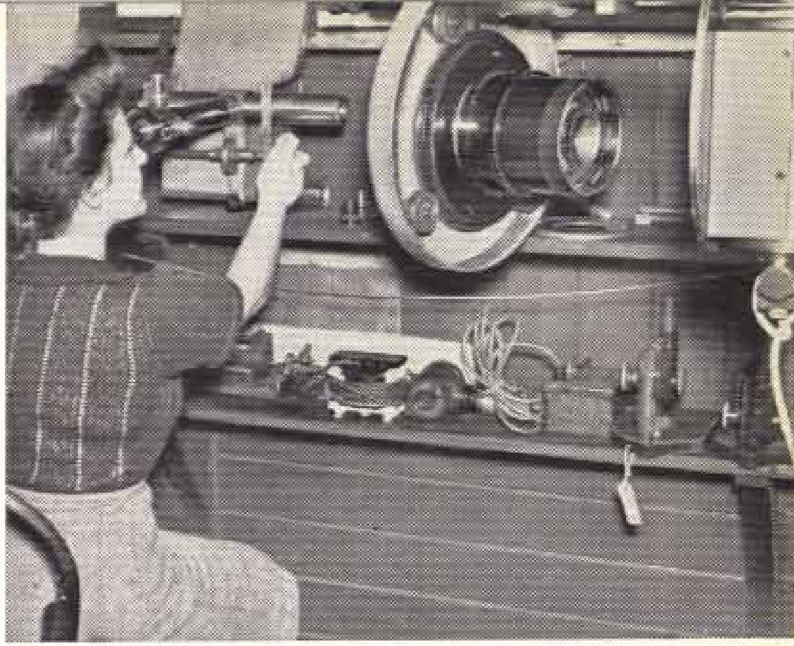
The manufacture of paint for civilian purposes practically ceased during the war, and it will be some time before it is again in free supply. The only big users have been the Admiralty, the Ministry of Supply, and the Ministry of Aircraft Production and their various contractors.

The paint industry has emerged from the war with its rather peculiar internal structure apparently unaltered. It is still a trade in which five great public companies, some 200 medium-sized firms, and about 300 small family businesses (handling only 11 per cent. of the output) can all survive and make profits.

The optimum size of the production unit in the paint industry will probably be worked out by the competition of rival research teams. Although the high cost of research favours the big firms, it does not necessarily doom the small one to extinction; not only has it the benefits of collective research by a state-aided station but it will also enjoy automatically the fruits of research undertaken by the great oilseed and oil, resin and colour firms.

The industry has no intention of allowing the urgency of the task of renovating and reconstructing Britain's shattered buildings to distract it from the opportunities of the export trade. There are many good reasons for the interest taken in foreign trade by every British paint firm, from the largest to the smallest. Before the war the trade exported no less than 16 per cent. of its products and even in war-time exports were maintained on a high and creditable scale, each market receiving its " ration " based on pre-war consumption.

It is well realized that the type of products to be exported may undergo a change. There is no disposition to challenge the right of other countries to maintain their own paint and distemper industries built up in the years when it was not possible for this country to supply their needs. The large companies are preparing, by means of new oversea companies and affiliations with oversea firms, to provide finance, advice and patent information and rights to help to establish paint industries abroad. Both large and small firms realize, too, that the best export market for paints and industrial finishes will be in speciality products giving a better performance than any other obtainable.



True optical glass is a product which is required for many war purposes. Left : One of the processes in the manufacture of optical glass. It shows blocks of glass being chipped into smaller pieces, free from flaws. Right : Making final tests of a long-focus aerial reconnaissance lens.

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BRITISH GLASS IN MANY FORMS

BETWEEN the two wars progress in equipment and in the technical control of processes in glass-making in this country has been so thorough-going that the industry was fully capable of tackling any problem given reasonable facilities for acquiring essential raw materials, labour, and machinery; and it has certainly demonstrated during the war period its power to meet difficult conditions by adaptability and ingenuity.

Of the imported raw materials sand was before the war the most important. About one half of the 750,000 tons required annually, including all the purest, came from abroad : from France, Holland, Germany, and Belgium. Immediately on the outbreak of war both committees and individual technical experts in the industry systematically combed the country. From the neighbourhood of remote Loch Aline, on the Sound of Mull, a sand was obtained by mining which, after treatments worked out initially by research laboratories, yielded a material purer than the best ever supplied from the Continent ; and by the end of 1944 120,000 tons of Loch Aline sand had been dispatched to the far-away glass factories. The quarries at King's Lynn also raised their output of chemically treated and of water-washed sand from a weekly average of 1,800 tons in 1939 to 3,900 tons in the peak war period. Important sources of supply were also developed at Fairlight and Reigate, and minor ones elsewhere.

All glasses made for binoculars, naval range finders, microscopes, and the finest cameras must be of supreme quality. The telephoto lenses of cameras attached to reconnaissance aircraft contain components of considerable total glass thickness. In one very fine British telephoto lens two of the components are each 3lb. in weight ; so that in order to obtain photographs with sharpness of detail the glass used must have great clarity and light transmission. Clear spectacle glass or very fine commercial crystal glass would be useless. True optical glass requires for its manufacture the purest of raw materials, melting crucibles especially resistant to corrosion (even platinum is now used for some glasses), and elaborate stirring of the molten glass for many hours ; while the inspection is so severe that after being thus made the major part of the glass may be rejected.

At the outbreak of war two British firms were making optical glass. The larger producer, with nearly a century's reputation in this field, was making more than 100 varieties. It stepped up its own output and, based on its experience, a dispersal factory, with approximately equal production, was erected. Moreover, when bombing became severe, it made arrangements for a fac-

tory to be set up in Canada and assisted in the general planning and in the training of personnel. This fine new factory has supplied not only substantial Canadian needs but also in the earlier war years helped to meet United States requirements. The sale of fine optical glass made in Great Britain in the peak war year was nearly seven times that in 1936. Large quantities were supplied to India, Australia, and China, as well as to the United States and Canada. In addition a special process was worked out for making the large quantity of optical glass needed for tank periscopes—a process which avoided the need for two additional optical glass plants.

Of the manifold other uses for glass during the war, there is space only to quote a few. Vast quantities of sheet and wired glass were needed for the huts and buildings for naval, military, and air force establishments, and for the new armament factories and depôts. Huge demands arose for making bombed houses habitable and for restoring greenhouses used for food production. When all possible sheet drawing plant had been pressed into service and remained inadequate, machinery was adapted to produce a rolled substitute for sheet glass which added many millions of square feet per annum to the total.

For powder factory works many thousands of explosion-proof glass lighting fittings were supplied capable of withstanding pressures of 150lb. per sq. inch, which, in the case of units 15in. in diameter, meant a total load of 12 tons. Moreover, the glass had to be of such heat-shock resistance as to withstand, when in running operation, being hosed down by cold water. A special glass refractor with a very wide light spread was designed for the engine rooms of aeroplane-carriers. Special lighthouses lit up aerodromes, and many thousands of contact light fittings, capable of withstanding a load of 15 tons per square foot, were let into the sides of runways giving light to facilitate landings of aeroplanes at night and in misty weather. Lenses with a red filter, giving a fan of light at 5deg. above the horizontal, were first used in France to facilitate the safe landing of gliders on D Day. Among various other forms of glass associated with aeroplane navigation was one transmitting only ultra-violet light, which, in conjunction with fluorescent paint, illuminated the instrument panels.

At one stage of the war many hundreds of thousands of sticky bombs were made with which to attack tanks, the explosive charge being placed in a specially designed spherical glass container. Some 150,000 bullet-resisting panels, consisting of five layers of selected plate glass with four thin plastic interlayers, were used to give protection in fighter aeroplanes; while hundreds of thousands of windows, made on a similar multiply principle, were supplied for tanks. Many millions of square feet of laminated glass were manufactured, being used for goggles, by the million, for army respirators and airmen's goggles. Other goggle glasses with special heat and light absorption properties gave protection to airmen flying under special conditions, as in the tropics; and half a million goggle glasses to give protection to acetylene welders have been supplied.

Toughened (armour-plate) glass screens of great mechanical strength were used in blast-proof hoods in gun turrets and to give protection to instruments, to searchlight emplacements, and to personnel against blast and heavy weather in naval vessels.

Glass fibre, drawn originally in filaments finer than the finest silk, had a host of uses; for air filtration in gas cleansing stations, aircraft factories above and below ground, and vehicles operating in the desert; for heat-insulating panels attached to the hulls of ships, making living conditions tolerable, either in the tropics or in the Arctic; for lagging the many miles of service pipes in R.A.F. stations and Royal Ordnance depôts; for several million insulation slabs in food containers used in battle areas. It was applied to silence noise within aircraft. Over 30,000,000 yards of glass tape and 500,000 square yards of woven glass cloth were employed for electrical insulation. Black-dyed glass cloth was used to shade the upward glare from parachute flares. Glass fibre is unaffected by the hot and humid atmosphere of the tropics, and white ants will not eat it. Accordingly, petrol lighter wick and even bootlaces have been made from it.

Radio valves and similar devices made from glass and metal combinations, in 1,500 varieties, and ranging in size from an acorn up to 44½in. in length and 11¾in. in diameter, have been supplied during the war to the extent of more than 130,000,000. In the peak year of the war the production of glass bulbs for electric lamps and radio valves probably reached 200,000,000; while the glass tubing of various kinds and diameters probably exceeded 100,000 miles.

The number of varieties of electric lamps made for all purposes is too large to be estimated with certainty; but the three services alone had more than 2,000 reference numbers for lamps in common use. Of these, the smallest which have been

on active service—namely, sextant and astrograph lamps—have a bulb only one-fifth of an inch in diameter, while the largest filament lamps were probably those used in aerodrome floodlights. They were of hard glass and the spherical part of the bulb was about a foot in diameter.

In regard to glass tubing, apart from its uses in all kinds of lamps and valves, it provided the basis for innumerable articles, such as thermometers of all kinds; many forms, simple and complex, of scientific apparatus; and hundreds of millions of ampoules for medical supplies and for military control purposes.

Glass pipe lines and large-scale condensing towers and coolers have replaced metal and other materials in a number of chemical factories. The production and use of fused silica glass have greatly expanded for many objects large and small, where very great heat, chemical or electrical resistance were needed. The cultivation of penicillin has called for hundreds of thousands of flasks and huge quantities of vials made from chemically inactive glasses; while blood transfusion for the services has required 3,500,000 special bottles.

Upwards of 5,000,000 bottles have been supplied for holding vaccines and sera. The glass bottle industry, in spite of labour shortage, maintained an annual output of 15,500,000 gross of bottles throughout the war years, 3,500,000 gross being for medicines and drugs, nearly 1,000,000 gross for milk, and 8,000,000 to 9,000,000 gross for other foodstuffs.

Under the stress of necessity, even the high pre-war rates of automatic machine-drawing of sheet glass, rolling of plate and blowing of bottles were exceeded by 20 to 33 per cent., and the furnaces, operating continuously day and night, were run for longer periods than in pre-war years, not infrequently for two years. Two processes were developed for drawing glass tubing of precise internal and external diameters.

The manufacture of "white" spectacle plate, all of which had been imported before the war, mainly from Germany, was undertaken with such thoroughness that the annual deliveries to the spectacle makers averaged 20,000,000 circles and 4,500,000 squares.

Improvements in the pressing of glass to give high surface finish enabled prisms for aerodrome lighthouses to be pressed with a light distribution efficiency of 90 per cent. of that of the pre-war optically polished type. New and more stringent specifications of dimensions, of strength, and of light transmission were accepted for thousands of articles, whether machine or hand made. Thus the hand-made, cone-shaped cathode-ray tubes, of which some millions were supplied for television purposes, had to be made to such close specifications of diameter, wall-thickness, freedom from bubble, and pressure-resistance,

A large mercury rectifier for the conversion of electricity from alternating to direct current. This is an example of the highly specialized use of glass in the electrical industry.

that for quite a period the rejections in some factories greatly outnumbered those accepted.

Similarly in grinding and polishing processes, grindings to 1/1,000th inch have been common on a certain electric insulator; and all-glass hypodermic syringes have been produced in many thousands a week with barrel and piston ground to 1/10,000th inch. The precision grinding and high polish now attained in British plate glass made that material ideal for moulding Perspex parts for aircraft and for standard-levelling plates in tool setting. Gap and plug gauges in glass were quietly developed in England two years before publicity was given to similar American developments.

There were some peace-time products the manufacture of which was interrupted, but they were not numerous. They included Vitrolite and glassware decorated by cutting, engraving, sand-blasting and acid etching. The Board of Trade order which resulted in the closing down or

telescoping of pottery works and certain other businesses had little effect on the glass industry save that glass cutters and decorators for whom essential war work could not be found were directed to other occupations. Their number would scarcely be one per cent. of the total employment roll of the industry. The firms making decorated and "luxury" glassware in peace-time found ready employment for their furnaces in producing technical and utilitarian glassware. One such firm relinquished its high-class domestic glass-ware trade in 1939 and undertook with great success the manufacture of high priority glasses made to stringent specifications.

No account, however brief, of the glass industry's war effort is complete without mention of two things: First, that quite a number of firms equipped with automatic machinery put part of their engineering equipment at the Government's disposal for the machining of shells and aero engine parts and for salvage work on wrecked aeroplanes; secondly, that good will and co-operation were marked features of the relationship between firms in the industry.

The post-war prospects of the industry are good. In the manufacture of drawn sheet, bottles, electric light bulbs, and safety glass, both laminated and heat-treated, this country in its machine-equipment and methods compared favourably with any in Europe before the war; while in methods of polished plate production it led the world. We are likely to remain self-sufficient in all these products, and in optical, chemical, heat-resisting, and electrical glasses, in radio and allied glassware and in fibre glass and its products; while a number of developments, held up by the war, such as fluorescent lighting and the manufacture of cheap, yet presentable, domestic glassware by automatic machinery will go forward.

In regard to export, it is known that heavy demands exist oversea for all kinds of glassware, constructional, technical, and domestic. The large Continental pre-war producers, Germany, France, Czechoslovakia, and Italy, must inevitably take time to recover. Japan, a big producer, must be counted out, and the U.S.S.R., by 1938 the largest European producer of heavy glass, has probably had its facilities impaired by the ravages of war. There have been some developments in glass-making during the war in South America, South Africa, and India, and further expansion is envisaged. But for some time to come heavy demands both in the home market and for export will continue to confront the United States and Gt. Britain.

Two examples showing the application of glass to meet the demands of war are seen above. Left: Grinding prismatic lenses for aerial beacons. Right: The sticky bomb, the body of which is comprised of a glass flask.

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POTTERY AND CERAMICS

DURING the past six years, besides supplying hundreds of millions of cups, saucers, and other crockery to the armed forces, British Restaurants, and factory canteens, the British pottery industry has produced a wide range of highly specialized ceramic wares directly essential to the war effort, including laboratory porcelain, porous diaphragms and electrolytic cells, filtering media, sparking plugs, acid-proof chemical stoneware, porcelain insulators, and many special items to replace plant or accessories formerly made in metal, rubber, and other materials in short supply.

In addition, there was a tremendous demand for humbler but no less essential clay products, such as bricks, tiles, sanitary fittings, drainpipes, and conduits—all of which were required in vast quantities for the construction of war factories, camps, aerodromes, hospitals, and other buildings. Refractories, which also form a section of the ceramic industry, are dealt with in the following chapter.

In relation to output, the laboratory porcelain section is probably the smallest in the industry. None the less, it is of vital importance to the British scientists and technicians, and the manufacture of chemical porcelain has been well described as a " master key industry."

To the research work carried out in numerous laboratories in Great Britain and allied countries we owe the development of new explosives, chemicals, and drugs, as well as important discoveries in many other fields. Such research, in turn, depends to a great extent on the availability of high-grade chemical porcelain crucibles, dishes, beakers, combustion boats, funnels, and many other types of equipment. The ware has to withstand chemical corrosion, high temperatures, and thermal shock, and its manufacture calls for exact control of materials and processing at every stage.

Even at the time of the Franco-German war Germany realized the increasingly important part science would play in future conflicts and planned a monopoly of scientific instruments and laboratory equipment. In this she virtually succeeded, and 1915 found Great Britain in a critical situation so far as scientific research was concerned. Stocks of German laboratory porcelain were nearing exhaustion and the manufacture of similar ware in this country had never been officially encouraged. Two famous British pottery firms saved the situation then by producing, in a few months, a sufficiently reliable ware to enable the work of scientists to proceed. Since that time they have maintained the manufacture of this essential product, improved its quality, and during this war have been able to meet the most exacting requirements. Moreover, the export of laboratory porcelain to allied countries and the Dominions greatly increased during the war.

Other technical porcelain wares which have been in demand during the last six years include porcelain formers for rubber gloves used by doctors and nurses ; special parts used in making parachutes, webbing equipment, medical sutures ; and synthetic threads for rubber tyres. Another specialized branch of the industry has been the manufacture of ceramic sparking plugs upon which the efficiency of all the many types of internal-combustion engines used in the prosecution of the war so largely depended.

The outstanding characteristic of chemical stoneware is its resistance to all acids and other corrosives, with the exception of hydrofluoric acid and hot, strong caustic alkalis. During recent years the mechanical strength of chemical stoneware and its resistance to thermal shock have been enormously improved, with the result that this ceramic material has been used to replace certain types of equipment formerly designed and made in metals. It must be emphasized, however, that besides such uses as an alternative material there is a wide sphere of applications in which chemical stoneware is the only feasible material, because of its resistance to corrosion. The fact that the material can be made by several different processes, including throwing on the potter's wheel, moulding, casting, pressing and extruding, permits considerable flexibility in design. Another advantage is that stoneware pipes, valves, impellers, and similar equipment can be precision-ground to exact measurements, as, for example, when vacuum-tight joints are required.

The following is a very small selection from the many hundreds of essential war-time products in the manufacture of which chemical stoneware has played a part :—

Explosives: Cordite, fulminates, guncotton, pentonite, picric, R.D.X., and T.N.T.

Acids: Acetic, formic, hydrochloric, nitric, phosphoric, and sulphuric.

Chemicals and Drugs, &c.: Aspirin, anti-gas bleach ointment, bismuth, bromine, chlorine, chloroform, D.D.T., ethyl chloride, hydrogen peroxide, insulin,

The British pottery industry produced hundreds of millions of cups, saucers, and other crockery during the war for the services and factory canteens. Some of the utility crockery is seen in production.

iodine, M. & B. drugs, mepacrine, penicillin, sulphanilamide, potassium, selenium.

Other Products: Photographic emulsions, plastics, synthetic and reclaimed rubber, soap, synthetic oil, textiles, titanium, thorium, and tungsten.

The range of equipment supplied by British chemical stoneware manufacturers includes pipelines, cocks, valves, pumps, tanks, mixing pans, storage vessels, transport jars, absorption and scrubbing towers, vacuum and pressure filters, fans, nitrating pans, &c. Other applications of stoneware were practice bombs, electric kettles, and rings for electric heaters.

Many millions of stoneware containers, such as N.A.A.F.I. jars, rum jars, A.R.P. food and water containers, mugs, beakers, and foot warmers, were also supplied.

Throughout the years of war it was imperative to maintain uninterrupted communications by radio, telephone, and cable for planning combined operations, for coordinating the efforts of the United Nations, and for speeding supplies from the factories to the various fronts. In these spheres, as in important new developments, such as radiolocation, electrical porcelain insulators of many different types and sizes were an indispensable component. Without an assured supply of insulators the distribution of electricity for lighting, heating, and cooking in homes, factories, and canteens could not have been maintained, and the transport services—electric railways, trams, and trolley-buses—would have broken down.

The number of porcelain insulators produced by British potters for these and similar purposes ran into hundreds of millions, and there was also an immense export demand to be met at the same time.

Large numbers of porous ceramic filters were needed for water purification, especially for use in tropical or undeveloped countries, where the risk of water-borne infections was a constant menace. Similar porous media were used in the chemical, pharmaceutical and food industries for many different purposes.

A well-known British pottery firm designed a special dechromator, embodying a porous ceramic diaphragm, which greatly lengthened the period of service of chromium plating solutions—a most valuable contribution to the war effort in view of

the serious shortage of chromic acid. Filter tubes for aircraft rate-of-climb indicators were another important war-time development.

In addition to all these activities, domestic requirements for crockery had to be met. Some 100,000,000 cups and saucers are estimated to be broken in British households every year. The only way such a demand could be met, without prejudicing supplies to the services, was to limit production to plain, undecorated crockery, and even then inevitable shortages arose. Such decorative wares as were still permitted under official regulations were reserved for a few export markets which had always looked to Great Britain as a main source of supply. In the first two years of the war, in particular, the pottery industry made a very important contribution to exchange funds by actually increasing the value of exports by some £2,000,000.

The war-time record of the British pottery industry is all the more remarkable when it is borne in mind that these results were accomplished with a labour force reduced to less than half the pre-war figure and in face of great difficulties created by restrictions in the use of coal, gas, and electricity, on which the pottery manufacturers depend for firing their kilns. Much of the solid fuel available has been of inferior quality.

On the other hand, the industry was fortunate, compared with many others, in that some 96 per cent. of the clays and other basic raw materials are found in Great Britain. The substitution of the remaining 4 per cent.—especially of high-grade Scandinavian feldspar—presented problems for a time, but, thanks to the intense research of British ceramists, these and similar difficulties were overcome without detriment to quality.

It was in Great Britain that this age-old craft of pottery-making first developed into a vast modern industry. The high regard in which British-made ceramic wares are held to-day throughout the world may be attributed to three main factors :—

(1) English ball and china clays from Dorset, Devon, and Cornwall are superior in quality, uniformity, and colour to those found elsewhere ;

(2) British skill and craftsmanship, handed down through several successive generations, have utilized to the full this basic superiority in raw materials ; and

(3) Technical research during the past 30 years has resulted in an intimate wedding of traditional craftsmanship and modern scientific methods, with the result that the appearance, strength, and reliability of British pottery are unsurpassed.

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REFRACTORIES AND THEIR DUTIES

HOW often during the war period has the question been asked " What are Refractories ? " They are materials capable of resisting high temperatures, rapid temperature changes, slag and clinker action, abrasion and other factors of destruction occurring in all types of industrial furnaces. They are basic to the operation of blast furnaces, steel furnaces, and all other metallurgical furnaces, for copper refining, and the manufacture of aluminium. They are also essential, *inter alia*, to the carbonization of coal at gas undertakings and coke ovens ; the production of electric power and light ; for the boilers of locomotives and ships—naval and mercantile ; the production of glass ; the production of cement ; kiln construction for all the ceramic industries ; zinc distillation, and to many chemical processes. Therefore, it can quite properly be said that refractories are an absolute necessity to the production—directly or indirectly—of almost every one of mankind's requirements in peace and war, but because they are built mainly inside furnaces they are rarely seen by the public and, therefore, do not attract much popular appeal.

Manufactured refractories include bricks, blocks, and tiles made of magnesite, chrome, dolomite, fireclay, silica, and sillimanite. They are produced in a large number of sizes and shapes, and must be made to meet the technical and other requirements of the furnaces and processes in which they are to be used. Refractory cements, compositions, and other ground materials also are produced in large quantities.

Of the raw material magnesite, the United Kingdom possesses no natural deposits ; before the war supplies were drawn from Austria, Greece, Manchuria, and India. The supply from Austria was cut off immediately war broke out, and in due time supplies from Greece and Manchuria also ceased. Therefore, in order to meet the ever-increasing demands of the steel

and other industries for magnesite bricks it became necessary to develop the production of refractory magnesite by the sea-water process. Apart from those in the Shetland Isles, there are no deposits of chrome ore in the United Kingdom, but within the Empire there are abundant reserves and, despite the acute shipping difficulties, ample supplies were forthcoming to meet the country's urgent war-time needs from Rhodesia, Transvaal, and India. Notwithstanding shipping difficulties and rail transport problems in India, supplies of kyanite have been maintained at a level adequate to meet the heavy war-time demands for sillimanite products.

The other raw materials, fireclay, silica stone, and dolomite, are indigenous. They are either quarried or mined.

Without refractories the nation could not possibly have achieved its amazing production of aircraft, ships—naval and mercantile, locomotives, tanks, armoured cars, guns, shells, bombs, and other munitions. Neither would it have been possible to provide the materials required for the Mulberry Harbour and "Pluto," which contributed so abundantly to the success of the allied cause, nor the huge quantities of building materials required for the construction of ordnance and other war factories, aerodromes, camps, and hospitals.

The use of refractories is not confined to war-time production. They are equally vital to peace-time requirements; they are necessary, directly and indirectly, to the production of all classes of building materials, the production of food, power, and heat, the manufacture of china, earthenware, pottery, glass, goods and passenger transport vehicles, domestic utensils of every description, and, of course, all classes of machinery.

The refractories industry is comparatively small, for, although there are approximately 200 undertakings, the total number of operatives employed, male and female, is less than 14,000. Some firms make more than one class of product; for example, most of the basic brick manufacturers also produce silica bricks.

The industry was not faced with any serious change-over problems at the outbreak of war, because its peace-time products are materially the same as those for war purposes. This circumstance and the fact that it was well organized enabled the industry to take prompt action to fill the important role it was to be called upon to play during the war period. A careful survey of the industry's resources and capacity indicated that it possessed plant, equipment, and (with the exception of the raw materials required to be imported—*e.g.*, magnesite and chrome) raw materials to meet all war-time requirements and that the only limiting factor was likely to be that of labour supply.

Although from the outset of the war the operatives were granted a large measure of reservation, it was inevitable that a substantial proportion of the younger men would either volunteer for or be called to the services. In consequence, the industry's chief problem throughout the war was that of labour shortage. Every possible step was taken to relieve the position; the employment of females was materially extended, Italian prisoners of war were employed on a considerable scale and a greater measure of mechanization was introduced where practicable. The introduction of mechanization, especially in the moulding processes, is necessarily limited by the large number of special shapes which are called for, many of them of intricate design.

In a further endeavour to relieve the labour shortage, the manufacturers and users, together with their technical advisers, took steps to encourage a greater measure of standardization of certain types of refractories; that action proved to be very beneficial.

Large quantities of coal are necessarily used in the actual processes of manufacture of refractories as distinct from its use for steam-raising purposes. Therefore, the maintenance of an adequate coal supply was equal in importance to that of labour supply. The industry's vital needs were recognized, and, notwithstanding the general difficulties of coal supplies, there was no serious case of interference with production.

In the early months of the war the industry was faced with the urgent problem of preventing glare from kiln fires and chimneys. The manufacturers' central organization, the National Federation of Clay Industries, appointed a special committee to deal with the matter. The committee worked for many months in close co-operation with the technical officers of the Ministry of Home Security. Schemes for effective obscuration were made for all cases and to meet all circumstances, and as the problem affected every undertaking, each of which had, on the average, many kilns, the task was a heavy one. The committee received most valuable assistance

and advice from the director and officers of the British Refractories Research Association.

The industry cooperated closely with the Raw Materials Department of the Ministry of Supply through the Chrome Ore, Magnesite, and Wolfram Control; the relationship between the Control and the industry was a happy and effective one. That effective relationship was helped considerably by the Refractories Advisory Committee which the National Federation of Clay Industries appointed soon after hostilities commenced following discussions with the Ministry of Supply.

With the constant help of the Control production was maintained at a level which, on the whole, was sufficient to meet the allied requirements at home and abroad. The total production of refractories during 1944 was no less than 1,577,438 tons, a great achievement.

Between the two wars the quality of refractories was greatly improved. That was made possible by greater attention being given to technical research and development by some of the larger manufacturers and users of refractories, and especially by the efforts of the British Refractories Research Association. The latter association was formed shortly after the last war under the aegis of the Department of Scientific and Industrial Research. It has got together a first-rate staff of research workers and has acquired finely equipped laboratories. In conjunction with the Iron and Steel Industrial Research Council it participated in the setting up of joint research panels to deal with open-hearth furnace refractories of all kinds, electric furnace refractories, and casting-pit refractories. Similarly, the association joined with the Gas Research Board in appointing a joint committee to encourage research on gas and carbonizing refractories and with the British Pottery Research Association in the appointment of a saggar research panel. These developments have been of great benefit when, under the stress of war conditions, the manufacturers have had to resort from time to time to the use of untried imported raw materials for some of their products.

Throughout the war period the industry was fortunate in the relationship between the employers and their operatives. Wages and conditions of work have been discussed from time to time and agreements made by the Refractories Joint Wages Board, which consists of representatives of the employers' organizations and the operatives' trade unions; the industry has been singularly free from stoppages of work.

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LEATHER AND FOOTWEAR

FOOTWEAR is, with food and clothing, an essential article for an army in all ages, whatever be the types of weapons used. It might be expected accordingly that the foundation of the footwear supply problem could be laid in peace-time and be ready for automatic expansion when war comes about.

The facts, however, are far different. Service footwear is of a specialized type. The plant and lasts needed are not suitable for the bulk of civilian requirements. Only a few firms are needed to produce the limited quantities of boots required for the peace-time army. The output of very many more firms was needed to meet the situation which arose when millions of men were called to the Colours, and new problems of organization had to be faced and overcome. The footwear industry of this country was fully equal to the occasion and the necessary transformations were quickly made.

More complicated were the problems relating to the supply and distribution of leather for the service footwear. Much of the leather used for civilian purposes—both upper and sole—in peace-time is not suitable for service footwear. Heavier sole leather and thicker upper leather are needed for a man in the army than, generally speaking, the same man has in his peace-time vocation. Leather unfortunately cannot be made to a specification as cloth and other readily standardized articles can. It has to be manufactured from hides and skins which, for the most part, are the by-products of meat and are extremely variable in many respects.

The first step in the supply of suitable service footwear, therefore, is to obtain the most suitable types of raw material for the purpose. The resources of this country can provide only about 25 per cent. of its hide requirements (in sharp distinction to the position in the United States, where domestic supplies suffice for 90 per cent.

or more of her needs) and the balance has to be imported from many countries, mainly South American.

The withdrawal of Germany as a buyer of hides in South America helped the situation at the outbreak of war and no particular difficulty was at first experienced in obtaining the types of hides needed in sufficient quantities, and, by reason of prompt action taken here to canalize purchases, at prices which showed little advance above the pre-war level. In 1941, however, freight difficulties involved a substantial cut in purchases, and subsequently heavy sinkings produced a situation which has continued more or less critical ever since.

In contrast with the position in this country, there is evidence that in Germany the position of supplies of leather and footwear was relatively good. Germany had access to large supplies of hides, skins, and leather from the occupied countries, and information now forthcoming from that country indicates that a high standard of footwear was maintained both for Services and civilians right up to the end of the European war.

In this country, however, the utmost economy in the use of leather became essential, and the stocks on which the various Service Departments operated were reduced to a minimum. In the autumn of 1941 these stocks were cut to the bone by the dispatch of 3,000,000 pairs of boots to our Russian ally. The repairing and rebuilding of worn boots were developed to the utmost possible extent, and ingenuity was practised on the specifications of the 60 or 70 different types of service footwear to ensure the most economical use of every piece of leather available. Schemes controlling the distribution of leather from the producers to the boot manufacturers, repairers, and other users were put into operation with a view to using available supplies in the most economical manner. These involved the almost complete exhaustion of all stocks in the hands of producers, merchants, and users, and the elimination of all preventible waste in cutting.

Developments in the United States were on similar lines, though the position in that country never reached the degree of stringency over here and civilian footwear production in that country was more than maintained. To a substantial extent this was accomplished by the use of alternative materials, and the footwear from these was sold free of coupons. Nevertheless, the United States has experienced a growing shortage of leather from the autumn of 1943 onwards. Informal coordination which existed between the Leather Control and its American counterpart for the purpose of foreign hide buying was extended and consolidated in 1943 into formal arrangements under the auspices of the Combined Raw Materials Board, by which the whole of the hide supplies, both domestic and imported, available to Great Britain, the United States, and Canada, were subjected to division in agreed proportions. Arrangements were made also for regulating the quantities of hides going to neutral countries, and in the past few months the scheme has been further extended to embrace the supplies going to the liberated countries.

Later in the war similar difficulties arose regarding supplies of other classes of leather-producing materials. A large proportion of these other materials is in normal times provided by India. The great development in the Service requirements of India herself and the considerable expansion in civilian consumption of leather in that country combined with the increasing needs of Canada, South Africa, the United States and ourselves created in due course a critical situation in supplies of the rough tanned hides, goatskins and sheepskins, for which the rest of the world is dependent on India. This critical situation led to agreements to which the various countries concerned were parties. Raw goatskins were also the subject of formal arrangements between Canada, the United States, and the United Kingdom, and distribution controlled under the Combined Raw Materials Board regulation.

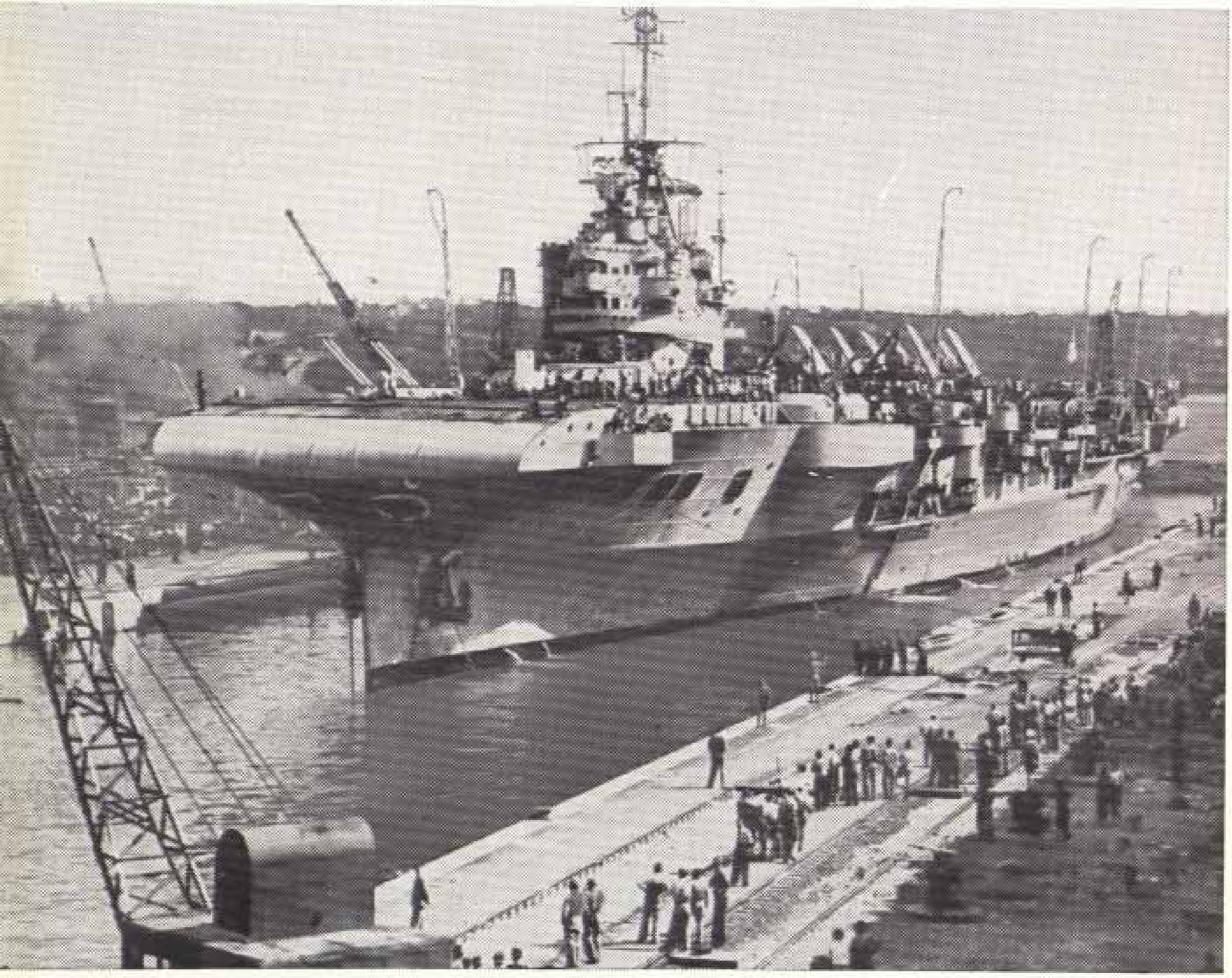
One of the most important new items of personal equipment in the Services during the war was that of gloves and clothing for air crews. Only a small proportion of the world's sheepskins reach the standard set by the high specification adopted by the Air Forces in the Allied countries, and an arrangement for the division of these skins between the United States and

ourselves was also reached. The highly mechanized type of modern warfare involves far more heavy " hand-work " than in former campaigns, and the production of the very many different varieties of gloves, needed by the Navy, Army and Air Force as well as by large numbers engaged in some class or other of munition manufacture, created from time to time some strain on the available sources of materials.

In past wars, when guns had to be dragged into position by horses, enormous quantities of leather were needed for equine equipment. The mechanization of artillery has changed all this, with consequent relief on leather supplies. Nevertheless, substantial quantities of leather continue to be used for many articles of equipment and a number of new developments due to the war occurred, calling for varieties of technical leathers. One of the most important of these was the oil seal leather needed in aircraft and tanks, which requires to withstand temperatures as high as 150deg. C.—a degree of heat which leather had never previously been produced to withstand.

Perhaps the outstanding feature of the war in the leather and footwear sphere was the extent to which cooperation between the United States and the United Kingdom was developed. The leather industry has always been one of the most international of industries—this country before the war imported hides and skins from more than 30 countries and exported leather to even more. The cooperation which developed during the war included not only regulation at the level of the Combined Raw Materials Board but also daily cooperation at the executive level through a Joint Hide and Skin Office set up in Washington. In handling the day-to-day business details of the distribution of raw material between the Allies, this organization has proceeded a very long way in the direction of practical cooperation in the international field.

The necessary adjustments were quickly made to enable the footwear industry of this country to meet the required output for the Services. This picture shows the making of fleece-lined flying-boots.



H.M.S. ILLUSTRIOUS AT SYDNEY

The aircraft-carrier H.M.S. Illustrious entering the new graving dock, one of the largest in the world, at Sydney. She was the first vessel to enter shortly before the official opening by the Duke of Gloucester and the naming "Captain Cook Dock" by the Duchess. The Illustrious was one of four aircraft-carriers completed in 1941, the others being the Victorious, Formidable and Indomitable. She took part in the pre-invasion attacks on Okinawa and was in dock for repairs.

VI. AID FROM THE COMMONWEALTH AND EMPIRE

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CANADA'S VAST OUTPUT

THE simple assertion that Canada held fourth place in war production among the United Nations gives only an indirect indication of the remarkable status this country attained as an industrial power during the war years. While large Canadian forces were fighting beside their allies on the battle-fields of Europe and elsewhere, another Canadian army of over 1,000,000 men and women was engaged on the industrial front at home; in work and output it enabled the Department of Munitions and Supply to make production commitments approximating $11,000,000,000 in value since 1939.

The country's daily war production bill, about $6,000,000 at the end of the war, rose from $1,500,000 in 1940 to $3,500,000 in 1941 and $7,000,000 in 1942; it reached its peak of nearly $9,000,000 in 1943. In the following year, by maintaining the physical volume of production, Canada rose to second place among the exporting nations. Her exports in 1944, excluding gold and consisting mostly of war goods and food products, amounted to $3,439,953,000, the highest total in the country's history. Of all the war equipment produced only 30 per cent. was needed for the Canadian armed forces; the remainder went to Britain, the United States, Russia, China, France, Australia, New Zealand, and other United Nations, ultimately finding its way to virtually every theatre of war.

When war broke out Canada had no armaments industry to speak of. She produced a small quantity of ammunition, a few experimental models of military vehicles, and some negligible quantities of other military items. Neither guns nor tanks were produced, no large ships, no aeroplanes. Since 1939 the country has more than doubled its industrial capacity and has produced a great variety of naval and merchant ships, aeroplanes up to the 15-ton Lancaster bomber, scores of types of small and heavy ammunition, more than 100 kinds of military vehicles, small arms in great variety, self-propelled guns, tanks, armoured cars, artillery, precision instruments, radar, uniforms, parachutes, and hundreds of other items needed for modern war.

In the early months of war the production assignments allotted to Canada were small and comparatively easy to meet; but as weapons became obsolete, and as Canadians demonstrated that they could turn out larger and more complex equipment, the assignments changed and grew more difficult. Production figures began to rise, but their statistical presentation never did more than suggest what was being achieved by Canadian industry. They did, however, indicate to those who cared to study them that a country, largely agricultural, was being transformed into a war-time arsenal, capable of meeting exacting production demands, notwithstanding shortages of man-power, tools, and materials. They reflected an adaptability, an enterprise, and an organization for war that were likely to place Canada in a new industrial position in the post-war period.

The responsibility for obtaining raw materials, machine tools, and plant facilities, of building and operating Government-owned plants, and of undertaking all supply purchasing for the

country's armed forces and her allies was centralized in one Government body—the Department of Munitions and Supply, under the direction of its Minister, Mr. C. D. Howe, now also Minister of Reconstruction. This centralized organization eliminated competition as between one branch of the armed services and another, or between one allied nation and another, and gave cohesion and strength to the mobilization of the country's war resources. Canada is believed to be the only country within the United Nations that handled all war supply through a single agency, and to ensure the channelling of raw materials into war output while assuring a basic civilian supply, almost all the primary and secondary materials were placed under a system of controls, operated jointly by the Department of Munitions and Supply and by a War-time Prices and Trade Board, responsible to the Minister of Finance.

In the process of organizing the country's productive resources these two bodies supervised virtually the whole field of Canadian economy. The Minister of Munitions and Supply was empowered to mobilize, control, regulate or restrict any branch of trade and industry. He exercised his authority through controllers (members of a War-time Industries Control Board) who had wide powers of control and jurisdiction over steel, metals, oil, coal, power, timber, chemicals, machine tools, aircraft, motor-vehicles, construction, ship repairs and salvage, transit facilities and miscellaneous supplies such as silk, rubber, and other commodities. A priorities branch fixed priorities of production, transport, and delivery; and the Government's authority found further expression through the agency of Government corporations operating in rubber, silk, and machine tools.

By the end of June, 1940, timber, steel, and oil controls had been established, and these were quickly followed by other controls. These controls made available essential materials for the production of war equipment, which was coordinated by a production board, under the chairmanship of the Coordinator of Production.

While the Industries Control Board had complete control of the supply and allocation of essential materials, the War-time Prices and Trade Board was the supreme authority in the whole field of price control. All goods and services not under the jurisdiction of controllers were subject to the authority of the board, which was also empowered to restrict and effect increased standardization in the production and distribution of goods and services; to make recommendations for the removal and reduction of taxes and duties; and, through a Commodity Prices Stabilization Corporation, to pay subsidies to prevent any puncturing of an established price ceiling. Coordination between the Industries Control Board and the Prices and Trade Board was particularly close, as the controllers were generally also administrators under the latter board.

In addition to controls effected through fiscal policies, restrictions on economic activities were imposed by export permit regulations; by the operation of the War Exchange Conservation Act, which prohibits or restricts certain imports; by War Labour Boards dealing with wages; by the Canadian Shipping Board; and by National Selective Service, controlling the supply and movement of labour. Other controls affected agriculture and foreign exchange transactions.

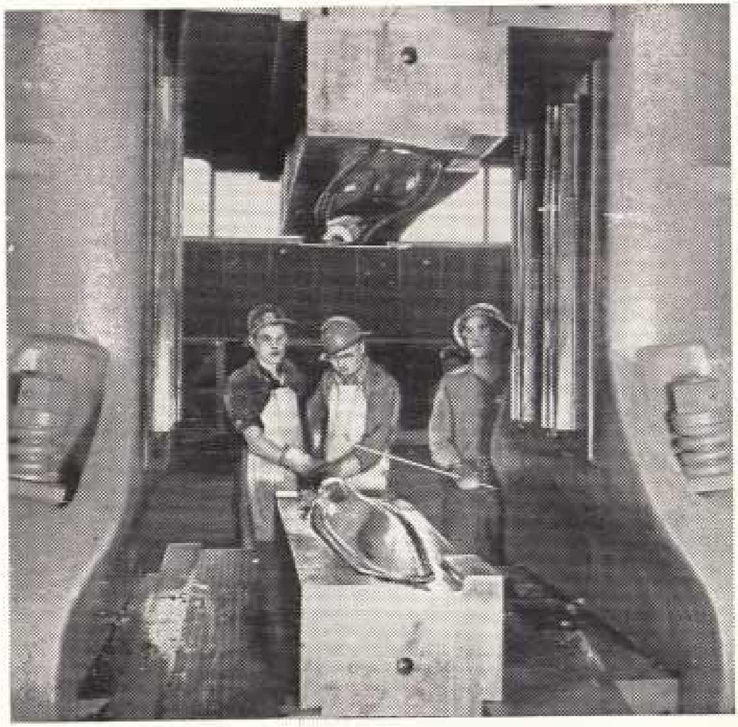
The Industries Control Board supervised civilian production and supplies through the agency of a number of controllers, who were empowered to see that productive facilities were expanded to meet requirements, and to limit, and, if necessary, to prohibit, production for civilian use of those materials which were scarce in relation to war and essential needs. This diversion of production from civilian to war requirements called for a high degree of coordination, both in integrating the activities of the controllers and in providing a centralized point of contact with other Government agencies and with related price, export, and import control. The board was structurally designed to facilitate coordination. It consisted of the Coordinator of Controls, as chairman; the Coordinator of Production; the Priorities Officer; the individual controllers; the Chairman of the Prices and Trade Board; the President of the Commodity Prices Stabilization Corporation; the Director of National Selective Service, and one or two others. The organization thus set up eliminated the possibility of the controllers working at cross purposes with each other, and enabled the whole programme to be kept in line with the basic objective—the effective mobilization of economic resources.

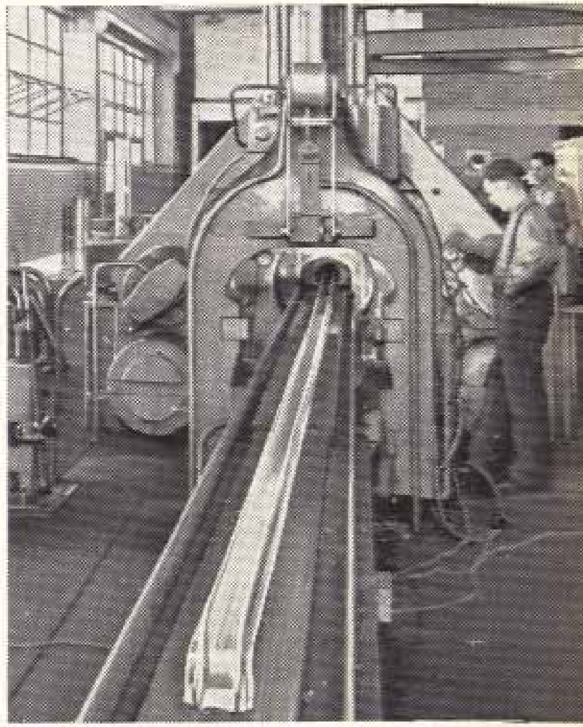
In the civilian field the Prices and Trade Board imposed controls and restrictions extending from the control of all prices and rents and the licensing of wholesale and retail business to the regulation of particular types of sales. The National War Labour Board, with regional boards, saw that wages were maintained at basic rates, with increases being granted only in special circumstances. Salaries likewise could not be increased,

A National Labour Relations Board, with associated regional boards, operated to enforce regulations governing collective bargaining and served to avoid industrial disputes or to make for their satisfactory settlement.

Thus, the Department of Munitions and Supply, which began as a purchasing board to prevent competition in obtaining supplies for the Canadian armed forces, evolved into an elaborate organization that touched almost every aspect of Canadian daily life, and impinged on the supply system that buttressed the allied war effort in every theatre of war. Under its supervision the country has become self-sufficient in many items it did not previously produce, and the organized allocation of requirements has led to the establishment of new industrial plants. By the end of December, 1944, the department had made commitments for investment in war production facilities totalling nearly $850,000,000. Expenditures included an investment of nearly $533,000,000 in land, buildings, and equipment for the erection of new production plants. Approximately $166,000,000 was invested to assist in the conversion to war production of privately owned plants producing for commercial markets at the outbreak of war. Some $70,000,000 provided housing for war workers.

A new step was taken in the establishment of Crown companies — Government-owned companies formed to increase production and to aid in controlling war materials. Three of these had the task of administering and improving the machine-tool position, of stockpiling and distributing silk, and of stockpiling and distributing rubber. Other Crown companies produced and purchased aircraft woods, built and operated a synthetic rubber plant, repaired machine tools, built ships, operated merchant vessels, directed the aircraft industry, constructed aircraft components and aircraft, made small arms, supervised chemicals and explosives production, dealt with





The industrial capacity of Canada has been more than doubled since 1939 and a great variety of war equipment was produced. Above are two photographs showing different stages of aircraft production in Canadian factories. Left: Forging a propeller. Right: Extruding a wing spar boom section.

the channelling of war orders from the United States, made intricate electrical apparatus and optical glass, and performed many other assignments. In all, 31 Government-owned companies were established, 10 to operate plants, 20 to fulfil administrative or purchasing functions, and one to deal with the disposal of Government assets.

While some Canadian industries, such as the steel mills, the automobile plants, the electrical and radio equipment trade, and the machinery plants, adapted themselves fairly readily to war needs, it was nevertheless necessary to expand the Canadian industrial plant on a large scale. The country has in fact undergone an industrial revolution in the short period of five years. In the process labour has acquired new skills and techniques, and great advances have been made in the field of labour-management relations. Trade union membership has about doubled, and consultation with organized labour is now accepted Government practice. The Canadian manufacturer has not only learned to produce many things which previously were not produced in Canada, but has benefited from new processes and materials that have been introduced. Although the industrialist during the war years was subjected to many rigid controls, the experience has shown that in special circumstances the Government can supervise the whole of a nation's economy without superseding private enterprise.

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AUSTRALIAN WAR PRODUCTION

AUSTRALIA'S war production was intimately related to the phases of the war itself, particularly as it developed in the Mediterranean and in the Pacific. Three main stages can be distinguished :—

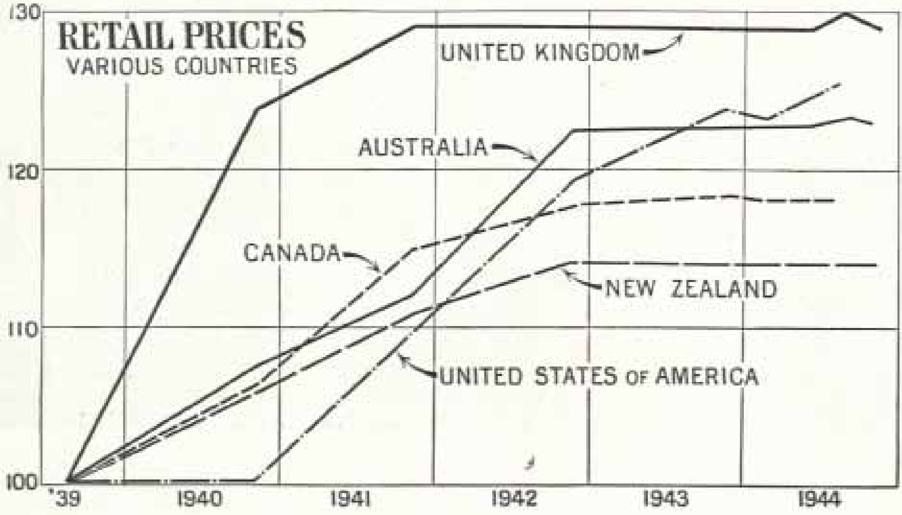
First, the period following the declaration of war against Germany on September 3, 1939 ;

Second, the southward thrust of Japan in 1942, the fall of Singapore, the occupation of the Solomons, and the direct threat to Australia ; and

Third, the defeats of the Japanese at Guadalcanal, in the battle of the Coral Sea and at Kokoda in New Guinea, and the assumption of the offensive against Japan by the allied forces after the early months of 1943.

In the first of these phases the contribution of the Commonwealth to the war against Germany was the maintenance of the Australian Imperial Force in the Mediterranean theatre and the supply of foodstuffs, raw materials, and some munitions to Great Britain. This was a period of organizing war administration, of reorganizing the industrial and financial structure, and of reviewing the resources of the nation.

In the second phase the nation moved into a



managed economy and into a period of intense preparation to resist Japanese aggression and a possible invasion. The expansion and training of the armed forces, and the partial blockade of the continent threw the Commonwealth upon its own resources in providing munitions and equipment at the cost of reduced civilian consumption and of considerable dislocation in rural industry and export trade. At the same time, Australia became the main allied base for the counter-attack upon Japan; American forces and equipment had to be accommodated, and defence works of all kinds from aerodromes to harbours had to be constructed. In these circumstances Government direction became necessary to divert resources from unessential activities, and economic controls were necessarily extended. By the middle of 1943 this second phase was complete, men had been trained, new arms had been produced, reserves of all kinds had been accumulated, and an acute budgetary problem was being successfully solved.

The opening months of 1943 saw the beginning of the third phase, the mounting of a cumulative offensive against Japanese positions. By now the mobilization of resources had been completed, but great new armies, navies, and air forces had to be supplied on a growing scale. New problems of supply accompanied the employment of new types of weapons and equipment for sea and jungle warfare; increased demands for troop needs were made upon the food and clothing industries. More ships were made available to enable exports of food to Great Britain to be increased. The Australian economy had now reached the practical limits to the employment of all resources.

All this development required by 1944 the re-casting of economic controls; and, in some directions, existing policy was changed or even reversed. The demands for food for Britain and for the allied forces in the Pacific compelled re-allocation of labour and release of men from the forces in order to maintain rural production. These were the urgencies prevailing in 1945, associated with the necessity for increased supplies of farm machinery and fertilizers. Unfortunately, the 1944-45 season developed into one of the most disastrous droughts in the history of the country and many of the production goals will not be reached.

The first year of war in Australia was largely a period of preparation for the struggle which lay ahead. The Commonwealth Parliament passed a comprehensive National Security Act, which was a blanket measure necessary to enable anything to be done under the Defence power. The next step was to bring about a progressive diversion of national resources to the purposes of war; and this took the form, first, of strengthening the industrial and financial organization upon which a total war effort would be ultimately built, and secondly, of easing the transition for the community. These aims were often incompatible, but the "sorting out" process proceeded without excessive friction.

In June, 1939, the Department of Supply and Munitions had been set up, while the Division of Import Procurement was organized under Trade and Customs to control the import-export structure in relation to home production. With the splitting off of the Department of Munitions from Supply and Development, sub-departments headed by proved business executives were set up. Industry was brought under the controls necessary for expanding essential, and discouraging unessential, production. The community was beginning to realize the problems of economic warfare. This reorganization was of prime importance because, at the outbreak of the war, the country was lacking in armaments production and its output of war goods was very small. By the end of 1941 Australia had established new precision processes and was energetically swinging into the production of aeroplanes, Bren gun carriers, anti-aircraft guns, machine guns, naval armament, and many other types of equipment. Blueprints were being got ready for much more.

Early in the war Australia was supplying a great amount of clothing, materials, and equipment to other parts of the Empire. The Eastern Group Supply Council was organized and based at Delhi "to make the best use of the productive resources of British countries in the light of war needs and the transport problems of the Empire." The figures below show the order of the achievement in this field of supply, and its relation to

changes in the direction of Australia's imports and exports :—

DIRECTION OF TRADE

AUSTRALIA : PRE-WAR AND POST-WAR

(£A. millions)

—	Imports		Exports	
	1938-39	1943-44	1938-39	1943-44
United Kingdom ..	40.4	23.2	68.7	38.9
Foreign ..	24.6	6.1	33.8	10.4
Canada ..	7.7	2.0	2.0	3.6
Other British..	8.5	6.4	13.1	34.1
EasternSupply*	3.7	15.3	3.3	16.9
U.S.A. ..	14.6	25.9	19.6	28.3
Total ..	99.5	78.9	140.5	132.2

* Eastern Supply = India and Ceylon.

This table will indicate broadly the theatres to which commodities were diverted by war necessities from normal export markets. The war-time trade relations between Australia on the one hand, and groups such as India-Ceylon, U.S.A., and "Other British" on the other cannot be regarded as permanent. They reflect economies in shipping owing to rearrangement of Australia's trade with nearer countries. It is unnecessary to specify commodities, but the enlarged imports of cotton and cotton goods from India, of tea from Ceylon, of tin-plate from U.S.A., and of exports of manufactures to New Zealand were typical of the way in which trade was forced into a new pattern.

As the war effort proceeded the main difficulty was the coordination of the different controls set up, and in 1942 the Department of War Organization of Industry was formed for this purpose. The normal operative principle adopted was the rationalization of production, in order to comb out unessential industries and unproductive labour so that the maximum effort could be made to meet the menace of Japanese invasion. Prohibitions of production or employment were the devices used for achieving the desired result.

Under W.O.I. the Director of Manpower was also set up to find 350,000 additional men and women for the Services and for war production generally. At this stage small businesses suffered greatly, and rural industry was drained of manpower for the forces or the war factories. Complete control was imposed upon new manufactures, civil building was prohibited, many established manufactures were cut down, and protected industries were combed for manpower. All employment had to be recorded through the Department of Labour and National Service. By the end of 1942 the general effect was to concentrate upon war needs 1.8 million out of the total normal employment of only 3.4 million workers, and reduction of civil services became drastic.

Price control had been established soon after the outbreak of war. It was realized early that a curb upon inflation was necessary if the cost of the war were not to be increased by rising wages, causing or caused by increased cost of living. Wage control through the Arbitration Court, and price control through the Prices Commissioner were essential implements of war finance, since the budgetary problem of meeting steeply rising war expenditure depended upon effective use of credit and savings.

In 1942 price control was extended to enforce limitation of profits. The over-riding purpose was to drain off excess purchasing power to meet the needs of the Treasury. To cope with the national emergency, taxation, loans, and credit expansion were all used to the full ; investment was rigidly controlled through the Capital Issues Board, and State loans for public works were drastically reduced. Income taxation increased rapidly, and a general tightening up of all financial transactions took place. The changing budgetary structure is shown below :—

AUSTRALIA : WAR FINANCE

1939-40 TO 1943-44

(£A. millions)

—	1939-40	1940-41	1941-42	1942-43	1943-44
National income (net real) ..	887	956	1,090	1,220	1,320*
War expenditure:					
Internal ..	45	127	273	483	489
Oversea ..	10	43	47	79	56
Total ..	55	170	320	562	545
War expenditure: Per cent. of national income ..	6	18	30	46	41
Financed by taxation	25	65	109	159	168
Loan	28	102	127	216	265
Central Bank ..	—	—	78	179	69
Treasury balances ..	2	3	6	8	43

* Estimated.

So great was the need for conserving all available supplies that the Government organized in 1942 a Rationing Commission, and embarked upon an austerity campaign. Price control and rationing went hand in hand, and the apportionment of short supplies was necessary for the maintenance of civilian morale. Price control and rationing were outstandingly successful, and the community behaved very well in the face of considerable restriction.

The third phase completed the transfer of all available resources to war purposes. This was the peak of the war effort for munitions and equipment, but the emphasis was now rapidly changing, because supply for allied forces in the South-west Pacific called for the creation of stocks and for a rebalancing of rural and industrial production. The defence situation was already easing by the middle of 1943 ; and, under the stimulus of Commonwealth control, State Agricultural Departments set about the problem of securing greater food production. The order of urgency is shown by the fact that the area of vegetable production was doubled in the 1943-44 season, and that in every field of primary production pressure was applied to increase output.

The chief interest of the Federal Government was still the financial aspect of the war. Monetary policy had to be firmly handled to prevent inflation and to maintain the production of essential commodities such as coal. Efficient price control and financial policy were basically necessary for this reorganization ; and, in order to stimulate production and stabilize the wage-price structure, the policy of allowing prices to follow costs was changed in April, 1943, to a policy of fixed price ceilings. This was done by providing subsidies out of consolidated revenue to compensate producers for rising costs in essential industries.

During all this period the War Organization of Industry had continued to widen and deepen its control. About 300 new essential industries had been approved, all the " trimmings " had been taken out of living, the total working population had risen by 620,000 since the outbreak of war, and no further economies in civilian consumption seemed feasible.

At the beginning of the war rural production had been stabilized by the Imperial Purchases Schemes under which Great Britain acquired all rural products, except wheat and sugar. The schemes were on the whole successful, but the changing emphasis of global war needs was responsible for a considerable amount of contradictory direction and subsequent loss of efficiency.

Australia's war production is summed up in the following figures :—

AUSTRALIAN PRIMARY PRODUCTION (SELECTED)

Year	Primary Production	Wool	Meat	Wheat	Butter	Timber	Mining	Coal
	£m.	Million lb.	Thousand tons	Million bushels	Thousand tons	Million Sup. feet.	£m.	Million tons
Average, 3 year, 1937-8 to 1939-40	261	1,045	956	184	203	780	34	12.4
1940-41 ..	261	1,142	942	82	193	857	40	11.7
1941-42 ..	272	1,167	994	167	168	940	41	14.2
1942-43 ..	280*	1,148	1,035	156	170	880	39	14.9

* Estimated.

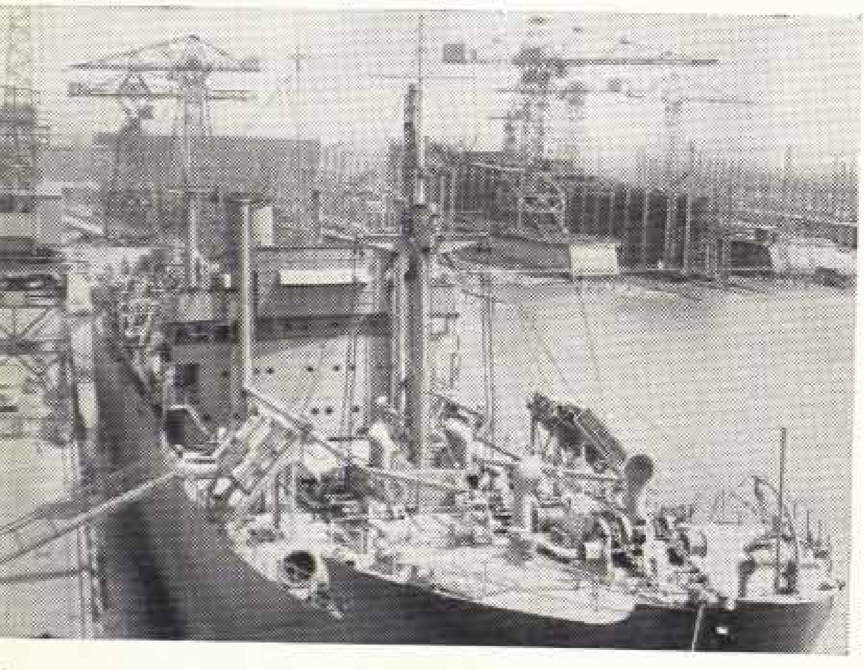
The Lend-Lease Agreement between Australia and the United States was signed in September, 1942. At September 30, 1944, Australian Reciprocal Lend-Lease aid to the United States totalled £198,000,000. Estimated aid to United States Forces in the Pacific in 1944-45, £110,000,000, represents 22 per cent. of Australia's anticipated war expenditure in the current financial year. In addition, Australia will be required to provide services and supplies to the British Pacific Fleet estimated at £21,156,000.

Australian aid to the United States also included transport and communications facilities and a wide range of works. Main items supplied to the United States were :—

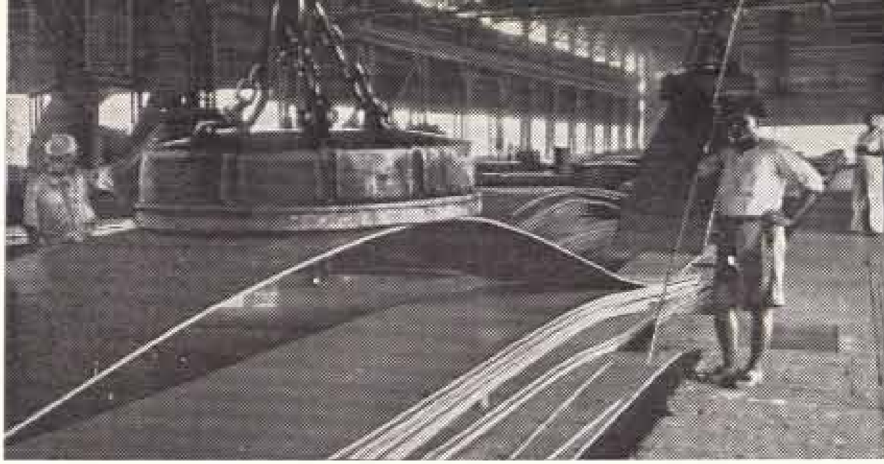
FOOD		
Meat, fresh and canned	117,000	tons
Bread, biscuits, and cereals (including flour)	163,000	,,
Potatoes	60,000	,,
Fruit and vegetables	164,000	,,
Canned goods (jam, fruit juice, &c.)	60,000	,,
Butter	11,000	,,
Butter substitutes	11,300	,,
Sugar	48,000	,,
Milk, processed	30,000	,,
Milk, fresh	6,460,000	galls.
Eggs	40,000,000	dozen
CLOTHING		
Boots	1,700,000	pairs
Blankets	1,800,000	No.
Sweaters	261,000	,,
Shirts	546,000	,,
Underwear	463,000	,,
Socks	8,700,000	pairs

There is little that need be added to this factual record of war-time production save some reflections upon the mistakes made and the lessons to be learned from this forced experiment in planned production. The mistakes have been errors of prediction, caused by changes in demand due to high policy and therefore not culpable; errors of judgment, that is, lack of knowledge in departments concerning essential facts; errors of personnel and of administration caused by departmental reluctance to admit that jobs might be better done by other departments, other persons, or other methods. In producing goods and services old prejudices have been too prominent; new ideas, speed of movement, adaptability, national outlook all too frequently lacking.

To say that, however, is merely to note that "there has been a war on." It is hard to see how this sort of thing can be avoided. The farmer *vis-à-vis* the bureaucrat, the politician *vis-à-vis* his electors—all are relations of war-time weakness. Even more costly has been the waste caused by the time-lag in shutting off programmes which have achieved, or have failed to achieve, their objective. Wooden ships that "won't do," dehydrated products that Service men won't eat, designs that never get into production, types that are born obsolete—but why prolong the "hateful, vaporous and foggy night" of a taxpayer's grievances? Australia did no worse perhaps in total production than others; she might, perchance, with more sceptical and more ruthless scrutiny by more experts more continuously have produced more or wasted less, but "things like that we know must be with any famous victory."



A scene at a fitting-out wharf at a shipyard at Whyalla, South Australia. A partially completed ship is seen on a slipway in the background.



Steel plates for shipbuilding being moved by an electric magnet at a steel plant in India. Steel production has been raised considerably.

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INDIA AS PRODUCER OF MUNITIONS

THE story of Indian war production is a complex one of industrial development over a very wide field from beginnings that amounted to very little either in the way of productive capacity for the needs of modern armies or organization for supply. In the year of the outbreak of war contracts for military stores placed by the then supply agencies amounted to 11.4 crores of rupees. In 1942-43 the value of the contracts placed by the Supply Department was 261.3 crores and indents were being accepted for the supply from indigenous sources of 20,000 odd articles that had not been manufactured in India before the war.

In 1939 India's assets for the production of munitions and engineering stores were a young but flourishing steel industry, a few Government ordnance factories, some 600 trade and railway engineering workshops, and excellent facilities for fabricated steel works. The more obvious weaknesses were that India had no non-ferrous metals industry, no general engineering workshops equipped and staffed for mass production, and no regular machine-tools industry. Added to these deficiencies was the dearth of technicians and supervisory staffs, which, although some 50,000 men were trained during the war for munitions work, remained a serious limiting factor throughout.

By the end of the war the number of ordnance factories had been tripled. Their crews numbered 100,000, as against 15,000 before the war. The number of engineering shops used by the Director-General of Munitions Production was 1,500. A non-ferrous metals industry has been established and includes in its achievements complex aluminium alloy forgings for aircraft engines. Machine tools, of which before the war fewer than 100 were turned out annually, are now being produced at the rate of 350 to 400 monthly. Steel production has been raised from 750,000 tons annually to over 1,000,000 and the industry has seen important new developments. India during the war has become a producer for the first time of alloy steels, high carbon tool steel, high-speed and stainless steels, special steels for the Royal Air Force, bullet-proof plate, and ferrosilicon.

That does not end the story. India, which before the war built only coasting craft, has to-day a shipbuilding industry with a labour force of 50,000 that since 1942 has been building ships ranging from steel minesweepers, anti-submarine patrol boats, and assault craft to 16ft. dinghies. Repairs, many of them of a size never before attempted in India, have been made to 4,600 freighters and tankers (30,000,000 tons of shipping) and to naval vessels. A floating dock —one of the largest in the world—has been built for the Admiralty and another is in construction. The presence of the Royal Air Force in India has resulted in the repair and maintenance of aircraft engines and other components becoming a substantial new industry and has promoted many new lines in manufacture. Indents from the R.A.F. for 13,270 different items were accepted by the Supply Department in 1943.

Other achievements include the establishment of a chemicals industry. Soda ash, caustic soda, bleaching powder, and many other important chemicals which before the war were produced in very small volume or not at all are now in substantial production. About 400 drugs and medicines which used to be imported are to-day being produced locally. With the help of lend-lease equipment from the United States India made the United Nations' entire requirements in strychnine, caffein, and santonin. A substitute

for quinine was manufactured from pyrethrum flowers and agar produced from Indian seaweeds. Penicillin has been produced on an experimental scale. The cutlers of Sialkot, descendants of the swordmakers of old, were shown how to make surgical instruments. They are now turning them out in excellent quality at the rate of 30,000 a month.

There was a very small and languishing silk industry in India before the war. Seed was flown from China and, with difficulty, the ryots were persuaded to cultivate them at a time when food was short. Filatures were built in India from specimens of French machinery and old boilers were adapted. There were teething troubles, but in the end silk parachutes as good as any were produced. India's cotton parachutes, of which a quarter of a million were manufactured monthly, were praised by the American Air Force as the best they had. India evolved its own formula for anti-gas fabric, as also for an aeroplane dope which was made chiefly out of old cinematograph films.

Oxygen was made for aircraft flying over the "Hump" to China, and a pure spirit for de-icing. India's 70-year-old industry was the United Nations' largest supplier of the indispensable mica. The demand was so urgent that mica—as many an intending passenger knows to his cost—had a high priority by air. Last, but not least—although this survey does not pretend to be exhaustive—India turned each year 16,000 to 18,000 tons of home-grown rubber into ground sheets, tyres for aircraft and road vehicles and other equipment for the United Nations' armies.

The production of weapons and munitions was the function of the Government ordnance factories, supplemented mainly by the railway workshops. The factories were modernized and expanded, and new ones were built to enable India to turn out field gun, howitzer, anti-tank and anti-aircraft gun parts, machine-guns, mines, bombs, depth charges, binoculars, stereoscopes, telescopes, and fire control instruments. A new factory was established for the manufacture of high explosives and subsidiary plant for the production of toluene. The output of rifles was increased tenfold, light machine-guns twelvefold, bayonets seventeenfold, small arms ammunition fourfold, gun ammunition twenty-sevenfold, and gun-carriages ninefold. The vastly increased rate of ammunition output was maintained in spite of the introduction of new types, which involved a complete change of production methods and filling technique.

Alongside this went the mobilization of existing civilian industry for the equipment of the forces. The Supply Department until this year took the entire output of the woollen, steel, and cement industries, almost the whole of the leather industry's output, and at one time 35 per cent. of the production of the cotton textiles industry. At one stage of the war India was almost wholly responsible for the supply of bulk stores to the Middle East. Indian-made pipelines carried water to the Army in the Libyan desert. Indian rolling-stock, track, and equipment made the desert railway. Indian paints and hemp nets camouflaged the guns at El Alamein. Ninety per cent. of the tents, canvas and ground sheets used in the desert came from India. The troops wore clothes made in India, to a lesser extent walked in Indian boots, ate food of which a large proportion came in dehydrated form from India, and received from India immense quantities of their medical stores and comforts. Apart from the value of the stores, use of the shorter supply route from India to the Middle East meant substantial economy in United Nations shipping.

The organization of India's war production was the work of the Supply Department of the Government of India. This Department was formed at the outbreak of war as the secretariat of a War Supply Board, which was a committee of secretaries of Departments. The executive of the Supply Department was the Directorate-General of Supply, which took over all peacetime purchasing agencies and the ordnance factories. Later the War Supply Board was replaced by the War Resources Committee of the Governor-General's Executive Council, which may be described as a policy committee at the Ministerial level.

Then, as work became heavier, the Directorate-General of Supply shunted off the production of munitions and the control of heavy engineering to a Director-General of Munitions Production in Calcutta. Later a Directorate-General of Shipbuilding and Repairs was formed, and in October, 1943, a Directorate-General of Aircraft, the function of which was to look after the R.A.F. in India by the purchase and manufacture of parts and the repair and maintenance of aircraft.

Under the directors-general planning, production, and purchase proceeded in parallel. To the purchasing sections were attached technical directorates which attended to the expansion and diversion of existing industrial facilities and the establishment of new factories. Honorary

advisers or panels of advisers from private industry and transport gave invaluable assistance. Until the spring of 1941 the purchasing sections used the peace-time method of competitive tendering. As defence demands absorbed more and more of the industrial capacity competition disappeared and the method was adopted of negotiating with industry after ascertaining the costs and profits margin.

The third phase, after Japan's entry into the war, was that of control. The manufacturing capacity of the South-east Asia countries, which for war supply purposes had been coordinated with India's under the Eastern Group Council, disappeared. By this time, too, the civilian markets of India were denuded of stocks. Food for the civilian population was threatening to become short and prices of other necessities, more particularly textiles, were soaring. It was now a case of making allocations as between essential defence and essential civilian needs and the controlling and rationing of distribution.

This situation led to the establishment in the autumn of 1942 of a separate Food Department of the Government of India. Later a Department of Industries and Civil Supplies was formed to take over responsibility for cotton textiles and the supply of civilian consumer goods generally. The undeveloped character of India's economy was a great impediment to the effective working of the Departments' controls; but along with the financial measures of the Government of India these have assisted to keep price levels reasonably stable for the past two years.

Upon the basis of their experience in this war the Supply Department regret that more thought was not given in advance to the capacity of vital services such as transport and coal in relation to expanding industry. Both, particularly in the fourth and fifth years of the war, were serious bottlenecks. Another handicap was that, although before the war the potential capacity of existing industries was known, the Department had no accurate indication of the demands likely to be made on them or the pace of development that would be necessary to meet the requirements of the defence forces. It was accordingly difficult to keep production ahead of recruitment and training. The defence preparedness of a country in time of peace should, in the Department's view, include a complete plan of production which can be put into operation as soon as war breaks out.

A photograph taken in a railway workshop in India where plant was installed for the production of munitions. It shows one of the processes in the manufacture of shells. Some 1,500 engineering shops, apart from ordnance factories, were used by the Director-General of Munitions Production in India.

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NEW ZEALAND RESOURCES

THE story of New Zealand's war production tells of the re-birth of pioneer resourcefulness. Save for her land products the Dominion in 1939 had little of the equipment for total war. She lacked, too, most of the materials and industries needful to produce equipment. But necessity—to furnish the means for home defence, and to equip an Expeditionary Force—spurred her people to rediscover the genius of their forefathers for building what they needed from the materials they had.

Starting without indigenous metals, heavy industry or physical laboratory, the country, after five years, was supplying many of her own needs, and filled gaps for the Eastern Group Supply Council and the Pacific fighting forces; the total achievement is small by comparison with industrialized Britain, but for New Zealand it is much from little.

What was done, moreover, was without diminution of those war supplies that the country could so well furnish—foodstuffs, wool and wool products, a creditable achievement, for the Dominion early faced two farming problems—man-power shortage and scarcity of fertilizers. Measures were taken to meet the new difficulties; rationing of fertilizer, use of substitutes, recruitment of land girls, cooperative mechanization of farms, so far as this was possible. When the immediate Japanese menace receded and New Zealand's Third Division returned from the Pacific Islands theatre, land labour was reinforced, but there is still much ground to be made up. From the outbreak of war to the end of 1944 the principal food supplies to Britain have been:—

Meat	1,654,500 tons
Butter	734,000 tons
Cheese	638,000 tons

Adjustments had to be made from time to time to meet Britain's most pressing needs. For example, in the 1941-42 season a substantial diversion was made from butter to cheese—cheese production had been raised in the previous season by 38,000 tons—and in the following season a return to butter was required. Substantially increased quantities of dried milk were also sent. Again a request was made for the production of linen flax, a crop not previously grown in New Zealand, and over several years 20,000 acres of high-grade fibre have been harvested and processed with equipment made locally.

When American forces came to the South Pacific new food demands had to be met. Meat, butter, meat and vegetable rations, service biscuits, apples, and potatoes were furnished in huge quantities. Arrangements were made, by contract with market gardeners, and the establishment of State vegetable farms, to supply fresh vegetables. Dehydrating plants were also set up, and thousands of tons of the dried and fresh produce were shipped to the island war theatres. For example, within four days of the American landing on Okinawa the invading forces had fresh vegetables from New Zealand. The principal

Preparing cabbages for the use of the forces at an Internal Marketing Department Centre in Auckland, New Zealand. Thousands of tons of dried and fresh products were sent to the different war theatres.

food supplies to the American forces (to April 30, 1945) were :—Meat, 132,300 tons ; butter, 16,924 tons ; cheese, 5,658 tons ; canned and dehydrated vegetables, 15,783 tons ; fresh vegetables, 78,202 tons. Fresh fruits, dried milk products, bacon and ham, and other foods were supplied in quantities that often meant shortages for the Dominion.

Rationing was applied to augment exportable surpluses. Rationing amid plenty is not easy, but with the slogan " More for Britain " the response was splendid. New Zealanders were probably the biggest meat and butter eaters and sugar-users in the world, and the rations, though apparently generous, represented a really severe cut. Clothing has been rationed moderately, but market shortages often intensified the ration scale. This has applied also to many unrationed food lines—tinned fruits, fish, and so on—unrationed only because there was usually none to ration.

One of the greatest achievements in war production was that of the woollen manufacturers and clothing and boot-making trades. They equipped the New Zealand Divisions, Air Force and Naval men, also the women's services, and supplied in addition substantial quantities of goods for allied nations. New Zealand battledress has been pronounced one of the best-wearing uniforms in the world and manufacturers quote with pride that Field-Marshal Montgomery has worn it. Clothing has been sent to Allied forces in India, the United Kingdom, and other countries. The yearly output of these industries was almost doubled during the war period by calling back married and retired workers and installing locally made machines. In boots and shoes a 50 per cent. increase in production has given the Dominion sufficient for her own troops and also over £1,000,000 worth sent to the Eastern Group. Output figures for the services include :—Boots and shoes, over 3,000,000 pairs ; jackets, trousers, and greatcoats, over 3,700,000 garments ; blankets, 900,000 pairs.

Most difficult was the establishment of arms and munitions manufacture. New Zealand had an efficient small arms ammunition plant (since duplicated and responsible for the production of about 250,000,000 rounds) but she had little else. Mr. Sullivan, Minister of Supply and Munitions, went to Australia to see what could be bought or borrowed there. He found Australia most willing to help, but with an even more urgent need of her own to meet. " We must see what we can make for ourselves," he said.

The resources of railway workshops, motor assembly plants, and other engineering works were surveyed. The country was combed for lathes and odd bits of plant. Then, a stock of gauges having been built up, a system of precision measurement was designed to bring into the task small workshops, motor repair shops, and other plants throughout New Zealand, some even in the foothills of the Southern Alps. Grenades, fuses, and mortar bombs were made in this way. Small shops divided the task of making the hundreds of parts for assembly at central plants.

Machinery had to be adapted or improvised ; material diverted from other uses, or obtained from scrap. It was really beating ploughshares into swords. Everybody helped. Jewellers and watchmakers and the university physics laboratories made fine instruments that could not be imported. Telegraph department and radio mechanics designed a new type of field wireless set, to stand the shocks of war use, and found it so highly esteemed that an order came from India. Later the set was to prove a model for an improved British design.

When Admiral Halsey's ships came to the Pacific there was an urgent call for radar before it could be supplied from America. New Zealand supplied installations and technicians to be trained in their use.

Again at the request of the Pacific forces our chemists developed a flame-throwing compound in substitution for the service compound that could not be got quickly from America.

The spirit was that of always being willing to try. Major-General Pakenham Walsh, Controller General of Army Provisions in the Eastern Group Supply Council, summed it up in saying : " We have turned to New Zealand when we have been in a really tight spot and she has put up quite a notable performance." New Zealand even helped fill a gap revealed by the Ardennes push—a shortage of shell fuses.

Difficulties were many and varied. When 3in. mortars were first made material could not be procured from oversea. Worn axles from locomotives were treated, turned and bored, and passed all tests. Sometimes blue-prints could not be obtained. While waiting for drawings and specifications of universal carriers and Bren gun carriers, the Munitions Department secured an old carrier and the engineers made their own drawings. The proprietor of one remote garage workshop thought he would be late with his quota of mortar barrels because a milling machine

could not be obtained in time. He designed and made the machine himself.

Some of the Dominion's products have been :—

Over 5,000,000 grenades, 1,000,000 shell fuses, and some thousands of trench mortars ; 1,000,000 mortar bombs, also universal and Bren gun carriers. Much of this has gone to the Eastern Group. As experience was gained, workers trained, and machines and material obtained, bigger jobs were undertaken. Training aircraft have been built and efficient servicing shops set up.

Beginning with the conversion of fishing trawlers and ferry-boats for mine-sweeping, ship-building plant has been expanded to meet all repair needs and to supply Fairmile motor-boats and many useful small craft for the Pacific forces. New Zealand air ground staffs working with the Americans on island bases have won their highest praise. Nothing was too badly smashed for the New Zealanders to repair, they said. That was the result of training in the early days when a plane, though it looked like a heap of junk was one of the few and must be kept in the air.

In recent times New Zealand's role of handy-man in the South Pacific has taken a wider form. Implements and utensils of all kinds were made to meet needs known or expected as the Japanese were rolled back and liberated territories needed help in rehabilitation.

All this has meant direction of the use of industry (and of labour also), for the most part voluntarily accepted. Thus in various industries the percentage output for war has been :—

Engineering, 84 ; sawmilling, 84 ; woollen mills, 70 ; clothing, 75 ; electrical, 85 ; radio, 90 ; biscuits, 81.

It should be noted that before the war the full output of these industries supplied only part of the local civil demand. Now the civilians have had 10 to 30 per cent.—and fewer imports.

From the war production experience New Zealand has learned one thing of great value : that her people have technical skill which, properly applied and directed, may enable her to produce economically a variety of manufactured goods. Further, the cost handicap imposed by small establishments endeavouring to produce too many types of goods, or goods having too many components, can be overcome by speciali-zation in types, or, with precision measurement, division of production processes.

In the war these principles were applied under most favourable conditions. The Ministry of Supply and Munitions as a centre guided and helped coordination and cooperation. Acting in close association with committees from the various industries, the Ministry was able to place contracts to obtain the greatest output and the most economical use of manufacturing power. How far this experience may be applied for peace production without destruction of competitive enterprise has yet to be discovered ; but at least it may be stated that New Zealand has crowded into five years experience that she would not have acquired in 10 years of peace.

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SOUTH AFRICAN SUPPLIES

SOUTH AFRICA'S war production, which at two stages of the war contributed substantially to victory, was made possible by the fillip to local industries given by the war of 1914-18. During that war, cut off from oversea supplies, our numbers of factories and operatives nearly doubled themselves. The following table tells the story :—

Year	No. of Factories	No. of Employees	
		European	Other
1915-16	3,998	39,524	61,654
1919-20	6,890	62,483	113,037

(There are no reliable statistics for the years before 1915-16, the South African Industrial Census having been established only in 1917.)

That modest spurt was followed by a modest but consistent advance until the beginning of the thirties, when the South African Iron and Steel Corporation (Iscor) began serious production. Iscor, which would have been impossible without the encouragement given to South African enter-prise by the war of 1914-18, was the foundation of the Union's production in the war. It has three blast furnaces in operation, smelting half a million tons of South African ore a year ; and with its ancillary works it has turned, during the past five years, to the production of special steels which would have been far beyond its ambition in normal times.

With this firm basis, South Africa was able gradually to build up a production of guns, shells, bombs, and engineering components which, although light by European and American standards, was a godsend to allied commanders in the Middle East and Burma because of its accessibility.

South Africa contributed very heavily towards the arming of her own troops in North Africa and the Western Desert through her production of two-pounder—and later six-pounder—anti-tank guns, howitzers, armoured fighting vehicles (on imported chassis), mortars and mortar bombs, aerial bombs, and ammunition. Towards the end of 1941, when things were decidedly " sticky " in the Western Desert, a special appeal was made to South Africa for mechanics to repair tanks, and the required number was sent off within 48 hours. Later the Union itself became the repair shop of the Middle East, turning out big stocks of spare parts for vehicles, tanks, guns, and planes, and undertaking emergency repairs on small but important parts flown from Egypt. These productions and repairs helped to ease the strain on allied shipping, which until the fall of Tunisia was forced to use the Cape route. Throughout that period repairs were constantly being made to allied ships in South African ports. It was recently disclosed that more than 12,000 ships received minor or major repairs here.

Later, when the restored freedom of the Mediterranean reduced the importance to the Middle East of South African production, it was possible to supplement the production of Indian factories to the eventual discomfiture of the Japanese in Burma. In 1944 South Africa was asked to supply howitzers and mortars, with ammunition, to the Indian theatre, as well as large quantities of 25-pounder ammunition. These supplies, at a time when Britain's domestic production was needed in Europe, and Australian in the South-West Pacific, were a useful contribution to the Fourteenth Army's equipment.

According to the latest figures, issued towards the end of 1944, the Union's war deliveries had included more than 50,000 tons of shells and shell-cases, more than 28,000 tons of mortar bombs, grenades, and land-mines, almost 20,000 tons of small arms ammunition, more than 70,000 tons of high-explosive bombs (including 1,000-pounders), more than 6,000,000 pairs of Army boots, more than 4,500,000 blankets, and more than 14,000,000 items of personal equipment and clothing. The output of explosives was one of South Africa's " best achievements."

This achievement was made possible by the centralization of orders for war supplies in the hands of the Director of War Supplies, Dr. H. J. van der Bijl, head of Iscor. His office coordinated both requisitioning and the dispersal of production throughout the many small factories in the country. South Africa had little experience in arms production at the outbreak of war, and had to use talent where she could find it. Iscor, the South African Railways workshops, and the workshops of the goldmines provided a foundation for the heavier work, but small parts were made wherever there were machines ; and where there were no machines they had to be improvised. Fortunately, South African engineers displayed

Women assembling hand grenades in a South African factory. The output of explosives was one of the Union's most useful contributions to the war effort.

a talent at improvisation which surprised themselves as much as it served the country.

Coordination of production was assisted by a control of man-power so rigid that it amounted almost to the conscription of labour. Artisans could be ordered to work at specified jobs, and could not change their employment without leave from the Controller of Man-power. Shortage of skilled labour was made up by the employment of women and by the rapid training of young men both for industrial work and for the army technical services. This training has proved one of the most valuable lessons of the industrial emergency caused by the war. It has shown that suitable young men can be trained to reasonably high efficiency in a few months in trades where the normal apprenticeship period runs into years. This system will be continued in the Government's present drive to repair the country's desperate shortage of housing. Whether it will survive in other trades, or in the building trade survive the housing emergency, it is impossible to predict. The trade unions have a strong vested interest in the apprenticeship system.

Owing to the political divisions of the country, as well as the presence of several millions of Africans, most of them illiterate, there was little direct rationing. Petrol, tyres, and motor vehicles were rationed directly. Raw materials were rigidly controlled. Foods like butter and tea were bulk rationed by the device of allowing tradesmen varying quotas of their average pre-war sales. New electric refrigerators, stoves, garden hose, and so on were unobtainable. Clothing was unrationed but dear. The Government has consistently declared that the benefits of rationing food and clothes would be offset by the difficulties created by our mixed population.

Now that the worst of the emergency is over South Africa is satisfied that her engineers and factories have performed a miracle of production. Some of this production would have been uneconomic in normal times, but skills have been learnt and ambitions created which will result in the maintenance of a high level of production in the future. But this development should not impair the prospects of British exports to the Union. Increased South African production after the war of 1914-18 was accompanied by increased imports from Britain ; and the present hunger of the country for commodities of all kinds, whether produced locally or not, is such that for a time at least persuasion will be an unnecessary component of salesmanship.

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NORTHERN IRELAND'S WAR EFFORT

Northern Ireland's contribution to the war effort of the United Kingdom comes under two main headings. The first was strategic. The denial of the naval bases in southern Ireland and Lough Swilly in Donegal was a crippling handicap to the forces engaged in keeping open the Atlantic routes, but Northern Ireland prevented it from becoming disastrous. It became the advanced base covering the Western Approaches, but for which it is doubtful whether the enemy could not have made the Clyde and Mersey ports virtually unusable.

The second contribution came from the basic industries of the country or their developments under the stress of war ; agriculture, shipbuilding, textiles (with their concomitant of shirtmaking), rope, tobacco manufacture, and machinery. These industries are relatively few, but specialization made them among the most important of their kind. For instance, the bulk of all the shirts worn in the services and by civilians came from round about Londonderry. Extraordinary adaptations were made in the linen mills, which became the chief providers of tentage. The story could be greatly extended.

Sir Basil Brooke, Prime Minister of Northern Ireland, gave details of the province's war effort in the House of Commons on July 24, 1945. Figures he quoted included :—

AGRICULTURE.—The province sent £3,000,000 worth of fat sheep and cattle to Britain annually during the war and provided 20 per cent. of her home produced eggs.

SHIPBUILDING.—Belfast constructed 140 warships and 123 merchant vessels. The merchant shipping represented approximately 600,000 tons, or 10 per cent. of the total merchant building of the United Kingdom.

ARMAMENTS.—For the Army, Northern Ireland produced nearly 500 tanks and over 500 guns, 14,000 gun-barrels and other gun parts, 42,000 carbine machine-guns, and approximately 75,000,000 shells.

AIRCRAFT.—The province had constructed 1,500 heavy bombers and carried out repairs to approximately 3,000 heavy, medium, and light aircraft.

TEXTILES.—Over 2,000,000 yards of cloth for the services had been woven and over 30,000,000 shirts made. Belfast ropeworks had produced 250,000 tons of rope, 500,000 camouflage and cargo nets, and tens of millions of yards of twine and whipcord.

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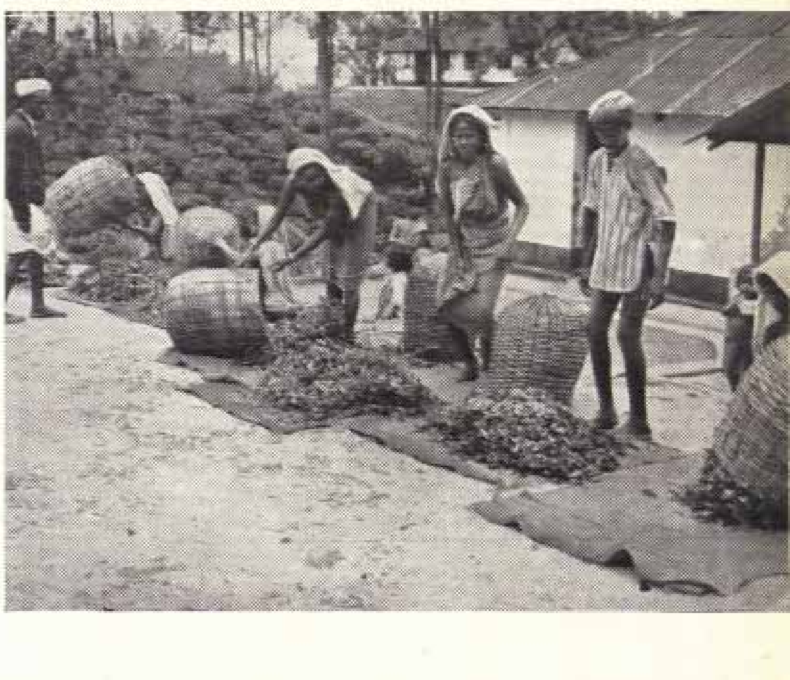
FOOD AND RAW MATERIALS FROM THE COLONIES

THE British colonies are agricultural communities whose peace-time economy was based on the production of crops for the export market. The war thus exposed them to a double strain. The interruption of communications and the shortage of shipping compelled them to grow subsistence crops to replace foodstuffs previously imported; and their export production was restricted or diverted to crops which had a value for war purposes, the new and urgent demand leading sometimes to the intensification of previous agricultural practice and sometimes to the development of fresh branches of culture.

The far-reaching character of the adjustments involved is illustrated by the experience of Ceylon. After the Japanese conquest of Burma, Ceylon set out to make herself as independent as possible of rice imports. By August, 1943, 450,000 acres of land were brought under cultivation, principally with rice—an expansion which involved irrigation works on a large scale—and by 1944 there were three Government rice mills, the largest of which produced about 25,000 bushels a month. By this effort Ceylon was able to produce enough rice to meet half her normal domestic rice requirements. Supplementary foodstuff production included the production of yams, cereals, beans, fruits, sugar, ginger, chillies, onions, and tumeric. Local fisheries were also developed.

The principal Ceylonese export was tea, and after the loss of the Netherlands East Indies in 1942 the whole of the colony's exportable surplus was bought by the British Ministry of Food and allocated by the Combined Food Board. After tea, coconuts were in peace-time the most important of Ceylon's agricultural products. The war brought developments of the processing industries dependent upon this crop, such as copra, coconut oil, desiccated coconut, and coir. Cinnamon and plumbago, being used in the manufacture of munitions, were also in increased demand, but the chief call was on the island's rubber supplies which, after the fall of Malaya, became of crucial importance to the United Nations. At the beginning of the war Ceylon was producing about 7 per cent. of the world's rubber. After the loss of the Far Eastern sources of rubber supplies to Japan every effort was made to increase production to the maximum, to the extent of "slaughter tapping"—tapping the rubber trees so intensively as to exhaust the trees within two years. As a result records in rubber production were achieved in 1942 and 1943.

All this expansion of agricultural activities would in normal times have involved the importation of considerable quantities of agricultural machinery, but war conditions drove Ceylon back on her own potential resources and the war years consequently saw a notable development of secondary industries. A steel rolling



Coolies on a tea estate in Ceylon emptying their baskets of leaves after picking. The whole of Ceylon's exportable surplus of tea was bought by the British Ministry of Food and allocated by the Combined Food Board.

mill was erected in 1941 at a cost of 270,000 rupees to turn scrap metal into hoop iron, steel bars, nuts, bolts, and rivets. A plywood factory, using locally made glue, was opened in November, 1941, and in the following year textile mills and a bleaching and dyeing works were started at Colombo to produce war materials from yarn imported from India. Other local industries were established for the production of wallpaper and writing paper from the citronella grass which grows on the island, for twine, condensed milk, rubber and leather goods, cement, acetic acid, quinine, glass, pottery, and chinaware. The people of Ceylon even found plants from which to produce dyes to replace those previously imported from Germany.

In the West Indies the main objective was self-sufficiency in foodstuffs, and as the population of the West Indian Colonies is about 3,000,000 and the value of imported foodstuffs had exceeded £2 a head, success in their enterprise notably eased the strain on the Empire's shipping. The new sources of production called for a new marketing organization, which was rendered specially difficult in the larger colonies of British Guiana and Jamaica by the shortage of both petrol and vehicles and even in oil-rich Trinidad by the lack of tyres and spare parts. There was a good deal of local friction, but in the end the problem of distribution was resolutely attacked.

In Jamaica the Department of Commerce and Industry, established in 1943, organized 130 marketing depôts all over the island, operated a cornmeal factory and controlled a cassava flour mill. Other processing activities, including the curing of local hams and bacon and the manufacture of lime oil, offer new openings to labour in an island suffering from over-population.

Even more significant for the future was the effort of the Caribbean colonies to supplement one another's deficiencies, mainly through the operations of the schooner-pool, thanks to which local sea-going transport was turned to the best account.

British Guiana, the only Caribbean colony well suited to rice culture, set itself to extend production in order to replace some of the former imports from Burma. It also aimed at meeting deficiencies in meat supplies. Here as elsewhere the sugar estates were called upon to divert part of their acreage to other food production, and responded by raising 6,000 pigs and fattening 2,000 cattle besides planting 6,000 acres with vegetables. The colony's area under food crops doubled between 1940 and 1943.

Jamaica went rather farther. Its food acreage in the same three years rose from 80,000 to over 200,000, and it was able to dispense with imports of rice. The island contains good grazing ground, and in a drive to raise the quality of livestock 42 centres were established to direct improvements in the breed of cattle, sheep, goats, and pigs.

Grow More Food campaigns were started in most of the islands with seeds, and demonstrations to back a vigorous propaganda. In Barbados the acreage under sugar which was diverted to food production by official order gradually rose from 5 per cent. to 35 per cent. and smallholders were similarly ordered to plant 25 per cent. of their holdings with vegetables. The Government built and ran a factory to manufacture cassava and sweet potato flour and the island was eventually able to substitute home-grown carbohydrates for its imports of rice. Trinidad set up a Food Control Department which broke new ground by taking over abandoned cocoa lands near villages and cutting them up into allotments ; the oil companies helped by planting large vegetable gardens ; and the small island of Tobago, which is governed from Trinidad, had managed by 1943 to double its food exports to its larger neighbour in spite of transport difficulties.

Similar policies were pursued in the smaller islands, several of which also increased their production of Sea Island cotton, used not only for clothing and equipment but as a substitute for silk in barrage balloons. British Honduras, British Guiana, and Trinidad tapped wild rubber and the two last colonies drew lavishly on their mineral resources, British Guiana on its bauxite and Trinidad on its oil. Since, in the earlier stages of the war, there was a considerable diversion of labour from agriculture to work on the new American bases, the total contribution, direct and indirect, of the Caribbean colonies to the Empire's war effort was worthy of their ancient loyalty. The same may be said of another island-colony, Mauritius, on the other side of the world. By 1943 Mauritius had diverted over 34,000 acres from sugar to vegetables, and was planning to be self-sufficient in rice and tea and substantially to reduce its imports of flour.

The group of colonies in East, West and Central Africa provides some of the more romantic episodes of the war effort. Before 1939 little

Inspecting sheets of rubber processed in a village factory in the Gold Coast. After the Japanese occupation of Malaya great efforts were made to organize the production of rubber in many parts of Africa.

rubber was produced in Africa. Wild rubber was hardly touched and in face of competition from Malaya many planters had turned their land over from rubber to sisal. In 1942 such experts from Malaya as had escaped the Japanese invasion were sent to African territories to help organize the collection of rubber wherever it might be found. Native chiefs were enrolled to lend their aid and very large quantities were obtained. To get the necessary labour, recruiting campaigns were started and European supervisors trained unskilled labour in Tanganyika at tapping schools which were organized for workers in various parts of the territory. In the Gold Coast a school was established at Konongo at which young men were trained in the art of tapping and processing rubber.

Schoolchildren in the Gold Coast competed in rubber collection drives. One school collected more than 200lb. by tapping local trees, while another school processed the rubber thus collected. The Ministry of Supply sent a special message of thanks to Sierra Leone for its work in collecting and shipping rubber during 1944, and Tanganyika Territory has the credit of discovering and utilizing unpacked machinery which the German planters had left some 30 years before.

With campaigns being fought in malarial regions, the war against the mosquito is as important as the war against human enemies of the Empire, and for that war an essential insecticide is made from pyrethrum, a daisylike flower whose pink and red varieties adorn herbaceous borders in Britain. Before the war, Japan was the world's leading producer of pyrethrum. Another important source was the Caucasus, where the plantations were overrun by the Germans during their advance into Russia.

Kenya filled the gap created in these two main sources of supply, becoming the United Nations' principal supplier of this plant. From 6,000 acres planted with pyrethrum in 1938, the area of cultivation was increased to 40,000 acres in 1943, and in August that year the United Kingdom Ministry of Supply agreed to purchase up to the end of 1947 the produce of a maximum of 50,000 acres. Kenya also supplied consignments of seed of the pyrethrum plant to a number of allied and Empire countries, Russia, Brazil, India, and Australia among them. Another pestilential insect, the locust, as dangerous to vegetation as the mosquito to man, was dealt with by a co-operative effort in which both East and West African colonies took a part. By March, 1944, anti-locust measures were in force on a scale never before attempted.

Besides reducing their imports of food to a minimum the African Colonies contributed to the war effort many thousands of tons of rubber, wheat, maize, tea, sugar, cotton, coffee, wool, flax, copra, minerals, timber, paper, quinine, oil seeds, and hides. Our supplies of margarine, soap, lubricants, and glycerine came very largely from an intensification of production of palm oil, palm kernels, and ground nuts from West Africa. Iron ore from Sierra Leone, manganese and peroxide from the Gold Coast and tin from Nigeria all contributed to the allied victory in Europe as well as to victory over the Japanese. In addition to exporting coal to neighbouring territories Nigeria's timber production, doubled since 1939, was used in the extensive building programme made necessary in West Africa by the arrival of large military, naval and air forces. Cocoa from West Africa is now being used to help feed liberated Europe.

Picking pyrethrum flowers in Kenya Colony. An essential insecticide is made from them and large consignments of seeds were supplied by Kenya during the war. Before the war Japan was the leading producer.

In East Africa the dehydration plants at Kerugoya and Karatina in Kenya employed 5,000 Africans, previously unskilled, who had been trained to handle complicated machinery, and bought vegetables from nearly 10,000 African farmers, many of whom had to be taught to cultivate unfamiliar plants. Kenya introduced flax growing and had 32 processing factories in operation by the end of 1940. Uganda helped to meet the needs of troops, prisoners of war, and refugees by exporting maize, bananas, and livestock to the neighbouring colonies and received the thanks of the United States Board of Economic Welfare for its increased production of tantalite and columbite.

Tanganyika inoculated over 4,500,000 head of cattle against rinderpest, built up its total of livestock to over 6,000,000, sold 100,000 head to a factory in Kenya which was supplying food to the forces in the Middle East, and increased its export of tanned leather fourteenfold in four years. After the loss of the Philippines had deprived the Allies of manila hemp East Africa grew sisal for ropes and twines, particularly binder twine, and the Kenya and Uganda railways gave further variety to the list of East African products by building lorries, ambulances, armoured cars, petrol tanks, and wagons, trench mortars, and land mines.

Africa was an important source of metals. When the demand was at its height the Northern Rhodesian mines worked a 24-hour day in order to meet copper requirements. The Gold Coast was given, and attained a target of 1,000,000 tons of manganese for 1944, as against 700,000 tons two years earlier, and in the same year was called on to produce 400,000 tons of bauxite, as against 180,000 tons in 1943 and 70,000 in 1942. In the previous year deposits of bauxite were opened up at a site 60 miles from the railhead at Dunkwa, which is itself 120 miles from the port of Takoradi. Production and transport involved the building of roads, railways, bridges, viaducts, and the cutting of roadways through the bush before complete surveys could be made, and the extensive development of port installations and dumping sites. It meant also the scouring of West Africa for mining and excavating equipment, rolling stock of all kinds and, of course, the enrolment of a great volume of African labour.

When demand began to exceed the capacity of transport from the first mine, a second mine, capable of producing half of the total required for 1944, was opened at a point three miles from the Accra-Kumasi railway, to which the material was conveyed by ropeway. By such imaginative improvisations as these the war was won.

The production of finished goods was naturally on a more limited scale. In the earlier phase of the war a Ministry of Supply mission had found in Hong-kong capacity for the manufacture of heavy presses, minesweepers, Diesel truck engines, scientific instruments, hospital equipment, optical glass to a total of 4,000 binoculars a month, telephone sets, and barbed wire. The tragic loss of the colony cut off these important

supplies, and in the later stages of the war Palestine came into the foreground for the output of industrial products. In the three years 1939-1942 the number of industrial establishments rose from 1,217 to 3,470, and the number of persons employed in them from 20,000 to nearly 50,000. There was further expansion in subsequent years, and the orders placed, often running into hundreds of thousands of units, covered stoves, pumps, electric cable, glass insulators, uniforms, camouflage nets, tarpaulins, tents, crockery, bottles, mess-tins, boots, medical supplies, concentrated fruit juices, fertilizers, and chemicals.

It must not be supposed that the varied activities of upwards of 50 territories, occupying one twenty-fourth of the earth's surface, will cease with the disappearance of the emergency which induced them. The war has raised the level of productivity in the Colonies and left them better equipped for progress in a world of expanding trade. While diminishing their dependence on imported foodstuffs, it has increased their exports, improved their storage facilities and marketing organizations, and fostered secondary industries. It has taught the need for co-operation between the various departments concerned with aspects of agricultural life and of all those departments with the health and education authorities. Most significantly of all, it has led to the establishment in many colonies of development and planning committees to which peace will bring new opportunities for furthering the public welfare.

The mining of bauxite in British Guiana. The output of this raw material for aluminium was greatly increased during the war years.

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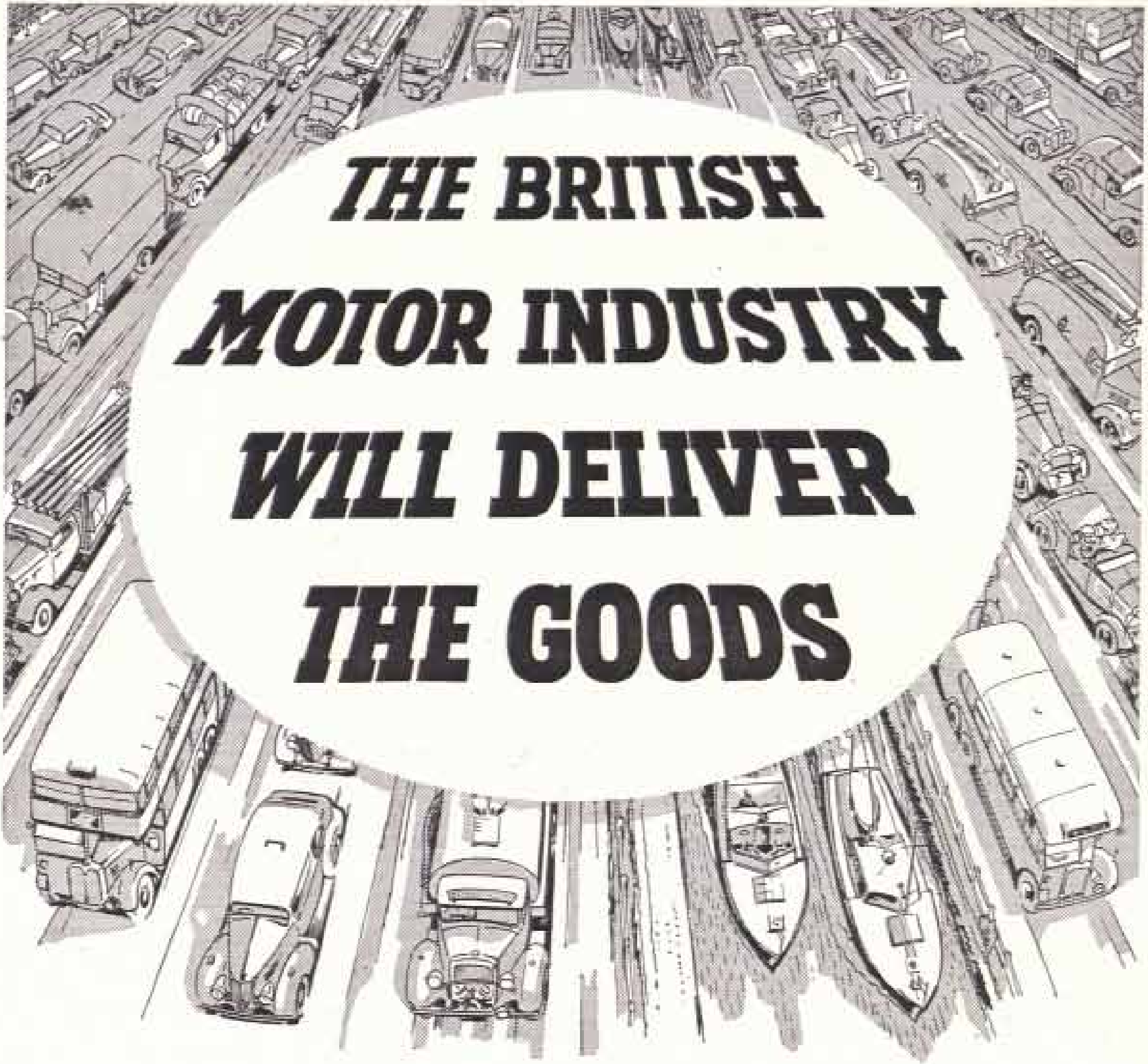

ALL the precision craftsmanship that went into the output of war equipment produced by the British Motor Industry will be reflected in the motor vehicles Britain is planning to send to the markets of the world.

The British Motor Industry is also building commercial and passenger vehicles to meet the specialised needs of operators overseas. Manufacturers who have solved the problem of tank and truck production during five-and-a-half years of war have gained valuable experience which they intend to turn to peacetime account.

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82, VICTORIA STREET, LONDON, S.W.1

Future of

ALUMINIUM

To meet the military requirements of the United Nations, the productive capacity of the aluminium industry has been expanded to many times its pre-war level. Present capacity is far in excess of industrial demand in 1939. Aluminium Limited, nevertheless, believes that it would be unjustifiable defeatism to turn back to the pre-war level of production and consumption. Instead, ambitious plans and optimism for the future appear justified by the following circumstances :

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From Wooden Walls ...to Ships of Steel

Throughout her long history Britain has always built the best ships, whether for peace or war. In the days of Elizabeth she made "the wooden walls of England" to guard her coasts and created the ships that took her merchant adventurers across the seven seas.

As the pioneer of the industrial revolution, Britain led the way in the transition from sail to steam, and it was in her shipyards that both the liner and the battleship were born.

In the winning of two wars against the same relentless foe the British Shipbuilding Industry has played a predominant part. Victory has again been won largely by its great contribution in building and repairing under handicaps, on the enemy's doorstep, such as no other nation has endured and in the pooling of its unrivalled skill, knowledge and experience.

First and Foremost

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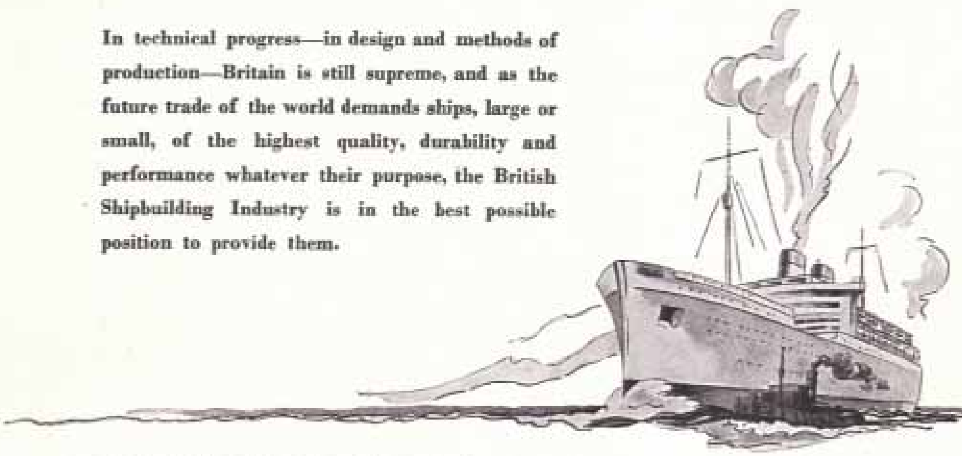
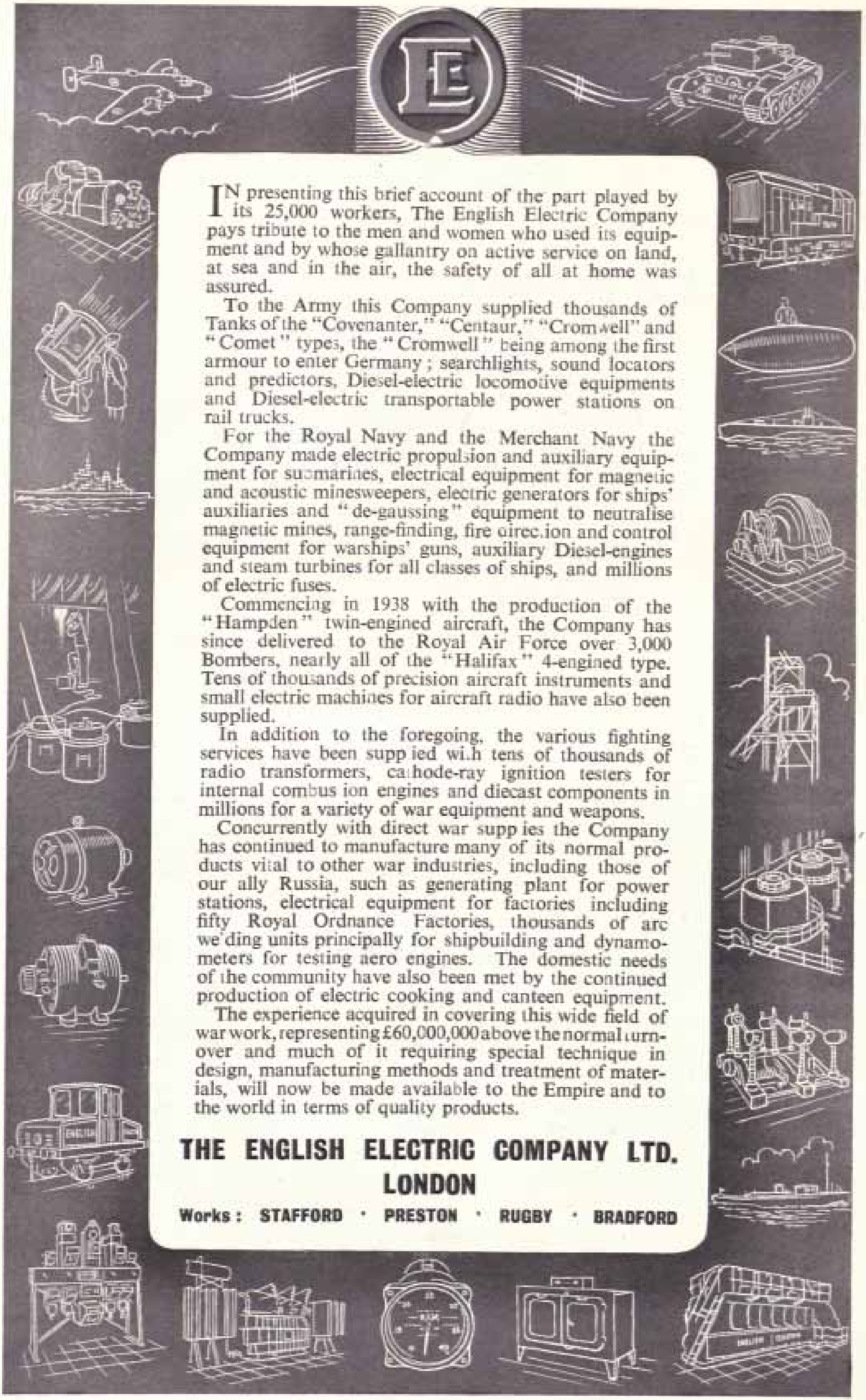
In technical progress—in design and methods of production—Britain is still supreme, and as the future trade of the world demands ships, large or small, of the highest quality, durability and performance whatever their purpose, the British Shipbuilding Industry is in the best possible position to provide them.



ISSUED BY THE SHIPBUILDING CONFERENCE, 21, GROSVENOR PLACE, LONDON, S.W.1.


IN presenting this brief account of the part played by its 25,000 workers, The English Electric Company pays tribute to the men and women who used its equipment and by whose gallantry on active service on land, at sea and in the air, the safety of all at home was assured.
To the Army this Company supplied thousands of Tanks of the "Covenanter," "Centaur," "Cromwell" and "Comet" types, the "Cromwell" being among the first armour to enter Germany; searchlights, sound locators and predictors, Diesel-electric locomotive equipments and Diesel-electric transportable power stations on rail trucks.
For the Royal Navy and the Merchant Navy the Company made electric propulsion and auxiliary equipment for submarines, electrical equipment for magnetic and acoustic minesweepers, electric generators for ships' auxiliaries and "de-gaussing" equipment to neutralise magnetic mines, range-finding, fire direction and control equipment for warships' guns, auxiliary Diesel-engines and steam turbines for all classes of ships, and millions of electric fuses.
Commencing in 1938 with the production of the "Hampden" twin-engined aircraft, the Company has since delivered to the Royal Air Force over 3,000 Bombers, nearly all of the "Halifax" 4-engined type. Tens of thousands of precision aircraft instruments and small electric machines for aircraft radio have also been supplied.
In addition to the foregoing, the various fighting services have been supplied with tens of thousands of radio transformers, cathode-ray ignition testers for internal combustion engines and diecast components in millions for a variety of war equipment and weapons.
Concurrently with direct war supplies the Company has continued to manufacture many of its normal products vital to other war industries, including those of our ally Russia, such as generating plant for power stations, electrical equipment for factories including fifty Royal Ordnance Factories, thousands of arc welding units principally for shipbuilding and dynamometers for testing aero engines. The domestic needs of the community have also been met by the continued production of electric cooking and canteen equipment.
The experience acquired in covering this wide field of war work, representing £60,000,000 above the normal turnover and much of it requiring special technique in design, manufacturing methods and treatment of materials, will now be made available to the Empire and to the world in terms of quality products.
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LONDON
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Lend-lease of an idea . . .

The advertisement from " Fortune " reproduced above is an American tribute to the success of the Mosquito and the work of British research workers. In 1939 B.I.P. chemists produced the first cold-setting, gap-filling, water resistant synthetic resin—Beetle Cement A. It was this cement which made possible the world's fastest bomber—a machine built of resin-bonded wood. One man (with the vital formula) sent across the Atlantic assured for the builders of the Canadian Mosquito all the supplies they needed of this essential adhesive—and from a North American works. The familiar phrase " Mosquito bombers were over Germany *in strength* last night " was true in more senses than one, as many other industries are discovering when they apply Beetle Cements to their own material problems of bonding and binding.

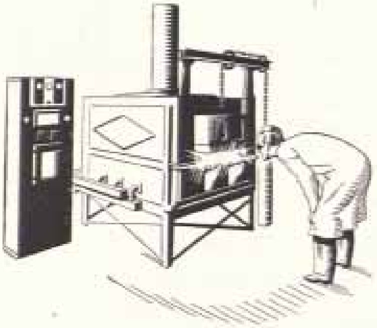
The B.I.P. Group of companies have specialised in amino-plastics. In 1926 they produced Beetle, the world's first white moulding powder, and their leadership in urea resins has been maintained. Their urea and melamine plastic products now include mouldstuffs, adhesive resins and cements, resins for paper making, textile treatment, coatings. Other divisions make plastic moulds and mouldings.

BRITISH INDUSTRIAL PLASTICS LTD., 1 ARGYLL STREET LONDON W.1.

At the service of the Peoples of the World

BRITISH IRON & STEEL

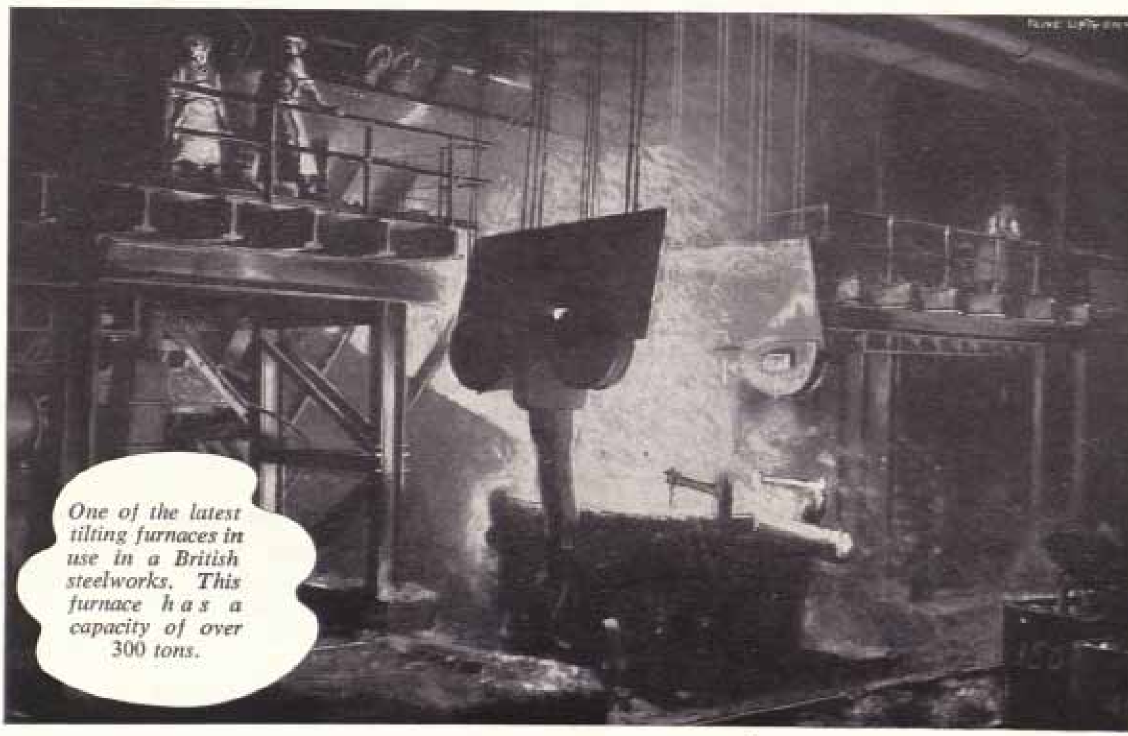
British Science, the greatest source of progress in the world's steel industry



Charles Schwab, the great American Ironmaster, has said : "In the steel industry every great invention had its origin in Great Britain." This inventive capacity has helped to maintain British world leadership in the production of high quality steels for every purpose. Here you see a scientist studying the properties of a steel which later will be produced in thousands of tons.

—And Britain's steel production is now the greatest in her history

Whether for war or peace, the most modern equipment is used in Britain to produce millions of tons of steel. All of it is tested and re-tested for quality and properties before it goes to the waiting world. The British Iron and Steel Industry has a full-time job on hand at present but is glad to be back with old friends again.



One of the latest tilting furnaces in use in a British steelworks. This furnace has a capacity of over 300 tons.

The greatest Naval tonnage under construction at any time in a British yard was at the Naval Yard of Vickers-Armstrongs Limited, Newcastle-upon-Tyne.

★ ★

The Vickers Group of Companies has established a pre-eminent world-wide reputation. Its contribution to the War effort in Warships, Armaments, Aircraft, Steel, and many other products represents an outstanding industrial achievement.

The vast resources and activities of the Group will be applied with equal vigour to the heavy tasks of post-war reconstruction.

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B T-H

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The British Thomson-Houston Co. throughout these six years of war has strained every nerve and sinew to provide more, more, and yet more, munitions of all kinds for the ultimate destruction of the horror which has threatened the entire world.

Not yet can the full story be told of the miracles which were achieved, the disappointments, the problems which were solved in connection with such things as Radar, Jet Propulsion, and many devices for the Admiralty, Army, and Air Force, which must still be kept secret.

The BTH Co. in turning from war to peace, will be able to provide a large proportion of the electrical equipment used in industry, including turbo-alternators, generators, switchgear, transformers, rectifiers, mining and rolling mill machinery, motors, control gear including electronic and amplidyne control, Mazda lamps of all types including fluorescent lamps, lighting fittings, and many other products.

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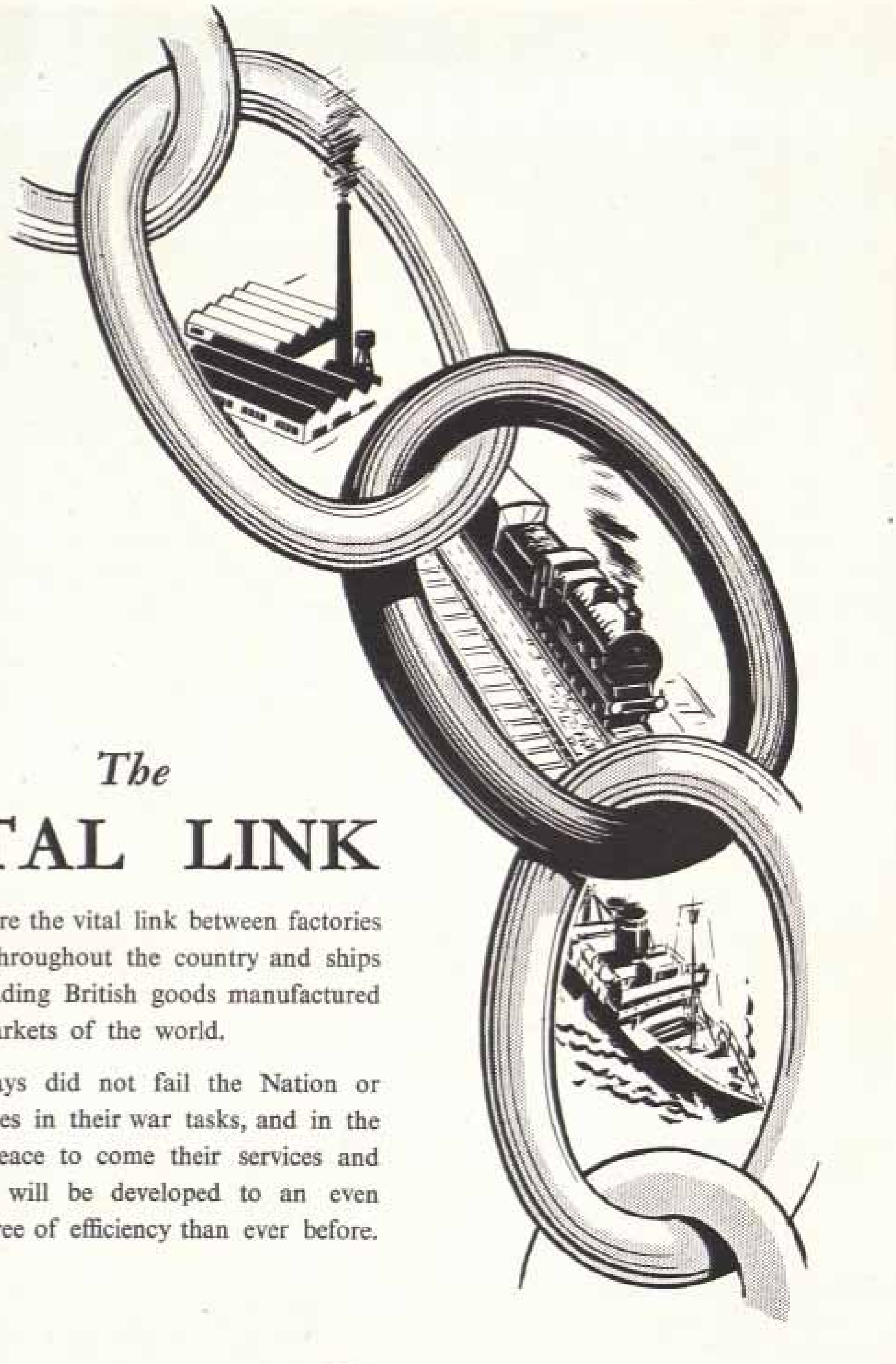


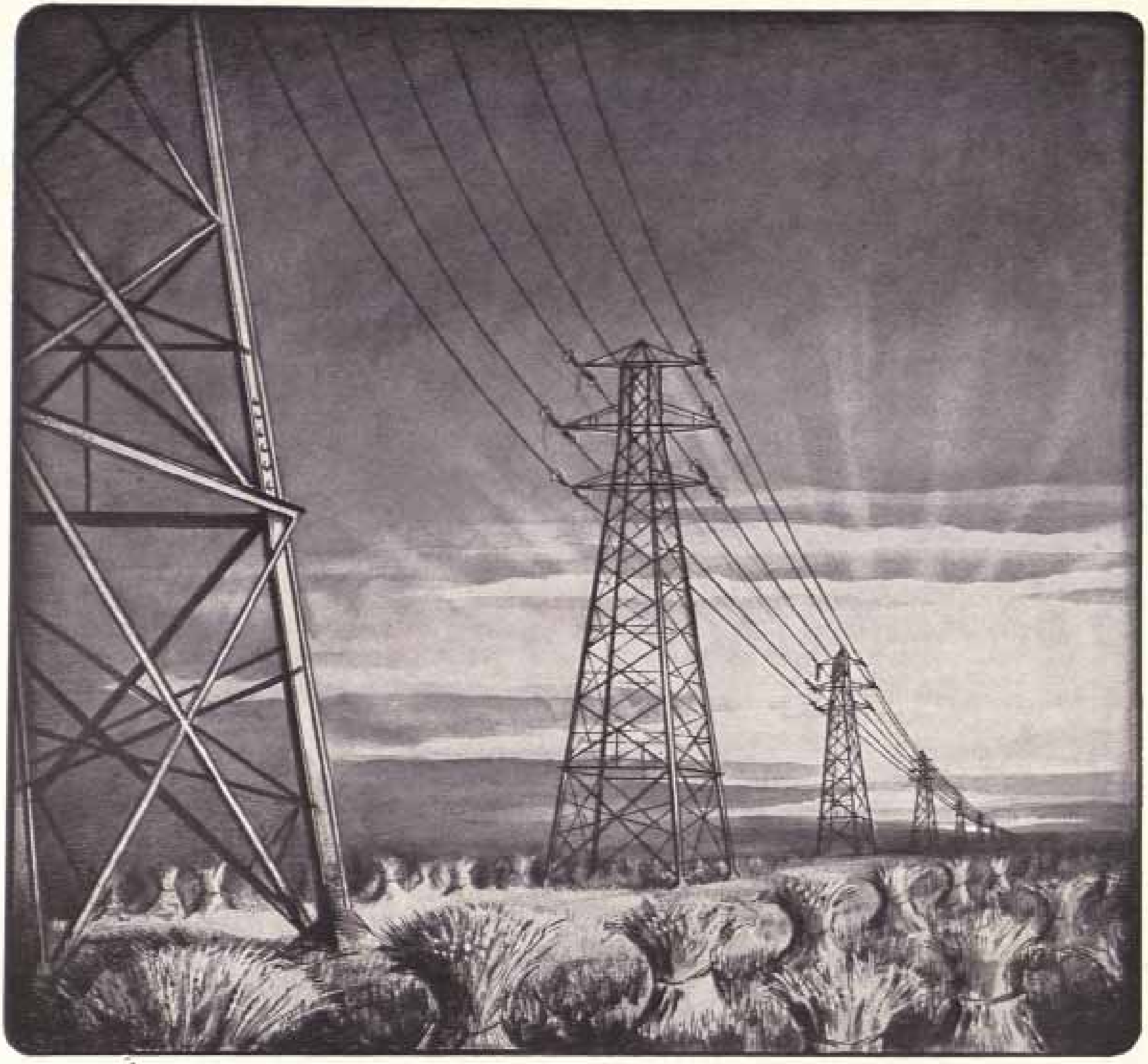
The

VITAL LINK

Railways are the vital link between factories scattered throughout the country and ships in port loading British goods manufactured for the markets of the world.

The railways did not fail the Nation or armed forces in their war tasks, and in the years of peace to come their services and equipment will be developed to an even higher degree of efficiency than ever before.

GWR · LMS LNER · SR



WINNING THE PEACE

An epic effort comparable in every way to that which secured final victory is demanded of industry for civilisation to win the peace. The amazing inventions elicited by the great emergency must now be applied to the complex and urgent tasks of reconstruction.

The Company is proud of its great war contribution in all applications of electricity, including the important one of electronics; and universally enriched as a result of the experience gained, goes forth to the tasks of reconstruction.

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THE GENERAL ELECTRIC COMPANY LIMITED OF ENGLAND

THE CABLE MAKERS ASSOCIATION WAS FOUNDED IN THE YEAR 1900 BY THE PIONEER FIRMS IN THE ELECTRICAL CABLE-MAKING INDUSTRY OF GREAT BRITAIN.

ITS POLICY WAS TO STANDARDISE THE PRODUCTS OF THE INDUSTRY, TO FOSTER THE PRODUCTION AND USE OF THE HIGHEST ATTAINABLE QUALITIES FOR ALL PERMANENT PURPOSES, AND TO INSTITUTE SYSTEMATIC AND CO-OPERATIVE SCIENTIFIC RESEARCH WITH THE OBJECT OF CONTINUOUSLY SECURING EVERY POSSIBLE IMPROVEMENT IN THE CONSTRUCTION OF ELECTRICAL CABLES OF EVERY TYPE. THIS POLICY HAS BEEN CONSISTENTLY FOLLOWED AND IT MAY JUSTLY BE CLAIMED THAT "C.M.A." BRANDS OF CABLE ARE ACCEPTED THROUGHOUT THE WORLD AS SETTING THE HIGHEST KNOWN STANDARDS OF PERFORMANCE AND RELIABILITY.

DURING THE WAR THE GREAT EXPERIENCE AND RESOURCES OF THE ASSOCIATION HAVE BEEN PLACED FULLY AND UNRESERVEDLY AT THE DISPOSAL OF ALL CABLE PRODUCERS SERVING THE MILITARY NEEDS OF THE UNITED NATIONS.

NOW THAT INDUSTRY IS REVERTING TO THE TASKS OF CIVIL REHABILITATION AND RECONSTRUCTION, THE CABLE MAKERS ASSOCIATION TAKES THIS OPPORTUNITY OF REAFFIRMING ITS LONG-ESTABLISHED POLICY AND OF ASSURING USERS OF ITS PRODUCTS THAT THEY WILL BE SERVED BY CABLES OF UNSURPASSED QUALITY FOR EVERY GENERAL AND SPECIALISED ELECTRICAL PURPOSE.

Y. Y. Purves

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HIGH HOLBORN HOUSE, 52-54, HIGH HOLBORN, LONDON, W.C.1.

"OVER TO YOU . . . ."

TOTAL victory in total war is clear proof and the vindication of a successful communication system. It would have been impossible to plan the long and arduous campaigns of the World War, impossible to bring the plans to fruition, without the patient, reliable and skilful work of thousands engaged in telecommunications across the vast theatres of war, and without the unremitting research and labour of the industry which supplied the communications equipment.

The telecommunications industry in Britain has been, from the beginning, a vital factor in the nation's war effort; and so it will remain, for its work is just as essential now that the Far Eastern enemy too is defeated. For six years the industry's capacities have been devoted unreservedly to the prosecution of the war. A great deal of its work was, of necessity, cloaked by a strong security silence during much of this period. Efficient communications in war are secret communications; and there were, in addition, whole sides of the industry's work—"alien products" the industry called them, unromantically—about which no hint could be allowed to escape, so long as a state of war continued.

Now something of the story may be told. The British telecommunication industry—working, as practically every factory in Great Britain had to work, under constant threat of air attack—supplied the vast bulk of signals and telephone equipment used by the Armed Forces of the Crown in the campaigns in the Western Desert, North Africa, Italy and North West Europe; it supplied, too, the equipment used in South East Asia, and the improvisation and perfection of the special processes to "tropicalise" this equipment (i.e. to adapt it to tropical use and protect it against the numerous ravages of a tropical climate) is not the least valuable of the achievements of the industry in this war.

The network of telecommunications, which was a vital part of the air defence of Great Britain in the Battle of Britain and onwards, was supplied by this industry: fighter pilot and control room, gun operations room and battery command post, Royal Observer Corps watcher on the coast, meteorologist, salvage and rescue party, roof-spotter, incident officer—everyone of the thousands engaged in the defence of these islands, from the first hit-and-run raid to the last V2, relied upon the telephone.

That reliance was so continuous and so undeviating as to be almost unremarked. In every kind of military operation, from the first exploratory conference, through blue-print stage and planning and training, to the last minutes before the assault, the communications system was there; and whatever other hitches might be expected, it had to be in efficient working order.

Whatever the war effort demanded of it, the industry performed. That is a record worth some pride. Extremely short of man power, with many of its best workmen and technicians on active service; working at constant high pressure; harassed by enemy action (the roof-spotters of one factory alone recorded 167 flying bombs within 24 hours, many of which dropped near it); with new and growing and changing demands upon it, the industry continued to produce the essential material required of it. That was all in the day's work. But, in addition, much of the industry's productive capacity was required for the development of weapons of war far outside its normal range. The transition was rapid and full-scale. The list of "alien products" turned out, for war purposes, by the telecommunication industry includes: aircraft electrical equipment and specialised wiring, the automatic pilot, the repeating compass, bomb release gear, A.A. predictors and gun dials, a very wide range of radio-location equipment for naval, military and air force use, navigational aids for the Royal Navy, air-field lighting devices used in "Fido," radio transmitters and receivers, Degaussing and "Asdic" equipment, apparatus for the generation of special sorts of radio interference, control equipment for H.M. ships, airfield control devices and lighting control, anti-submarine control gear, aircraft torpedo bomb lifts, shell hoists and conveyors for aircraft carriers. And even with all these the list is not exhaustive.

The industry proved itself, therefore, supremely adaptable as well as solidly reliable. It gave of its best, unstintingly, in technical skill, knowledge, research and experience, in war service. Now that the eastern enemy has been as completely vanquished as was the western, the industry will be able to devote itself once more to full-time service of the community. The knowledge and the improved technique it has acquired throughout the war will be unreservedly again at the disposal of the public, in the creation and development of post-war telecommunications. That, the industry well knows, is its true task—for the rebuilt world is going to rely, as never before, on its communications.

To that public service, which is the concern, not of one city, or of one nation, but of all peoples, the British telecommunication industry is dedicated. Its job had to be well done in war—and it was well done. It will be equally well done in peace.

ISSUED BY

TELECOMMUNICATION ENGINEERING & MANUFACTURING ASSOCIATION

ALDINE HOUSE, 10/13, BEDFORD STREET, STRAND, LONDON, W.C.2. *TEMPLE BAR 6824*

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The companies forming the four divisions of Tube Investments Ltd. provide a range of products and a wealth of engineering skills which, day in, day out, are being turned to good account in the service of industry.

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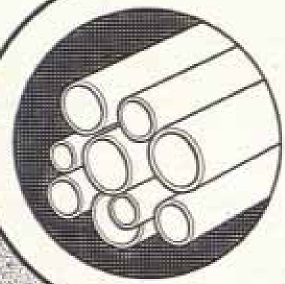

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Tube Products Limited, *Oldbury, Birmingham.*

Tube Rolling Mills Limited, *Wednesfield, Wolverhampton.*

Tubes Limited, *Rocky Lane, Aston, B'ham, 6.*

Weldless Steel Tube Co. Ltd., *Wednesfield, Wolverhampton.*

Aluminium Division

Hiduminium (Applications) Limited, *95, Farnham Road, Slough, Bucks.*

Hiduminium (British Exports) Limited, *5, Buckingham Place, Westminster, S.W.1.*

Reynolds Rolling Mills Limited, *Hay Hall Works, Tyseley, Birmingham, 11.*

Reynolds Tube Company Limited, *Hay Hall Works, Tyseley, Birmingham, 11.*

Cycle Division

Armstrong Cycles Ltd., *Sampson Road North, Birmingham, 11.*

Brampton Fittings Ltd., *Broadwell Works, Oldbury, Birmingham.*

Norman Cycles Ltd., *Beaver Road, Ashford, Kent.*

J. A. Phillips & Co. Ltd., *Credenda Works, Smethwick, Birmingham.*

Walton and Brown Ltd., *Phœnix Works, Downing St., Handsworth, Birmingham, 21.*

Electrical Division

Gowshalls Limited, *St. Paul's Street, Walsall, Staffs.*

Mersey Cable Works, *Linacre Lane, Bootle, Liverpool.*

Metallic Seamless Tube Co. Ltd., *Ludgate Hill, Birmingham, 3.*

Simplex Electric Company Ltd., *Broadwell Works, Oldbury, Birmingham.*

Associated Companies Overseas

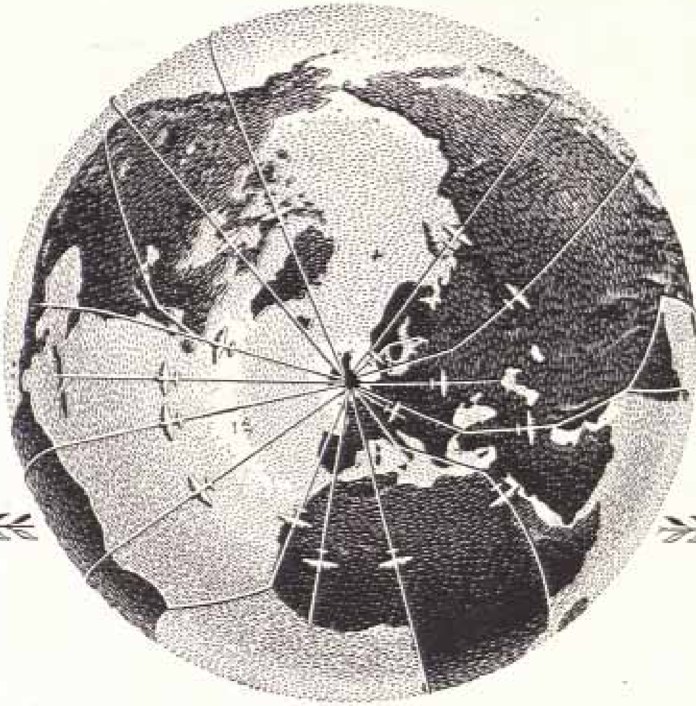
British Tube Mills (Australia) Pty. Ltd., *Adelaide, South Australia.*

British Tube Mills (South Africa) Pty. Ltd., *Johannesburg, South Africa.*

Simplex Electric Co. (South Africa) Pty. Ltd., *Johannesburg, South Africa.*

J. A. Phillips & Co. (South Africa) Pty. Ltd., *Johannesburg, South Africa.*

Great Britain, geographical centre of the earth's land mass, is the logical centre of world air transport industry. Fresh from triumphs in the design and production of the War's outstanding combat planes, British designers and engineers are now perfecting modern transport aircraft in every category of size and performance. Heirs to a matchless tradition on the Seven Seas, pioneers of jet propulsion and radar, they are meeting—and will meet—every demand of the air age of Today and Tomorrow.



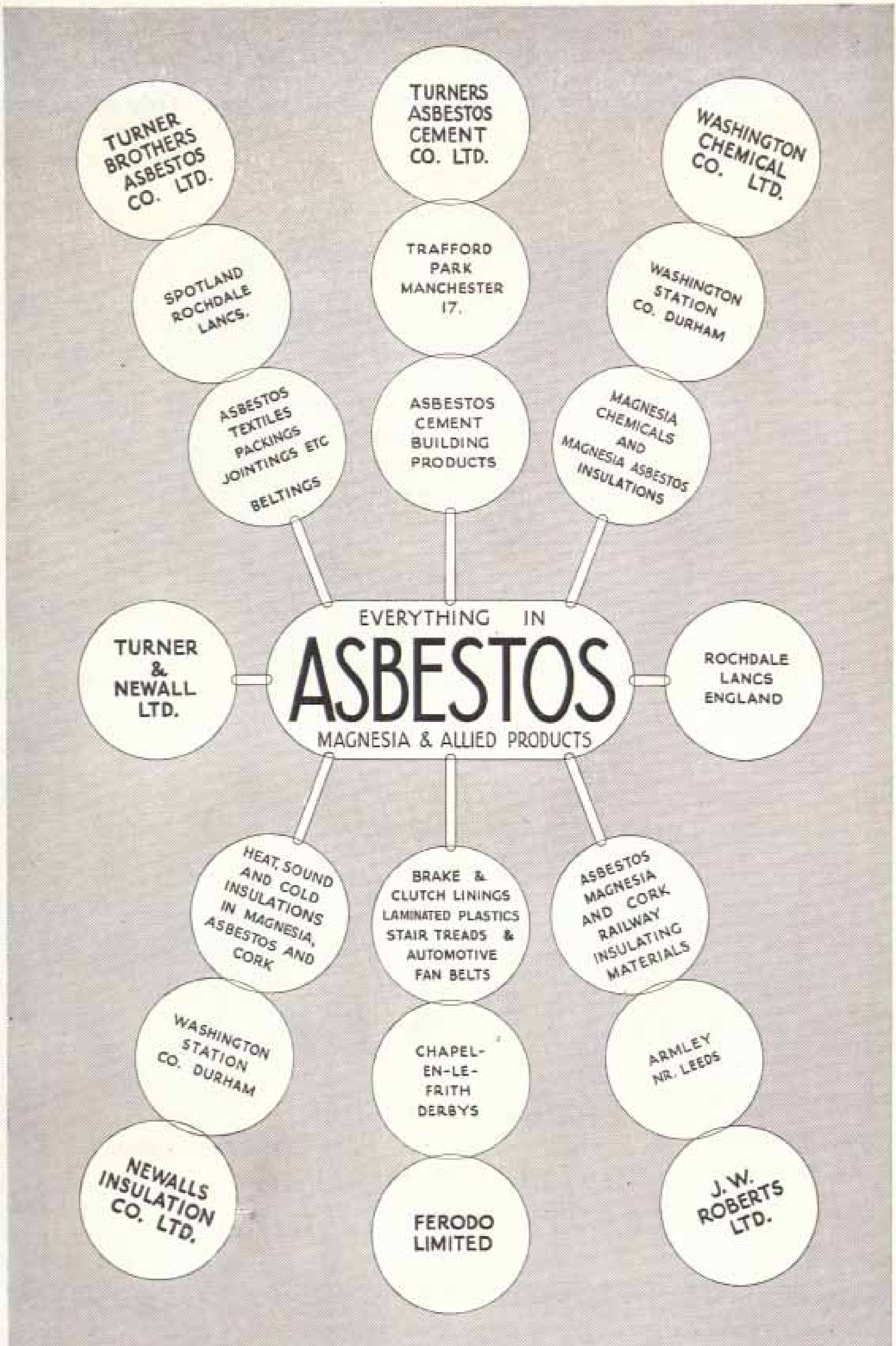
The

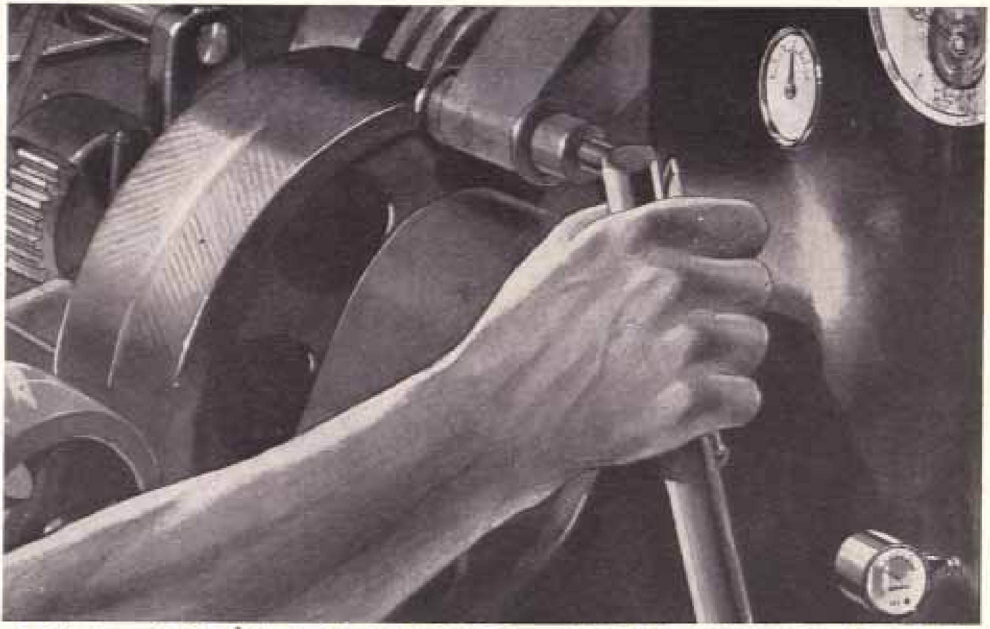
BRITISH AIRCRAFT INDUSTRY

triumphant in war

NOW BUILDS FOR THE AIR ROUTES OF THE WORLD

ANNOUNCEMENT BY THE SOCIETY OF BRITISH AIRCRAFT CONSTRUCTORS - LONDON - - ENGLAND


TURNER BROTHERS ASBESTOS CO. LTD.
TURNERS ASBESTOS CEMENT CO. LTD.
WASHINGTON CHEMICAL CO. LTD.
SPOTLAND ROCHDALE LANCS.
TRAFFORD PARK MANCHESTER 17.
WASHINGTON STATION CO. DURHAM
ASBESTOS TEXTILES PACKINGS JOINTINGS ETC BELTINGS
ASBESTOS CEMENT BUILDING PRODUCTS
MAGNESIA CHEMICALS AND MAGNESIA ASBESTOS INSULATIONS
TURNER & NEWALL LTD.
EVERYTHING IN
ASBESTOS
MAGNESIA & ALLIED PRODUCTS
ROCHDALE LANCS ENGLAND
HEAT, SOUND AND COLD INSULATIONS IN MAGNESIA, ASBESTOS AND CORK
BRAKE & CLUTCH LININGS LAMINATED PLASTICS STAIR TREADS & AUTOMOTIVE FAN BELTS
ASBESTOS MAGNESIA AND CORK RAILWAY INSULATING MATERIALS
WASHINGTON STATION CO. DURHAM
CHAPEL-EN-LE-FRITH DERBYS
ARMLEY NR. LEEDS
NEWALLS INSULATION CO. LTD.
FERODO LIMITED
J. W. ROBERTS LTD.



RE-STARTING INDUSTRY

One great job is done—Victory has been achieved. One more great job remains: to re-start our great peacetime industries. Now that the world-war is finished, British Industry will gradually—and thankfully—switch back to peacetime production. The great engineering organisation of METROPOLITAN-VICKERS, proud to have done so much during the war in making "the tools to finish the job," will be prouder still to produce in vast quantities Electrical Equipment of every conceivable kind to assist in the construction of a new world

METROPOLITAN Vickers
ELECTRICAL CO., LTD.
TRAFFORD PARK ··· MANCHESTER 17.

AX/A 507


What about this for EXPORT?
Many of the lighthouses in the world are designed and built by Chance Brothers—the famous English glass-makers and engineers. The market for lighthouses is limited, but there is no limit to the skill in glass-making available to any customer who wants to win export markets and who will consult with Chance Brothers.
Chance Glass
FOR SCIENCE, INDUSTRY AND THE HOME
CHANCE BROTHERS LTD.—GLASS-MAKERS SINCE 1824
HEAD OFFICE AND WORKS: SMETHWICK, BIRMINGHAM
LONDON OFFICE: 10 PRINCES STREET, WESTMINSTER, S.W.1
SCOTTISH WORKS: FIRHILL, GLASGOW, N.W.
EXPORT

BESTOBELL

Specialists in Applied Asbestos

Asbestos, "miracle among minerals," wrought wonders in and for Britain during the years of supreme trial and effort, wrought wonders on the seas, in the air, in North Africa, in Italy, on the beaches of Normandy and in the heart of the enemy's country. The full dramatic story includes giant partitioning curtains for aircraft-carriers, asbestos hose for planes and aerodromes, fire protection and insulation of fighting vehicles and aircraft cabin-heating systems, dyed asbestos cloth canopies for tanker-lifeboats, high-pressure oil jointing for "Fido," packing for gun-mountings, asbestos suits and armour for fire-fighting. The thousand and one problems swiftly solved in engineering works with the aid of asbestos enhanced and expedited British efficiency and prowess. The liberation of Europe was speeded.

Having evolved new products in hours of emergency, we are now engaged with all our might, skill and knowledge in making ready to assist the work of reconstruction and rehabilitation everywhere. As scientific specialists in *applied asbestos* we have seventy years' experience to call upon. The outstanding qualities of asbestos, resistance to heat, to acids, to alkalies and in particular an amazing flexibility, are of moment to industry.

Correspondence is invited directly with ourselves, through our accredited fo eign and colonial agents, through our subsidiary companies in the Dominions.

Engineers of every nationality can put their problems and ideas before us and be assured in advance of full co-operation and service.

BELL'S ASBESTOS AND ENGINEERING LIMITED

SLOUGH, BUCKS - - - - - - - - - - ENGLAND

24 Branches (including 10 in the Dominions)

Agencies throughout the World

WRITING COMMUNICATIONS HISTORY . . . .

FROM the day when a tired voice on the radio pronounced England at war, down to the moment which saw the defeat of our last enemy, the fateful years have made heavy demands upon world communications. Standard Telephones and Cables Limited, conscious of their trusteeship, have met and overcome the challenge of war, with its heavy responsibilities and its legion of problems, not the least of these being that of reconciling the insistent demand for increased production with rapidly decreasing staffs.

Speed was vital.

With the enemy thundering at our gates we had to plan and devise faster, and with greater skill and foresight than ever before.

We succeeded. Working around the clock — the calendar — the world — we saw to it that the national administration, the manifold demands of industry, the forces in the field, were served to the full.

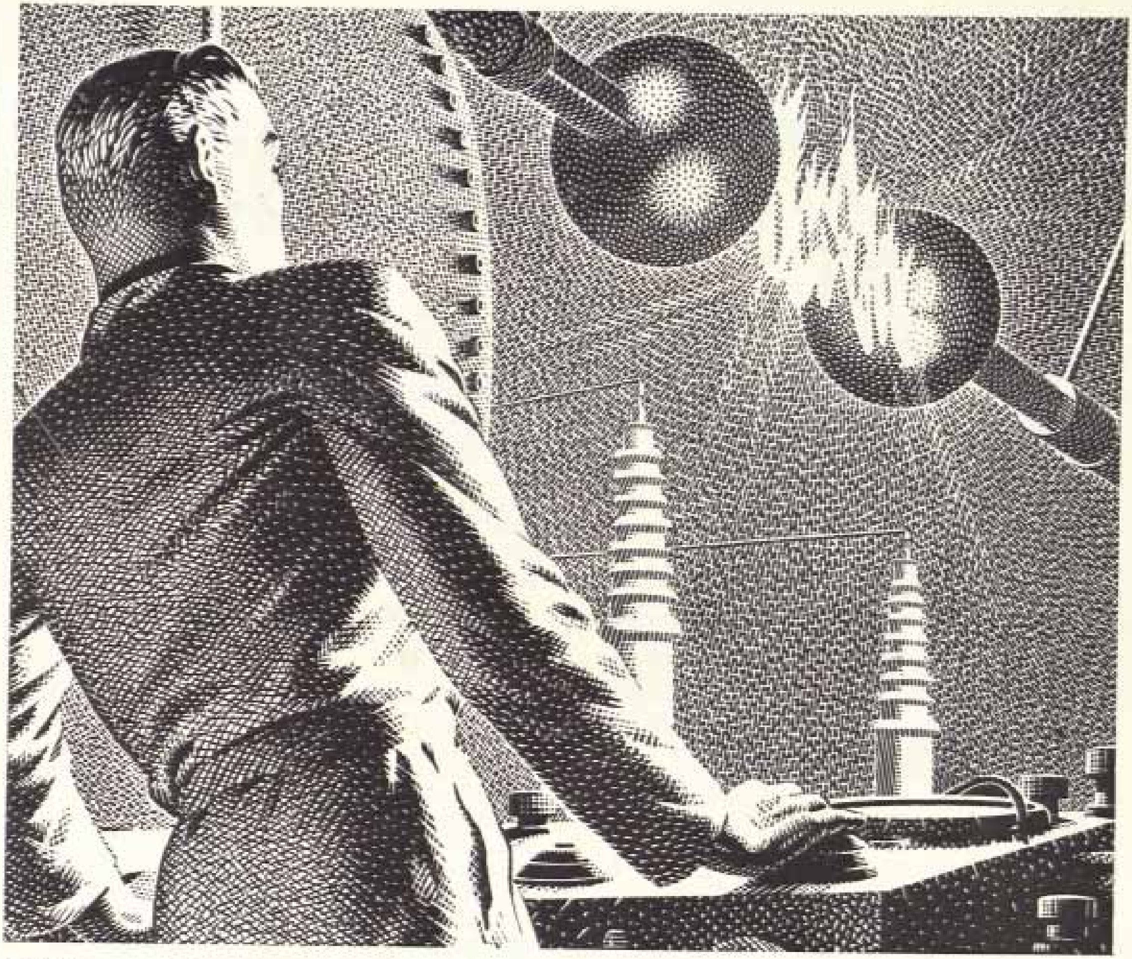
Great as was our effort, for us it was not enough. Through all our difficulties there shone, like a homing beacon, the day when we should be able to apply all that had been learned under the stress of war to the more normal needs of mankind.

—and so into peace.

Standard Telephones and Cables Limited now turns its vast resources to the requirements of a new industrial era and is ready to devote its wide experience to the peaceful needs of humanity, to create a standard in tele-communications that has never before been achieved: to develop new techniques and new efficiencies and, before the everlasting shrine of world peace, to draw the ends of the earth more closely together.

Standard Telephones and Cables Limited

CONNAUGHT HOUSE, ALDWYCH, LONDON, W.C.2



The Creative Spark.

On this depends the future progress of the world. In the field of electricity it has inspired the production of efficient and economical equipment—to the benefit of mankind.

Crompton Parkinson will maintain their leadership and continue to make their contribution to progress as they have done since the earliest days of the electrical industry.

A.C., D.C.,
Auto-Synchronous and
Fractional H.P. Motors
Generators
Alternators
Switchgear
Transformers
Instruments
Meters · Cables
Traction Equipment
Electric Vehicles
Electric Trucks
Batteries · Lamps
Lighting Equipment

CROMPTON PARKINSON

ELECTRICAL EQUIPMENT

CROMPTON PARKINSON LIMITED

LONDON OFFICE: Electra House, Victoria Embankment, W.C.2

There are Crompton Parkinson and associated factories throughout the British Empire
and Branches and Agents in most of the principal countries of the world.

How RESEARCH & RESOURCE led to Achievement

THESE last few years have imposed many trials and tests upon industry. Rapid transition from peace to war production and sudden demands due to emergency have called for the highest skill and resource. Mere improvisation would have been unavailing. Experience reaching far back into pre-war years was necessary to meet the new conditions. Bowrans were fortunate in possessing both the necessary experience and knowledge. For years their technicians had made a careful study of corrosion and kindred problems.

NEW AND VARIED DEMANDS

In this sense they were well equipped to meet the emergency, but the change-over demanded by war conditions at the outset produced many problems. One example of this was a request, without warning, for an extremely large order for camouflage paint to be completed within a week. Half the request was promised and duly fulfilled; and in the four years that followed millions of gallons were manufactured and delivered. The Bailey and Inglis bridges, which proved so essential to our rapid advance in Europe, had to be treated with special paints. Bowrans mid-bronze green was selected for this purpose, many thousands of gallons being employed.

PROBLEMS FOR THE CHEMICAL ENGINEER

In addition to supplying anti-corrosives, Bowrans were called upon to solve many problems in their capacity as Chemical Engineers, rather than solely as paint manufacturers. For instance, they devised special compounds for the protection of cable drums against bacteria and moisture. When the degaussing method was adopted to counter the magnetic mine, Bowrans produced the compound required to protect the wire against damage and corrosion, and indeed delivered large quantities. Then again, shortage of timber for ships' decking called for plastic deck sheathing, while air attacks at sea demanded plastic "armour" to protect the crews. Bowrans solved this difficulty also, and suitable material was supplied to many hundreds of ships.

TECHNICAL ENTERPRISE

As demands increased, output rose to tonnages amounting to many times pre-war totals, and while statisics of output may not convey much in these days of astronomical figures, the expansion in quantity, apart from the new varieties of products, indicates an achievement in which Bowrans take pride. Enterprise in technical matters has always been a characteristic of Bowrans. During the war these activities have been intensified due to emergency, adding greatly to an experience which was already comprehensive. The continuance of research work will result in a definite benefit to their friends at home and overseas, now and in the future.

ROBERT BOWRAN & Co. Ltd.

PELAW, GATESHEAD, 10, ENGLAND

Tel.: FELLING 82296/7

RAYON

A CARDINAL FACTOR IN RAISING STANDARDS OF LIFE THROUGHOUT THE WORLD

DURING the first forty-five years of the present century, rayon has given abundant proof of its ability to establish a higher standard of living for many millions of people.

To-day, when the whole world in general, and the European Continent in particular, is experiencing a serious shortage of the older textiles, rayon will undoubtedly be the means of alleviating the situation.

Paradoxically, in the midst of war tremendous advances are achieved in the pursuits of peace. This is noticeably true of the rayon industry, as will be realised when the time comes to place the result of war-time research at the disposal of the civilian market. Courtaulds, as the largest manufacturers of rayon yarns in Great Britain, can with justice claim a share in the development of new uses for rayon.

There will be rayon carpets for post-war homes. Rayon sheets, towels, and table cloths are setting a new standard in household furnishings. Spun rayon yarns, either alone or blended with wool and other fibres, produce cloths of exellent quality for suits, coats, and other items of personal attire. Rayon cord carcases for tyres have proved to be superior in strength and durability on all the battlefields of the world.

Courtaulds Limited believe in the vast potentialities of rayon, not only as a textile of immense and varied usefulness, but also as a new force in raising the standard of living for the many.

Courtaulds

COURTAULDS

RAYON

THE GREATEST NAME IN RAYON

ISSUED BY COURTAULDS LIMITED, 16 ST. MARTIN'S LE GRAND, LONDON, E.C.1.

THE GOLDEN ARROW SERVICE

Providing power for the Golden Arrow Wireless Stations was one of the many ways in which Lister engines served the nation in war. After the invasion of North Africa and during the invasion of France and Germany war reports were transmitted all over the world by Golden Arrow Wireless Stations. A Golden Arrow Wireless Station provided the Berlin link to London during the Three Power Conference.

WAR CONTRIBUTION

During the war Listers contributed to the war effort

100,000 Engines (totalling over 1,000,000 h.p.)
20,000 Generating Sets from 3½ to 24 k.w.
6,000 Marine engines and auxiliaries
10,000 Auto Trucks
Over two-million Shells
Over half-a-million key aircraft and other components

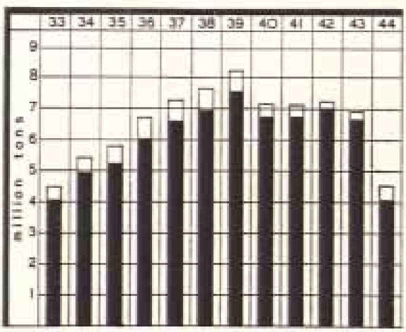
and, to increase butter fat and food production, over 25,000 cream separators and 28,000 tractor ploughs.

The vast manufacturing resources which made these supplies possible are now being converted to meet the requirements of our customers in all parts of the world, and it will not be long before we are able once more to offer that service which in happier days made the names of Lister and Dursley a symbol of efficiency.

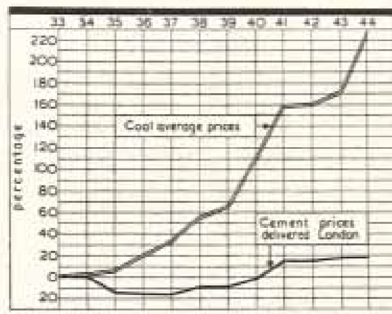
R. A. LISTER & CO. LTD., DURSLEY, ENGLAND

The story of Cement-in-the-War is a proud one. For defence? Tank-traps, fortifications, secret control rooms . . . For the offensive? The building of factories that made our munitions; runways for the great bombers; much of the glorious 'Mulberry" itself . . .

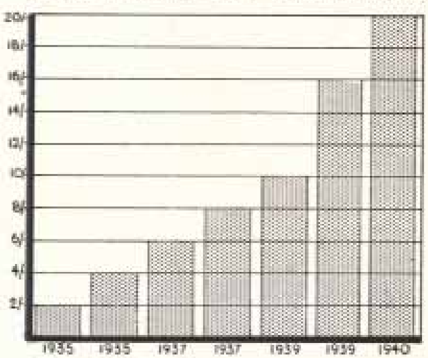
Cement-for-concrete needed no 'shadow' works, no improvisations, no new plant. The Industry's pre-war policy (shown below in graphic form) prepared its outstanding war history.



CEMENT DELIVERIES 1933-44 HOME ■ EXPORT □

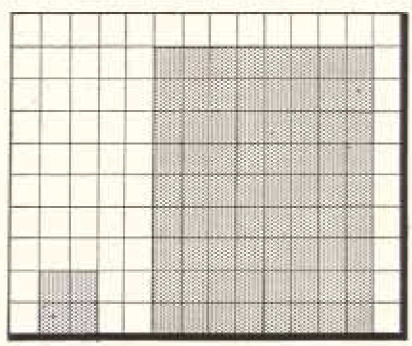


PERCENTAGE VARIATION IN COST OF COAL & CEMENT 1933-44
To manufacture 1 ton cement requires about 8 cwts coal



WAGE INCREASES

The graph shows wage *increases*, which were introduced when wages in other industries were still falling sharply.



PLANT

In the five years before the war obsolete plant (125,000 tons) was scrapped in favour of *new plant* (2,250,000 tons) with many times its capacity.

CEMENT

ISSUED BY THE CEMENT MAKERS' FEDERATION

BSA

WAR EFFORT *and* POST-WAR PLANS

Nearly 2,500,000 (2½ millions) of the small arms up to 20 mm. calibre manufactured for the war were produced by B.S.A. Among these weapons were:—

Besa Machine Guns for Tanks.

Browning Guns fitted to Fighter Aircraft which won the Battle of Britain.

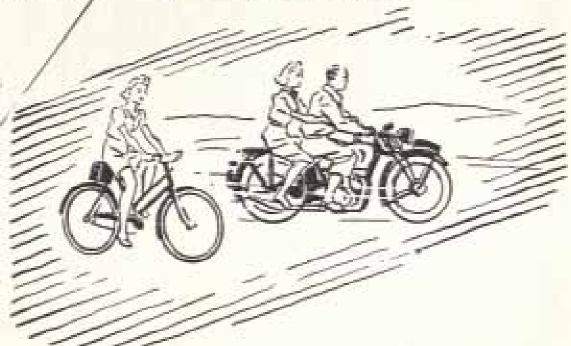
Hispano 20 mm. Cannon for Aircraft.

Oerlikon 20 mm. Cannon for the Admiralty.

Service Rifles, and many other munitions of war too numerous to detail, from Fuses to Gun Carriages.

Out of 400,000 **Motor Cycles** supplied to British Forces by the British Motor Cycle Industry, **115,000** were produced by B.S.A.

The **Folding Bicycles** dropped by air on D Day with our Parachute Troops were designed and manufactured by B.S.A.



With the completion of war commitments B.S.A. is able to switch vast resources to the production of an ever increasing number of Bicycles and Motor Cycles for the export and home markets. B.S.A. post-war Bicycles will lead the way in design, appearance, lightness and comfort, embodying a number of advanced features exclusive to B.S.A.

B.S.A. post-war Motor Cycles are the result of unparalleled wartime experience and of the ingenuity of B.S.A. designers who are practical riders, backed by comprehensive research facilities.

LEADERS in CYCLE and MOTORCYCLE VALUE-BSA

B.S.A. CYCLES LTD., BIRMINGHAM, 11.

Chosen FOR THE PLUTO PIPE LINE

"GACO" SEALS AND GLANDS

In "Pluto," the most famous of all pipe-lines, the most vital part was the section which crossed the English Channel. On the efficiency of this part depended the success of the whole achievement. It required a pipe-line, with flexible joints to allow for currents and tidal movements, yet capable of preventing both the ingress of sea water and the leakage of petrol at high pressure. "GACO" seals and joint glands were chosen after much experiment, during which the oil seals and glands were subjected to a test pressure of 3,000 lbs. to the square inch. Their success in operation is now a matter of engineering history.

SYNTHETIC GACO RUBBER

Our staff of qualified technical specialists is at your service. Consult us and we will solve your sealing problems.

GEORGE ANGUS & CO., LTD.

FLUID SEALING ENGINEERS

OIL SEAL WORKS, NEWCASTLE UPON TYNE

CERAMICS on Active Service

FROM the outset of the war, great demands were made on the Royal Doulton Potteries. Except for supplying minimum civilian needs, the whole of our manufacturing resources, in six large Works, have been concentrated since 1939 on producing materials which, directly or indirectly, were vital to the successful issue of the war.

TO tell the full story of problems solved and difficulties overcome is not possible here; it will form the subject of a special brochure now being prepared. Meanwhile, the following brief details may serve to indicate the scope of our contribution to the general effort.

CHEMICAL STONEWARE

Its resistance to corrosion, freedom from contamination and flexibility of design have made Doulton Chemical Stoneware indispensable in many fields and it has played an important part in the manufacture of explosives, acids, chemicals, foodstuffs and a wide range of other products, including M. & B. drugs, Mepacrine, Penicillin, D.D.T., Anti-gas Ointment and Anæsthetics.

LABORATORY PORCELAIN

Without assured supplies of Laboratory Porcelain, scientific research would have been gravely impeded. Far-reaching wartime developments in explosives, chemicals, metallurgy, photography, plastics, medicine and food preservation owed much to the availability of this material, in the manufacture of which the Royal Doulton Potteries were pioneers.

MAINTAINING EXPORTS

Besides satisfying requirements at Home, vast quantities of insulators, chemical ware and other products had to be shipped Overseas to meet special war needs. Exports of tableware also helped to provide valuable foreign exchange for the purchase of essential imports.

ELECTRICAL INSULATORS

For maintaining communications by wireless, cable and telephone; for radiolocation; and for distributing current to factories, docks, offices and homes—as well as to electric railways and other services—we supplied millions of insulators of varied shapes and sizes, many designed in our own drawing offices.

SANITARY FITTINGS, ETC.

Domestic demands practically ceased but there was an immense output needed in the construction of factories, aerodromes, camps, canteens, hostels, hospitals, and similar buildings. 90 per cent. of our total production of sanitary fireclay and stoneware drainpipes was concentrated on requirements connected with the prosecution of the war and also bomb-damage repairs.

ENGINEERING ACTIVITIES

Despite heavy demands on our Engineering Shops for maintaining plant and assembling fitted wares, nearly 1,000 orders for machine work were undertaken to assist important Engineering Firms to cope with the demand for gun-mountings, gun-carriage gear, shell plant tools and forgings.

IMPORTANT developments in raw materials, glazes and methods of making and firing will influence post-war production and further enhance the wide-world reputation which Royal Doulton products have attained, during the past 130 years, alike in the spheres of art and industry.

DOULTON & CO. LIMITED

Head Office: DOULTON HOUSE · LAMBETH · LONDON, S.E.1

Aluminium Alloys

in every

Cast and Wrought Form

The HIDUMINIUM series of light alloys in all cast and wrought forms is manufactured by

HIGH DUTY ALLOYS LTD

REYNOLDS TUBE CO. LTD

REYNOLDS ROLLING MILLS LTD

In order to secure the best use of Hiduminium light alloys the accumulated technical knowledge and practical experience of this important group of companies is available to all fabricators through

HIDUMINIUM APPLICATIONS LTD

Fabricators, designers and constructors overseas may obtain further information by sending their inquiries to

HIDUMINIUM (*British* EXPORTS) LTD

5 BUCKINGHAM PLACE, LONDON, S.W.1, ENGLAND

HIDUMINIUM

Nothing like Leather

A RECORD OF ACHIEVEMENT AND PROGRESS

BRITISH ENTERPRISE HAS BEEN exemplified during the war years by the leather and associated industries in a manner that has contributed valuable service to the armed forces and civilian population.

BRITISH leather producers have laboured under continual hardship of restricted supply of raw materials, inadequate labour and, in some instances, improvised methods of production due in many cases to the frequent air attacks. These difficulties have been surmounted with unqualified success and to-day British leather has improved under the stimulus of war and reaches standards of quality and durability not previously attained.

BRITISH shoe manufacturers have produced millions of pairs of footwear for the Allied Forces and maintained a supply for home needs in accordance with regulated output and prescribed standards of production. In the face of severe curtailment of labour, absence of normal types of materials suited to special classes of manufacture, British footwear manufacturers have sustained the home market and guaranteed the full requirements of the Armed Forces.

BRITISH leather goods manufacturers have been diverted largely from their normal activities to war work of highest importance. In this way they have rendered a valuable contribution to victory and satisfied the needs of the fighting services.

BRITISH belting has played an equally prominent part in maintaining the war effort not only in the home industries but overseas, to which markets all that could be spared for export has been shipped.

LEATHER. Exports have been limited on account of war conditions, but tanners and leather dressers are fully prepared to reinstate and expand overseas connections. Sole leather, rough tanned leather, upper leather, linings and fancy leathers can be produced for all purposes. Supplies will be available for footwear, leather goods, upholstery, for various purposes such as motor cars, furniture and aircraft, and for many other needs. Production standards will ensure the utmost satisfaction of overseas buyers.

FOOTWEAR. Restrictions on production, style and design have been necessary during the war, while the demand for the Forces and essential needs of the civilian population have curtailed the volume of export business open to British footwear manufacturers. As restrictions become easier and suitable materials reach the factories in larger volume, overseas trade will receive full attention and markets will be expanded.

LEATHER GOODS. Greatly impeded by war restrictions, British leather goods for civilian use have been manufactured on a limited scale, but with more latitude granted to producers, greater concentration on export markets will take place and the quality of British leather goods will again earn the appreciation of consumers overseas.

LEATHER BELTING AND INDUSTRIAL LEATHERS. Exports of these leathers have been maintained to the fullest capacity obtainable under a war economy and British producers are well forward with plans to enhance this trade and add to the prestige already gained by these commodities in all markets of the world.

LEATHER, FOOTWEAR AND ALLIED INDUSTRIES EXPORT CORPORATION LIMITED,

1, CATHEDRAL ST., LONDON, S.E.1.

L·F·A·I·E·C

Ransomes

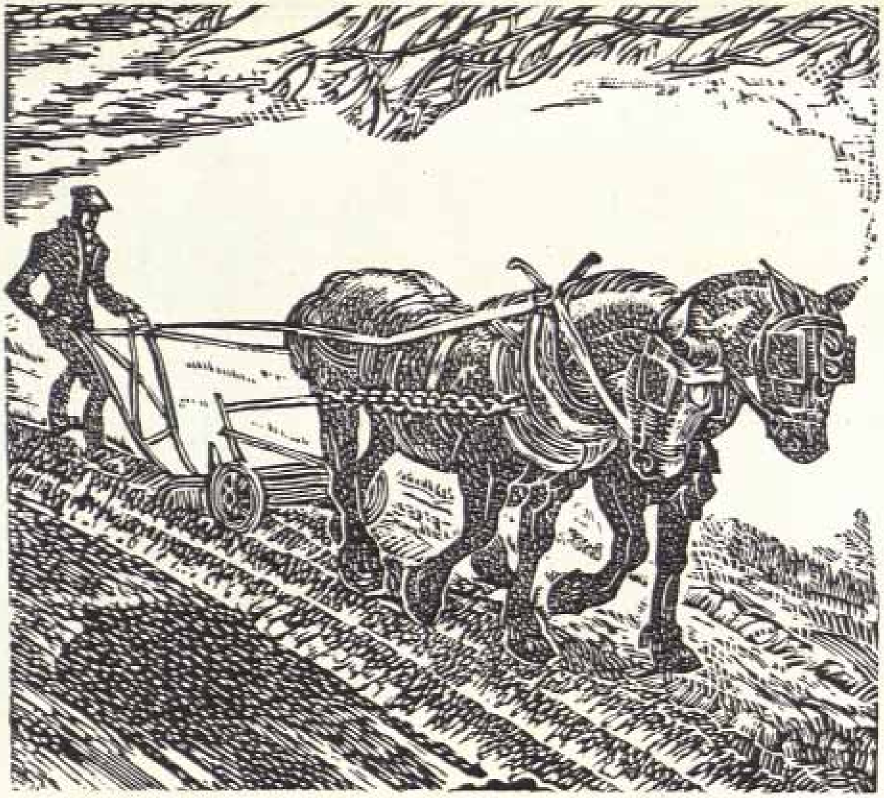
in addition to manufacturing large quantities of munitions and other equipment for the British and Allied Governments, supplied tens of thousands of ploughs and other implements for farmers in the United Kingdom, as well as large numbers of thrashers, balers, grain driers, garden tractors, etc. An appreciable quantity was also spared for overseas countries supplying food for the war effort.

With the advent of peace and the gradual return of men from the Services to the factory, Ransomes are planning to give special attention to the requirements of their friends all over the World.

Their productions also include electric trolley buses, electric industrial trucks for factories, railways, docks, etc., electric motors and dynamos, gang mowers for aerodromes and other large areas, hand, motor, and electric lawn mowers, etc.

RANSOMES, SIMS & JEFFERIES, LTD.

IPSWICH ENGLAND



"And he gave it for his opinion that whoever could make two ears of corn, or two blades of grass, to grow upon a spot where only one grew before, would deserve better of mankind than the whole race of politicians put together."

JONATHAN SWIFT

"Food will win the war" prophesied Lord Woolton, and beyond question the increase of food production in the United Kingdom during the war years was a matter of life and death.

Fisons contribution was the supply of over 1,000,000 tons per annum of fertilizers, both of its own manufacture—super-phosphate, Complete Compound Fertilizers (Granular and Powdered); Bilston Basic Slag; 'Nitro-Flix' Sulphate of Ammonia—and such factored fertilizers as Potash, Organics, Nitrate of Soda, etc.

The world shortage of food makes it more than a self-interested hope that circumstances will soon permit the renewal of exports to all overseas markets. In addition to 22 factories in the United Kingdom, Fisons have factories in South Africa and Canada.

It's Fisons for Fertilizers

HEAD OFFICE: HARVEST HOUSE, IPSWICH, ENGLAND.

INTERNATIONAL WOOL PUBLICITY AND RESEARCH SECRETARIAT

What it is

An organization for furthering all wool interests. With Head Office in London its activities, which necessarily were severely curtailed during the war, extend to all countries where wool is produced, manufactured or sold. Established in 1937 it is financed by the woolgrowers of Australia, New Zealand and South Africa.

What it does

The Secretariat finances scientific research into the textile properties of wool at various research centres of world repute. It makes economic investigations of all phases of the wool industry. Through various publicity channels it provides the consuming public with true facts about the textile qualities of wool fabrics. More generally it acts as a liaison office for all who have the interests of wool at heart.

SCIENTIFIC AND ECONOMIC RESEARCH

Despite the hampering effects of the war, knowledge of the chemical and physical properties of wool has been greatly advanced by the research work financed by the Secretariat. The increasingly greater understanding and control of the textile properties of wool promises a wider diversity than ever of attractive wool fabrics with exceptional qualities.

Closely linked with scientific research and publicity, is the economic service of the Secretariat. It holds a watching brief on all wool trade matters, and is constantly exploring new markets for wool. It publishes a fortnightly digest of wool news.

PUBLICITY AND CONSUMER EDUCATION

The Secretariat's publicity activities include Press and poster advertising, news and photographic service to the Press, exhibitions, fashion parades and window displays. Courses of lectures on wool are arranged at schools, universities and technical colleges, supported by illustrated books and charts. Trained speakers from the Dominions are available to talk to adult, audiences of every type. The extensive wool fabric library is available for inspection at the headquarters of this section, 22, Bruton Street, London, W.1 — where expert staff are always in attendance to give advice and help. There are also branch offices in Paris and New York.

In short **International Wool Secretariat**

is telling the story of WOOL

all over the world . . .

The Secretariat is there to assist all who produce or use wool. Address all enquiries to :

THE SECRETARY, INTERNATIONAL WOOL SECRETARIAT, GRAND BUILDINGS, TRAFALGAR SQ., LONDON, W.C.2

THE 600 GROUP OF COMPANIES

GEORGE COHEN, SONS & COMPANY LTD. ★ K & L STEELFOUNDERS AND ENGINEERS LTD. ★ T. C. JONES & COMPANY LTD. ★ BROWETT LINDLEY LTD. ★ METALCLAD LTD. ★ THE SELSON MACHINE TOOL COMPANY LTD. ★ THE NEW LONDON ELECTRON WORKS LTD. ★ POLLOCK, BROWN & COMPANY LTD. ★ WESTBOURNE PARK COAL AND IRON COMPANY LTD. ★ SOUTHALL & HAYES COAL AND IRON COMPANY LTD.

A Statement of PRODUCTION FOR WAR

The following data of our Companies' War Effort are by no means exhaustive since lack of space prevents comprehensible description of many of our Manufactures and Products — but the quantities and particulars cited may not seem unworthy of record:—

★ Manufactures:

AMMUNITION, WARLIKE STORES, etc.

AERIAL BOMBS for Filling—4,000 lb., 1,900 lb., 1,000 lb., 500 lb. and 250 lb.	**490,000**
Smaller Aerial Bombs	**2,400,000**
AERIAL BOMB COMPONENTS	**Over 3,000,000**
SHELL for Filling—9.2", 6", 5.5", 4.5", 95 m.m., 25 pdr., 17 pdr., 6 pdr., etc.	**4,500,000**
TRENCH MORTAR BOMBS for Filling—4.5" and 3"	**570,000**
ROCKETS—Major Components	**Over 2,250,000**
PARAVANES	**860**
FLAIL EQUIPMENT for TANKS—Developed, Manufactured and Fitted	**Several Hundred Sets**
BAILEY BRIDGE PANELS—Complete with Components	**15,500**
BRIDGING CRIBS	**4,000**
INGLIS BRIDGES—Complete with Launching Gear	**200**

AIRCRAFT WORK

NACELLES	**4,000**
WING DETAILS—Sets	**1,250**
ENGINE MOUNTINGS	**Many Hundred**
HYDRAULIC UNITS for Retractable Wheels	**Tens of Thousands**

PLANT, MACHINERY, STEEL CASTINGS, etc.

'JONES' MOBILE CRANES	**1,500**
'JONES' TRENCH CRANES	**400**
PETROL ENGINES	**5,500**
STEAM ENGINES & AIR COMPRESSORS, up to 5,000 cu. ft. per minute	**425**
STEEL CASTINGS for Tanks, Bridges, Gun Mountings, etc.	**52,000 tons**
FIVE COMPLETE PLANTS for ELECTRIC POWER STATIONS—Sent to Russia	

CONSTRUCTIONAL & CIVIL ENGINEERING WORK

AEROPLANE HANGARS	**450**
CONCRETE REINFORCING BARS	**Thousands of Tons**
STEEL-MESH REINFORCEMENT	**Over 2,000,000 sq. yds.**
MACHINE SHOPS, FOUNDRIES & OTHER INDUSTRIAL BUILDINGS—Fabricated and Erected all over the country	**Many Hundred**

We played a major part in the construction of **REINFORCED CAISSONS for MULBERRY HARBOUR;** also in the recovery and transportation of essential plant from bombed works and wharves to new sites.

★ Plant, Machinery & Industrial Equipment Supplied:

RECONDITIONED & SECONDHAND MACHINERY Electrical Plant, Power Plant, Boilers, Colliery and Mining Plant, Sheet-Metal Machinery, Contractors' Plant, Plastic Moulding & Rubber Machinery, etc., etc.	**Tens of Thousands of Machines**
RAILS & STEEL SECTIONS	**60,000 Tons**
NEW ENGINEERS' & CONTRACTORS' TOOLS, etc.	**More than a Million**
NEW MACHINE TOOLS	**12,800**

We acted as Sole Agents to the **MINISTRY OF SUPPLY** (Machine Tool Control) for **USED MACHINE TOOLS**

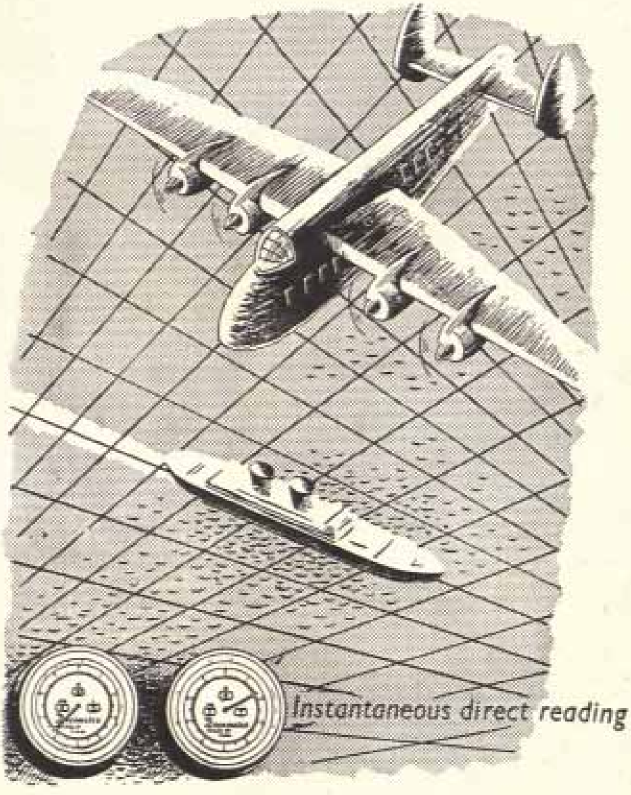
Our **FLEET of CONTRACTORS' PLANT,** comprising over 1,000 Excavators, Bulldozers, Cranes, Concrete Mixers, etc., has been kept working to capacity.

★ Raw Materials Supplied:

FERROUS SCRAP for the **IRON & STEEL INDUSTRIES & NON-FERROUS SCRAP** for the **FOUNDRIES** and **ROLLING MILLS,** etc.—including that resulting from the demolition and dismantling of Obsolete Industrial Plants and Structures, the Crystal Palace Towers, Gasholders, Old Guns, Limbers and Tanks, Damaged Premises, etc.	**Hundreds of Thousands of Tons**
TIN-COATED SCRAP and **OLD TINS DETINNED**	**Over 100,000 Tons**
TIN from **DE-TINNING**	**Over 1,000 Tons**

The Decca Navigator

When the British army of liberation made its historic invasion landings on the beaches of Normandy, the assault boats were guided by the Decca Navigator. The minesweepers that swept a safe passage for them to pass through also carried this revolutionary new British instrument that continuously indicates by dial readings the geographical position of a ship or 'plane, and makes unnecessary either the services of a skilled operator or instruments for calculation and computation.



The Decca Navigator is a light, compact radio receiver that picks up synchronised signals from land transmitting stations that set up in the ether a fixed pattern of an infinite number of intersecting lines that are superimposed or printed upon a standard chart or map. The accuracy of this instrument is unimpaired by weather, currents or altitude. The Decca Navigator now makes peacetime sea and air travel quicker and safer for large transport and private 'planes, ocean liners, trawlers and private yachts.

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History in the making

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WHEN, in due time, historians turn their attention to sorting the facts from the legends of the British Empire's victorious war against twentieth-century dictatorship, they will turn to the files of *The Times*. For *The Times*, in its duty, records history as it happens—fully, authoritatively and accurately.

To those who study the history of the past one hundred and fifty years the volumes of the Official Index to *The Times* are indispensable.

In addition to its newspaper and periodical publishing activities, *The Times* also lends its resources to the issue of volumes of contemporary record.

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The aims of *The Times* are :—To be the first, but not the hastiest, with the news ; to persuade and not to dogmatize ; to be graphic without sensationalism, and to give the news faithfully and fully without "featuring" the worst side of human nature.

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