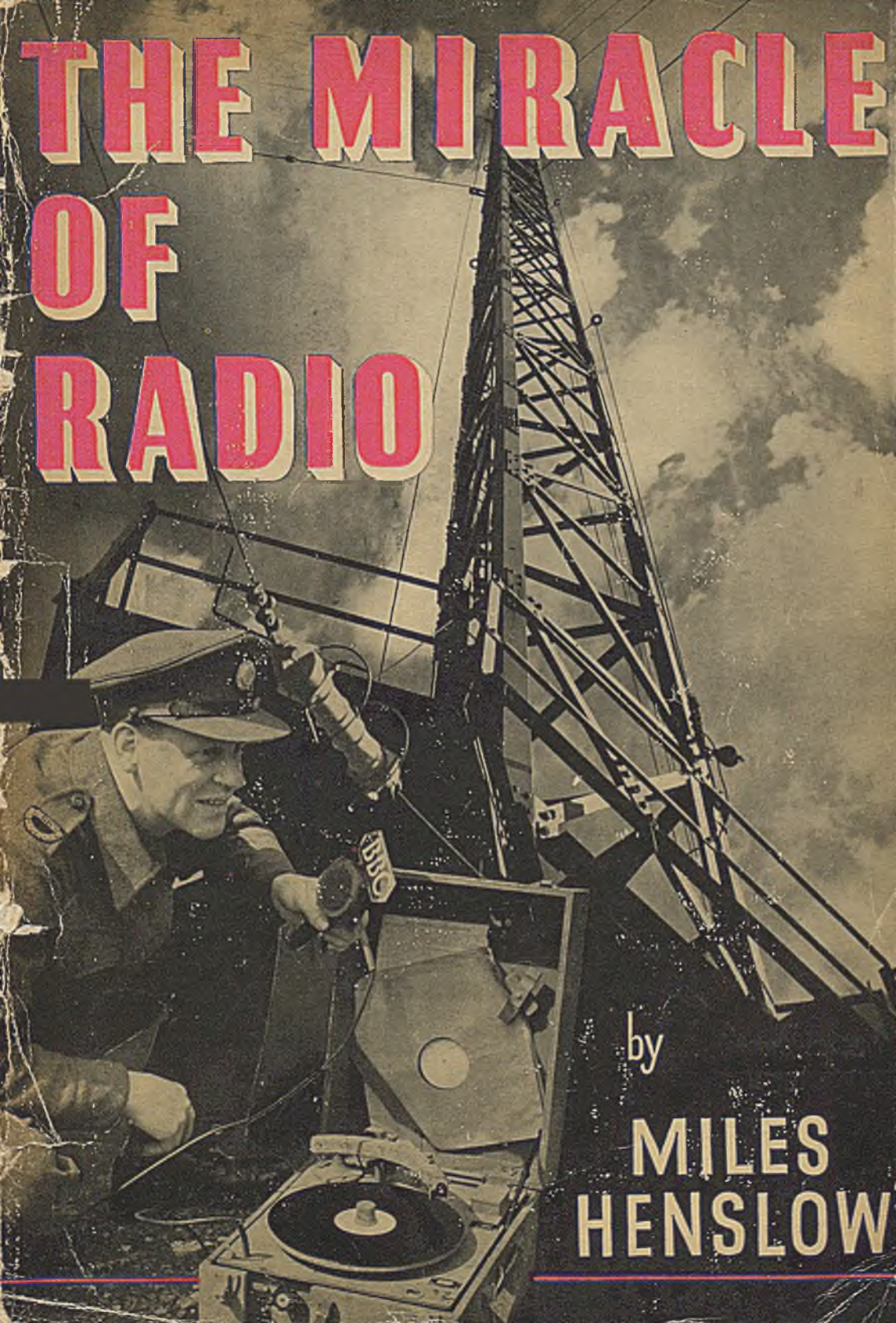
THE MIRACLE OF RADIO



by

MILES HENSLOW

THE MIRACLE OF RADIO

The story of Radio's decisive contribution to Victory

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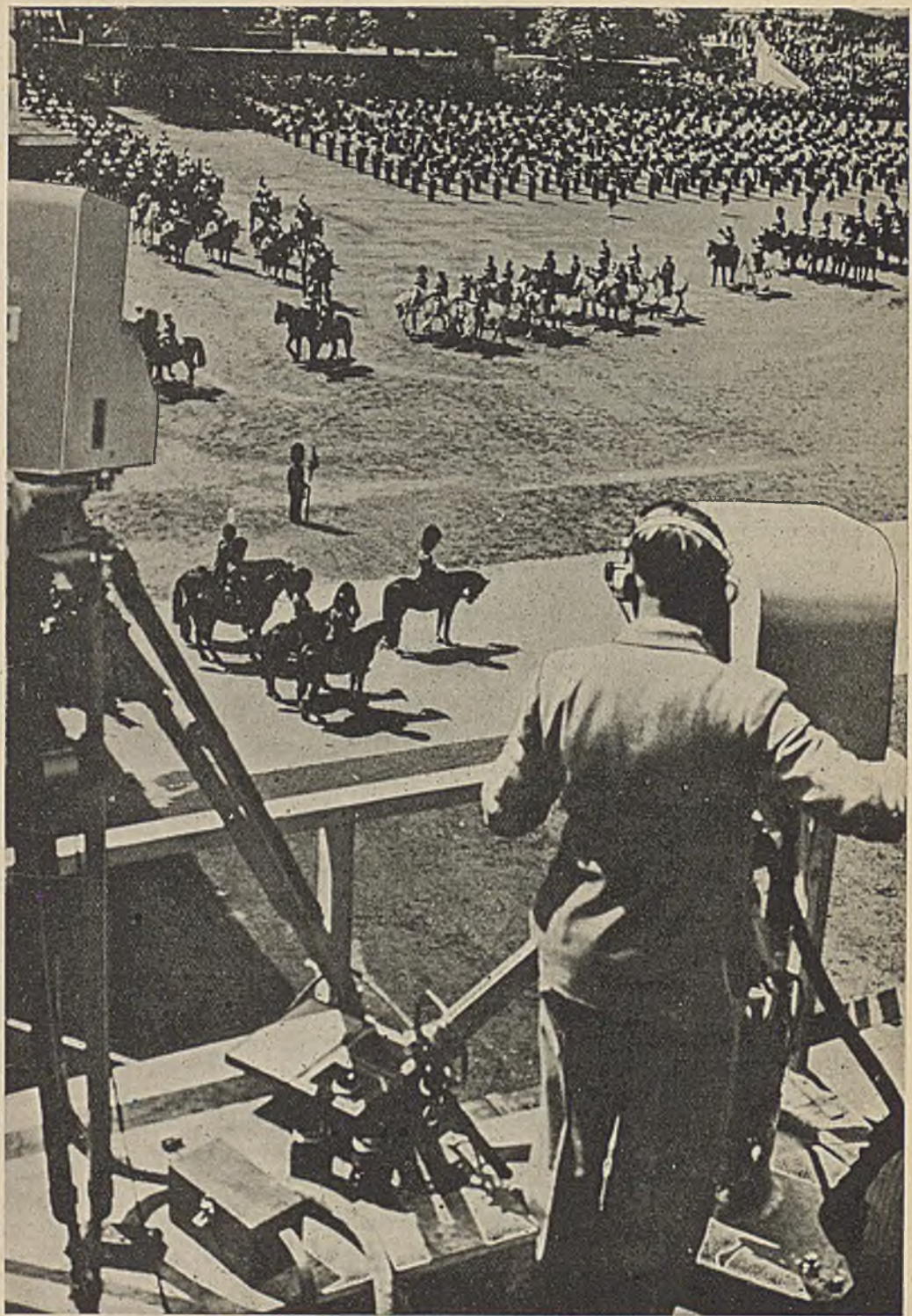
Miles Henslow

EVANS BROTHERS LIMITED, LONDON



This spectacular scene was flashed to the television screens in thousands of British homes as long ago as 1938, for it was British ingenuity which gave the world its first high definition television service. When radio went to war, it was that same British ingenuity which produced the radio miracles of GEE, BONZO, H.2S. *and* OBOE. *In peace, as in war, British scientists will lead the world again.*

CONTENTS

I am indebted to the Radio Industry Council for access to much of the material which forms the basis of this book.

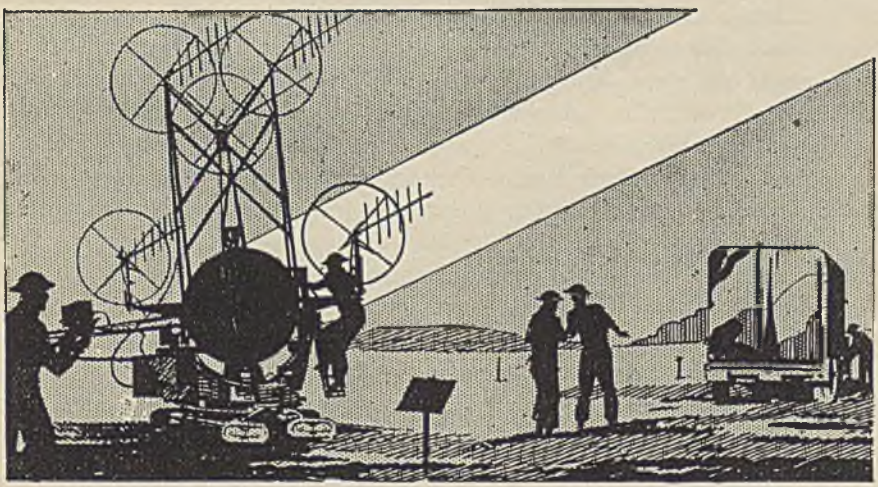
M. H.

First published 1946

Introduction

RADIO has played one of the most important roles in the drama of this war. It has been so intimately bound up with the strategy and tactics of every campaign that no living person could hope to unravel the threads of the story; and therefore no one will ever be able to assess the actual value of its presence in the day-to-day incidents of the past six years. One can only say that without the lead that Britain took, and held, in the science of radio, the war might well have been lost: it would most certainly have been prolonged by several years.

The glory that belongs to the British fighting man has been well recorded in the stories of this war; the machines and the weapons that he used—the planes, the tanks, the ships, and the guns—have all been dramatized in their turn; yet of radio, strangely enough, too little has been said or written. Perhaps that is largely because of the atmosphere of secrecy which has surrounded all things radio; again, perhaps it is because there is nothing in



Thousands of searchlights, fitted with radar apparatus, were on nightly duty in all parts of the British Isles. The radio waves picked up the target, still in darkness, and when it was located the light was switched on, thus giving the raider no warning.

a piece of radio apparatus, no matter how complex, that appeals immediately to the imagination. A grey steel box with a few knobs and dials has none of the majesty of a battleship in action, or the breath-taking dash of a fighting aircraft. But radio has its own story, none the less, and it is a story packed full with drama and romance.

Tin Huts on Wheels

Perhaps you have wondered, as you walked along a country lane at sundown, what purpose lay behind the "little tin hut on wheels," tucked away in the middle of a lonely field, turning slowly and ceaselessly round and round? It was a radio beacon, flashing out its short-wave signals to aid the navigators of our aircraft. Again, perhaps you have wondered at the short metal rods and the wire-netting screens fixed on to searchlights, or by anti-aircraft guns? They were the aerial arrays of just one form of radiolocation, directing a stream of radio pulses into the sky—invisible fingers, feeling the darkness for enemy aircraft—incredibly clever fingers, too, able to distinguish between friend and foe, and enabling their human operators to point searchlight and gun muzzle with deadly accuracy at the unseen target.

Radio Cobweb

You will certainly have seen the slender "fishing-rod" aerials that sway from the army trucks as they speed along the highways, and you will more than likely have noticed the aerial rods on tanks, and the commanders standing in their turrets, microphone in hand. These things represented yet another of radio's war-time jobs—communications. Spreading outwards in all directions, from the War Office in Whitehall to the staff-car in Germany, or to the infantryman on lonely patrol in Burma, is a vast and invisible web of radio. A similar web of radio communications binds together all the units of the R.A.F., and connects the pilot of every plane to a telephone on someone's desk. The Admiralty, too, has its own radio communications network which stretches round the world. Submarines, battleships, aircraft-carriers, the Merchant Navy, shore stations, lighthouses and lifeboats—all are in the radio telephone or telegraph directories.

Enough? But that is only a small chapter of the whole story. Those are only examples of some of the more straightforward of radio's war-time jobs. What of the men who have ventured into enemy territory, by boat or parachute, in the dead of night? They took radio with them—specially constructed sets with which to listen for their secret orders and to pass back information. What of the sailors who left our shores to seek out and destroy the U-Boats that threatened to break our Atlantic life-line? They used radio. What of the specially trained air crews who flew above enemy territory, in darkness and cloud, to locate the selected target in shadowy

The British Army, from infantryman to staff car, is "on the 'phone".

outline on a small glass screen? They used radio in one of its most fascinating and complicated forms.

Most Secret Devices

And so one could continue to list the more spectacular and, till recently, *most secret* applications of radio to modern war, in just the same way that one could catalogue its quite indispensable, if slightly less romantic, uses. And as yet no mention has been made of any but its duties on active service. There is the Home Front to be considered, the morale of the civilian population that was strengthened throughout the dark days by frank and truthful words from the ether, and the propaganda battle which was waged so skilfully and tirelessly by the B.B.C.

Every hour of every day and night the short-wave aerials of the B.B.C. spread the news of a world at war, in terms of truth, and in all the tongues of Babel. And every minute of every hour the monitoring loudspeakers of the many listening stations repeated the voices from other nations—truth, lies, news, views. In still more listening stations, batteries of high-speed machines made paper recordings of the millions of words that flashed through the ether in morse code.

So much for an outline of some of the jobs that radio has done to win this war. But with radio, as with any other implement of war, the real story lies around the people who designed it, created it, and used it. That story is told for the first time in the pages of this book. It is the story of almost incredible ingenuity on the part of British scientists, of the patience, perseverance, and skill of the engineers and factory workers in the industry itself, and of the army of men and women—the "Signals" of the fighting forces, who flocked from every corner of the Empire to master the difficulties of a complicated and vital job in order to keep open the eyes and ears of a threatened civilization.

RADIOLYMPIA 1939

RADIOLYMPIA was one of the highspots in the series of London's popular annual exhibitions, and each year the attendance figures mounted higher and higher. In 1938 more than 150,000 people passed through the clicking turnstiles to feast their eyes upon the latest marvels that the radio industry had created for their entertainment. In 1939 it was confidently expected that all records would be broken. For the first time the main theme of the exhibition was television, and ambitious plans had been made to stir up such an enthusiasm for this art that it would sweep the country.

High-definition television was barely two years old when the exhibition opened, but these two years had seen an amazing record of scientific development. The Industry had already succeeded in reducing the prices of television receivers to a competitive level, and some hundred thousand people were daily viewers in the homes, clubs, and hotels in the Home Counties of Britain.

The exhibition was opened by television. Sir Stephen Tallents, then of the B.B.C., made a speech in the studio at Alexandra Palace, and his audience clustered excitedly around the scores of screens and loudspeakers at Olympia, before moving along on its busy tour of exploration, down the aisles between the decorated stands of the many exhibitors. Significant, too, was the fact that many overseas visitors were among that audience.

The Big Pre-view

Television — radio — radiograms — car radio — portable radio — loud-speakers—valves and components. Never before had the country seen such an ambitious collection of apparatus designed solely for the purpose of providing entertainment for the millions. This was the giant pre-view, the warehouse of samples from which the thousands of retailers would select their stock, and from which the radio listeners and television viewers would return home to check over household budgets, and decide just what

they could afford—and simply must have. This was Radiolympia, 1939 edition, representing the potentialities of the entire radio industry—an industry which had grown up from next to nothing in a mere twenty-three years, an industry founded upon private enterprise and open competition, and developed to fulfil the needs of the British people in their ever-changing demands for newer and better entertainment. *A decadent people, it was said!*

And to the observant German visitor, of whom we may be sure there were plenty, this display of peaceful apparatus—those many loudspeakers and those entrancing television screens—must have provided a satisfying contrast to the other picture that he had in mind—a picture of feverish activity in the radio factories of his Fatherland, of lines upon lines of stereotyped field-grey boxes, housing radio for tanks, planes and cars, of Government decisions to permit the manufacture of only one model of television receiver, and a "people's set" for the masses, to cut down all unnecessary production difficulties. Yes, the observant Nazi must have smiled, and not without reason: for here, in Radiolympia, displayed for all the world to see, was the complete catalogue of Britain's radio warehouse for the years 1939–40. And there was certainly nothing to cause him any headaches.

A funny people, the British, he doubtless thought. Completely disorganized. Look at their aircraft industry: at least a dozen and a half private firms, one competing against the other, and all going their own sweet way, designing just what they saw fit to design, using whatever materials they chose—Blenheims, Oxfords, Tiger Moths, Wellingtons, Battles—. No controls, no rules, no instructions; and, of all the crowning acts of stupidity, not even any secrecy! Why, they even put their fighters and their bombers on show, inviting the foreign Air Attachés to come and be impressed! Exactly the same with their radio industry. No planning, no controls, no supervision.

1940 was to have been a great year for radio. The factories were all ready for television. The industry was on its toes for the orders of home and overseas buyers.

The Unseen Visitor

But there were men in Britain who held a fine, detached, half-way view of all this—neither the confident optimism of the uncontrolled industry, nor the despair that should have resulted from a knowledge of all the Nazi preparations. They were the scientists who had been working quietly for the past three or four years inside and outside the industry, Government servants, yet free from Government red tape.

They, more than many people in the Government, knew the size of the job that would be theirs if the worst came to the worst. On the other hand they had reason to bless the existence of the competitive range of radio components, born of unrestricted private enterprise, that enabled them to build and develop their peculiar apparatus according to their whims: on the other hand they wished, instinctively, that a large part of the industry's resources had been devoted to the production of the devices they had already designed.

The spirit of this small body of men was also a visitor to Radiolympia—an unseen guest on that summer's morning of 1939. He drifted, ghost-like and unrecorded, through the busy turnstiles. Outside, in the blazing sunshine, there was a chill in the air which only he had felt. This was August 24th. In ten days' time. In exactly ten days to the hour. . . .

The people were nervous. They could feel the tension. They had filled in forms for their identity cards. They had tried on their gas-masks. But somehow they could not believe that war would really come. Something was bound to happen. Something would turn up. It always did. Of course, if Britain *did* go to war, she would win. There was no doubt about that. How could there be? Meantime, there was no good in worrying unduly. Now, that television receiver. . . .

The Big Job Ahead

No, there was no lack of courage in the hearts of the thousands who thronged Olympia; only a sense of acute tension. The chill that was felt by the unseen visitor was not the sensation that was shared by the crowds of excited mortals: it was the result of an appalling knowledge. There was so very much to be done. There was so little time in which to do it. There was such urgent need for a plan.

Across the Channel, and behind the frontiers of the German Reich, the radio industry was geared for war—not only geared, but running at full speed. There they had a plan, an all-embracing and deadly plan, completely soulless but terribly efficient. The German radio manufacturer had no aluminium to spare for his domestic wireless sets. Aluminium was reserved for aircraft. Supplies of components were all scheduled. Schmidt might buy a thousand valves, and Braun might buy a thousand transformers —but no more. It was no good bidding in the open market, for the Govern-

Television broadcast. The microphone above them, and the wonderful Emitron cameras before them, three entertainers put on a show that is flashed through the ether to the screens and loudspeakers in thousands of homes.

ment had ear-marked the total output of radio components for mass-produced sets, Nos. A, B, C and D. Contracts for tens of thousands of those sets were already placed, and their prices were fixed. Radio was to play a highly important part in the coming war, and there was no room in the industry for such light-hearted nonsense as individual thought. Everyone had a job to do—a job that he was told to do.

All this the unseen visitor knew, and he, too, was aware of the splendid independence of the British radio industry. Aluminium? Why, if the B.Z. radiogram will be a better job as a result of a sheet of aluminium, then aluminium it shall have! And if Brown's aircraft factory needs aluminium, let Brown go out and buy some. There is enough to go round surely? And who would criticize the radio industry for such an attitude? Certainly not this unseen visitor, for he realised that all he saw around him was more than good; it was the finest of its kind in the world; and it was the best, simply because it had grown strong on individual thought and keen competition. But what chance had it against the organized and regimented industry of the Reich? Television sets and radiograms—they were already

on the production lines: what kind of an answer could they give to the German apparatus already installed in tanks and planes? What would occur if the British Government suddenly demanded a hundred thousand radio sets for tanks and planes? What on earth *would* happen?

* * * * *

"No, old chap, don't waste your time. It's no good looking at that television set. There won't be any television after the week-end. Not for five or six years, at any rate. *Radio is going to war.*"

"Eh?" The City business man looked up with a start. Funny, but he could have sworn someone had spoken to him. But there was no one near him; no one except the attendant beside the television set he had been examining, and had half decided to buy. It was Friday, September 1st. Radiolympia was nearly empty. Even the unseen visitor had gone. The guns were thundering across the Polish frontier.

The City business man looked at his watch and turned to go. He decided that, after all, he would wait a little while before making up his mind. He was the last man out. The doors of Radiolympia closed behind him. The great pre-view was over.

BROADCASTING deserves a prominent place in the contents of any popular book on radio, if for no other reason than the fact that it is the central thread around which the pattern of the whole industry is woven. It is a far cry from that day in 1922, when an official rebuke from the Postmaster-General described the broadcasting of Dame Melba's voice as " a frivolous use of the ether," to the present time, when the Postmaster-General acknowledges the receipt of approximately five million pounds annually from licence holders! The demand for radio entertainment, created by the keenness of those early enthusiasts, founded the British Radio Industry as we know it to-day, and enabled it to design, build and market some 25,000,000 wireless receivers for domestic use in the sixteen years before the war.

The B.B.C. was one of the most enthusiastic supporters of the pre-war Radiolympia exhibitions, and many will remember the ambitious, educational features that were such a great attraction. In 1938, when television was enrolling its first few thousand viewers, and when the whole art was still a first-class mystery to the general public, the B.B.C. erected a complete television studio and transmitting unit at Olympia, enabling thousands to see behind the scenes, and to follow the actual production of the "vision" programme that was being watched in the homes of Southern England where television receivers were already installed.

Radiolympia, 1939 edition, was no exception; and the B.B.C. found time and ideas to entertain its visitors, even while struggling with emergency problems to meet the crisis that had loomed so near. How seriously those problems were being tackled, and how much had already been accomplished by September 1st., 1939, is still not generally known, for the work was of a very secret nature, and the need for secrecy remained until the final defeat of Germany in May, 1945.

Emergency Measures

Alexandra Palace went "off the air" even while the last few of the exhibitors were answering the questions of potential buyers of television receivers. The B.B.C. switched over to a war-time system of transmissions the day before the evening papers announced "*Hitler Invades Poland*," and, as the gates of Radiolympia closed, and the long line of cars and lorries streamed away from the great exhibition hall to the country, the B.B.C.'s

engineering and programme departments were hard at work on the first of their great upheavals.

The B.B.C. with an almost over-developed modesty, confines its reports of war-time achievements to an impressive list of programme hours and similar statistics. Even its official handbook for 1945 only hints at the difficulties that were encountered in order to carry on with the essential job. Nothing is said, for instance, of the thousand-and-one minor incidents by which individual members of the staff contrived to keep Britian "on the air" without a minute's break, in so many different languages, for over six years. *A point that cannot be repeated too forcibly is the fact that the Luftwaffe never once drove the B.B.C. right off the air.* And we know well that our own R.A.F. closed down the Axis broadcasting stations almost every night when once our bombing offensive got under way.

The two major problems tackled by the B.B.C., *before the outbreak of war*, were decentralisation of vital apparatus and personnel, and modification of the entire system of transmissions in order to render the various stations useless to the enemy as radio beacons for guiding their bombers. No full-scale experiment of the emergency system was possible, for secrecy reasons,

Decentralisation of vital apparatus and personne That is how the B.B.C. continued to keep Britain on the air throughout the war. This picture was taken in an underground emergency control room, "Somewhere in England".

and the success of the scheme, when the switch-over was made, is deserving of the highest praise. The technicalities of the emergency system are too complicated to set down here; but, roughly speaking, the plan involved exact, synchronised transmissions on two wave lengths of a single programme from all the Regional transmitters—*and this was achieved, without rehearsal, in two hours.*

Baffling the Luftwaffe

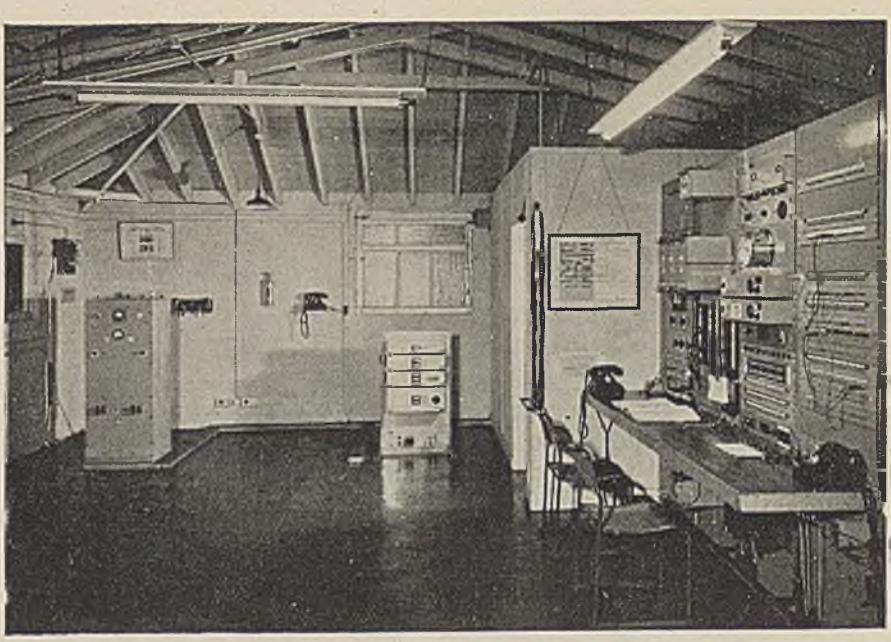
The idea was to make it impossible for an enemy aircraft to "home" on the transmission of any one station. If a Luftwaffe pilot tried to tune in to Bristol, he would be tuned in to, say, Bristol, London, Birmingham, at the same time, and so be unable to obtain a radio bearing upon any definite point. Only when he drew near to one of the synchronised stations would he be able to pick it out—because of the increased strength of the signal so close to him—but that point, too, was looked after. Fighter Command had all the main stations under its control, and could—and did—order the B.B.C. to switch off any main station when a raider came close enough to it to distinguish it.

The most elaborate steps were taken by the B.B.C., both for the purpose of maintaining the listener's programmes, and for defeating the raiders. For instance, the *three-minute rule* was created and strictly observed right through the war. This was an order to Engineers-in-Charge at all the B.B.C. stations, compelling them to switch off, *and stay off*, until ordered to resume, if they "lost" their programme for more than three minutes. For how else could the B.B.C. be sure that any one station would be "off the air" if Fighter Command so ordered it, if they had lost touch because the connecting lines had been bombed?

At the Ready

"Sirens will go in a few minutes, Mary. The radio's gone off!" Remember those nights? But, in fact, the radio never did "go off." The nearest main station was switched off as a raider approached, but there were always three or four more stations carrying the same programme, for those whose sets could pick them up. And to improve upon these hit-and-miss conditions suffered by so many listeners, the B.B.C. built and put into operation a completely new, auxiliary set of transmitters to cover the country. These stations, known as "Group H" stations, were installed at every centre where they could serve a population of 50,000 and over. They were low-power transmitters, some of them radiating as little power as is consumed by the 100-watt lamp in your living-room, none of them radiating more than a 1-kilowatt bar uses in an electric fire. There were over sixty of these stations in operation by late 1942, and their engineers had authority to keep them on the air until the local siren went. A secondary use for these "Group H" stations—planned, but fortunately never necessary—was a means of communication to the public for Regional Commissioners in the event of invasion.

The amount of planning and work involved in all this can be left to the



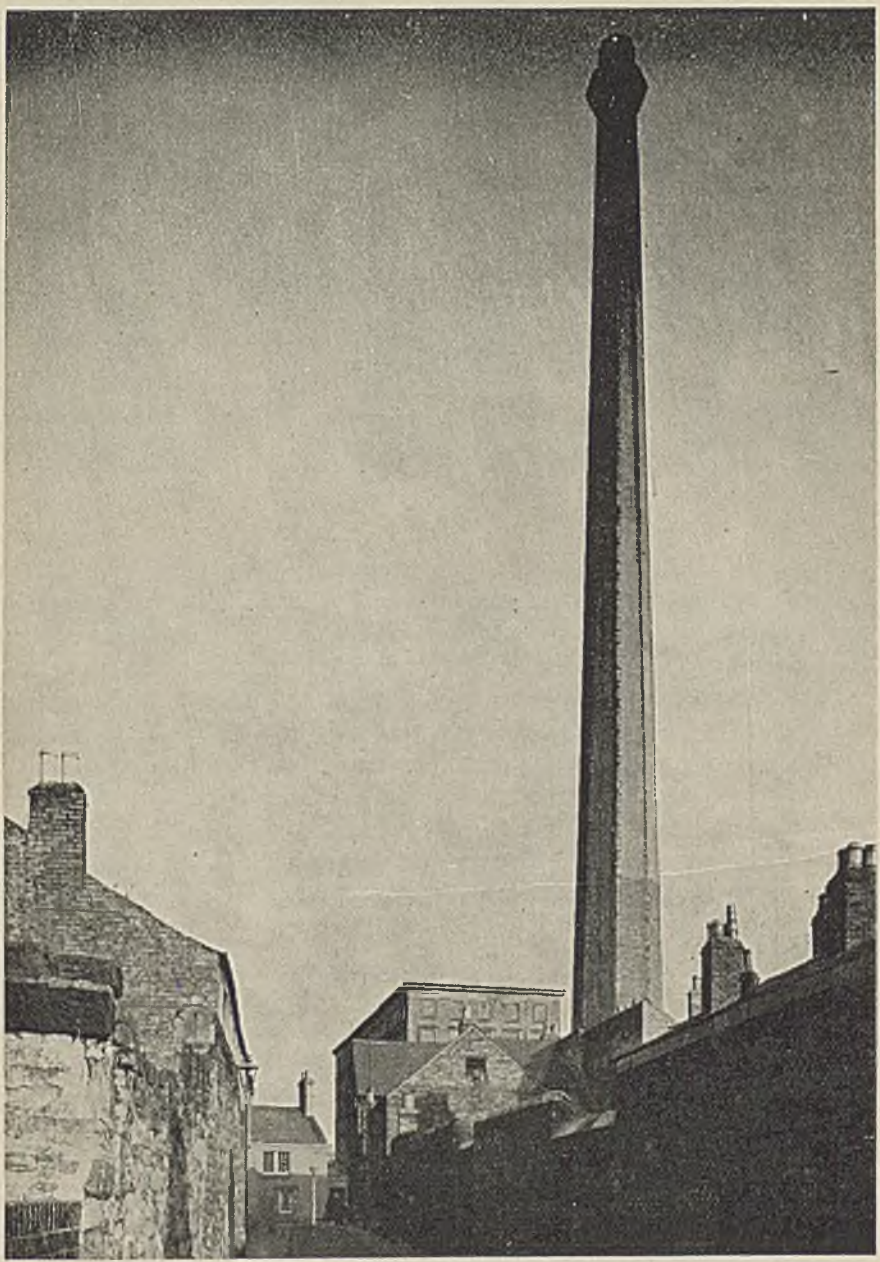
The control room of a typical "Group 11" station, showing the transmitter and the control desk.

imagination. Seventy semi-independent transmitters, plus the main stations (liable to be switched off at any minute without warning by a third party), had to be supplied with a programme by land-lines, not from one source, but from studios and other centres of entertainment all over Britain. And this with all the hampering circumstances of complete decentralisation, and with all the "incidents" which occurred from night to night.

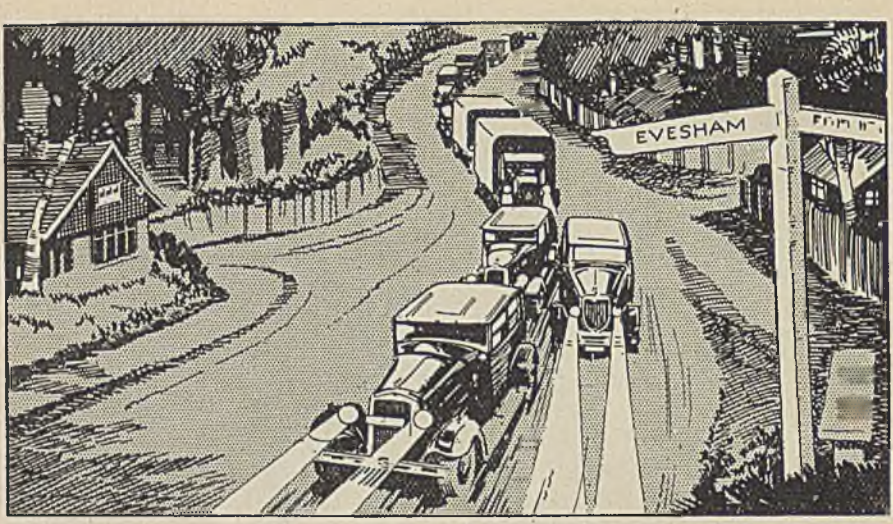
Decentralisation to the B.B.C. was an appalling thought, when it was first considered; for this organization, probably more than any other, had been dependent upon a close and intimate contact between all departments for its smooth running. Decentralisation meant that departments which had been, by design, six feet of corridor apart, would have to be separated by two hundred miles of telephone line. But it had to be that way, and so the impossible was accomplished. And, to add to the new difficulties, fresh networks for foreign broadcasts were built up even while the upheaval was in progress. There was no apparent strain in the arrangement—no serious gap in the programme plan, yet "Variety" moved westward to Bristol, "Drama" journeyed to Manchester, and many other activities were moved to new country headquarters at Evesham in Worcestershire.

"Variety Went to Bristol!"

How easy it is to say, "Variety went to Bristol!" Ever since the days of Munich, in 1938, the B.B.C. had been preparing secret plans for mobiliza-



Dixon's Chimney, Carlisle. This was the 306 ft. high aerial mast of the local "Group H" station installed by the B.B.C. in 1941. Over sixty of these low-power transmitters were put into operation, and each served a centre with a population of 50,000 and over. They were able to remain "on the air" during raids until the local siren went.



The B.B.C. bought up buses and cars. When Hitler moved into Poland, the B.B.C. moved out into the country.

tion and decentralisation, yet it was not until Friday, September 1st, 1939, at 6 o'clock, that "Variety" received the word "GO." Producers, secretaries, and engineers climbed into their cars and headed for the "Safe area" one hundred and twenty miles distant. Variety still went out from the transmitters without a break—by means of recordings. And even while the discs were revolving on the turntables, everyone was working hectically to make studios out of any buildings that were available, parish halls included. Only three days after Britain had declared war, the first "live" variety show went on the air. But with the fall of France, the illusion of Bristol as a safe area was rudely shattered. Variety had walked right into it with a vengeance. John Watt, its director at the time, is best able to sum up what followed:—

"No one in variety is likely to forget those days and nights in Bristol when the blitz *did* come. Acoustics, so dear to the engineers, did not seem to matter so much after all when, on one memorable occasion, all the windows of Central Hall were blown out and we broadcast practically in the open air. Peace-time standards of lighting also went by the board when, as on more than one occasion, we broadcast our scripts by the flickering gleam of hurricane lamps. Variety—in Bristol—certainly 'had it.'

"But despite the bombing, and many other difficulties beside, variety grew so rapidly that it was necessary to move once again, and in April, 1941, the whole outfit travelled to Bangor in Wales. A special train was needed for that—432 of us, not to mention seventeen dogs and a parrot. And, arrived at Bangor, we had to start all over again fitting up more church halls, and—this time—a cinema theatre, as well as the Grand Theatre at Llandudno. Bangor meant a round-trip for most artists of

about five hundred miles—yet they came, stars like Jack Hulbert and Cicely Courtneidge, Jack Buchanan, Arthur Askey, Jimmy O'Dea—and Lucan and McShane to start 'Old Mother Riley.'

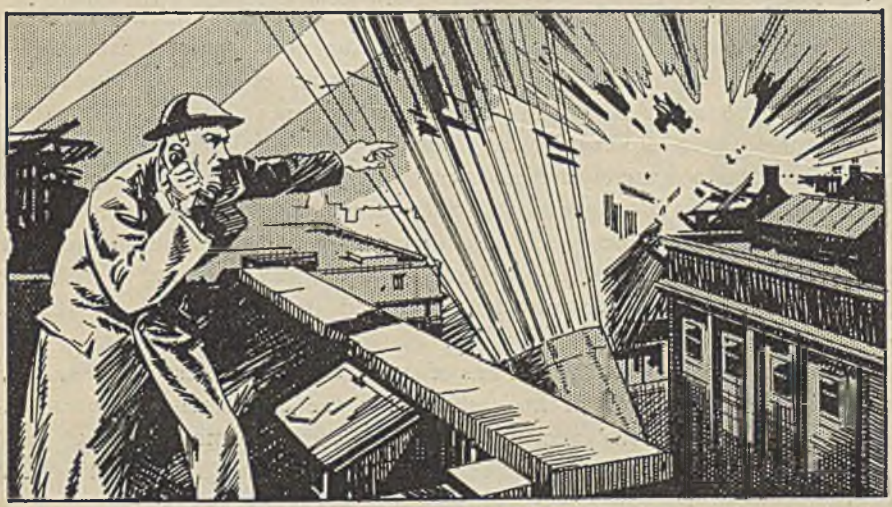
"From Bangor the Variety Department gradually trickled back to London, so that by the autumn of 1943 we were all more or less home again—home from the hills, and incidentally from the sea. But not to our old home at St. George's Hall, which, like Queen's Hall next door, the Luftwaffe had considered a worthy military target in our absence. But we came, anyway—in plenty of time for the doodle-bugs."

And, as it was with variety, so it was with drama, which "went to Manchester."

London Carried On

Broadcasting House, which carried on in London, was hit three times. On one occasion during one of the heaviest night raids on London, three separate B.B.C. establishments were hit. Yet not once did any service go off the air, and within a few hours the staff were re-installed with equipment and in buildings that had been set aside for just such emergencies.

Many listeners will remember the occasion when the announcer's voice hesitated for just a few seconds during the reading of the News. That was the only sign the world had that a bomb had penetrated Broadcasting House, passing through three floors and lying there for some thirty minutes before exploding. Many people, too, will have heard the famous story about the B.B.C. land-mine; nevertheless, it is good enough to be repeated. A roof-spotter who was keeping the staff informed of what was going on, suddenly announced that a parachute was on its way down, but he couldn't see what was attached to it—he'd look over the parapet and see. He did.



"——it's coming so close that I could almost catch it!"

Quite calmly and cheerfully, standing alone in the lurid light of flames and explosions all around him, he called out, "It's coming so close that I could almost catch it!"

A few seconds later it hit the ground only a few yards from Broadcasting House in Langham Place, and exploded with an appalling crash, bringing down masonry from buildings all round. He knew then what had been attached to it, but he wasn't hurt.

An equally calm and cheerful voice greeted him through his head-phones—"Butter-fingers!"

Creating Additional Services

While all this was going on, the B.B.C. Services had to be increased many times to cope with the demand for news to the rest of the world in a dozen-and-one different languages. And, even as all *this* was going on, the man-power of the B.B.C., in common with almost every other organization in the country, was being slowly drained to fill the ranks of the fighting forces. How it was all achieved, not even the people who managed it can tell. Somehow, they collected together near Evesham a band of men and women of all nationalities—many of whom could not speak a word of English—and trained them all to become news-readers in their own tongues. These men and women, who were stationed near Evesham, included many different nationalities. They were housed, fed, looked after, and duly shepherded to the microphone at their appointed time, none of them ever being a second late for his scheduled time once during the five years and more, during which the service was operating at full pressure.

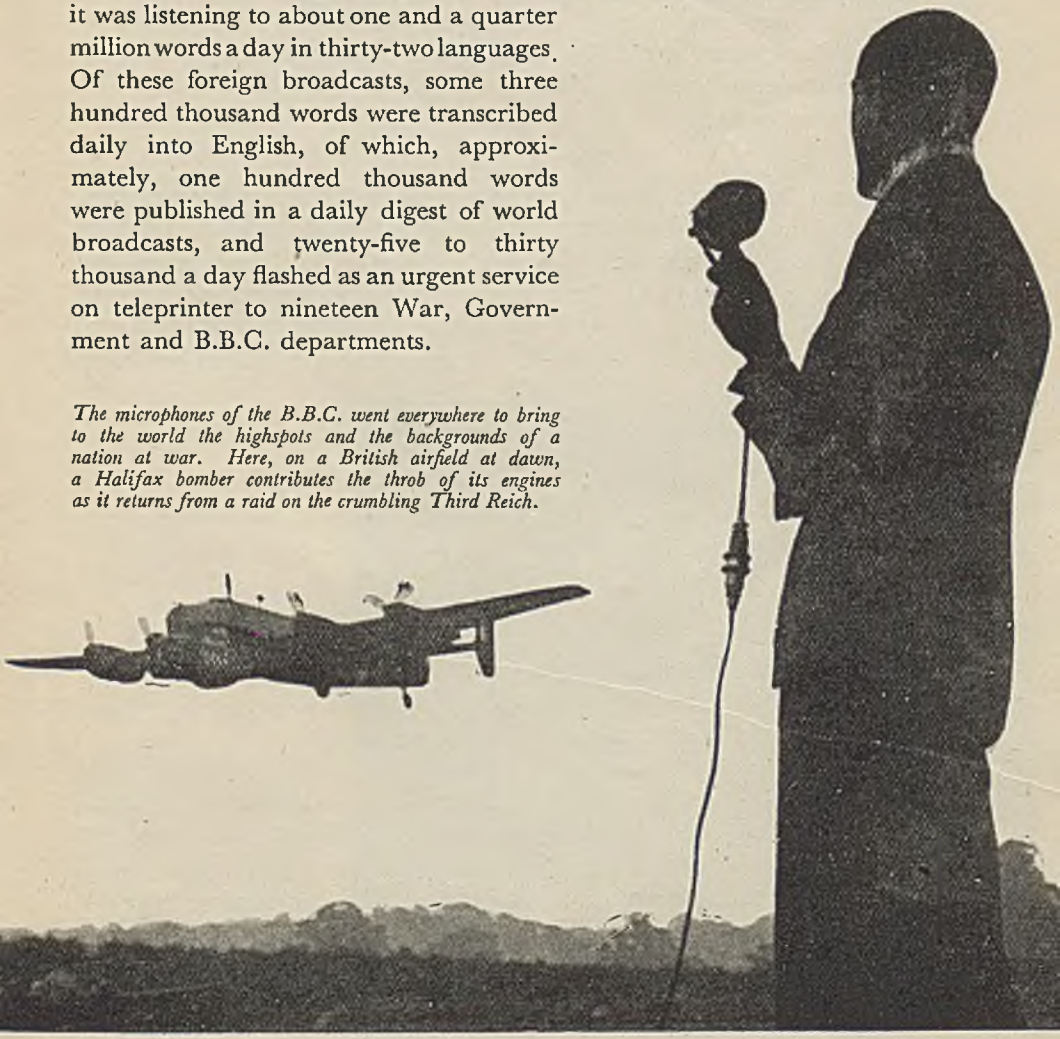
The Monitoring Service of the B.B.C.

In addition to the thousands of programmes which it radiated during the war years, the B.B.C. was given the stupendous task of listening to and digesting the tens of thousands of programmes that were broadcast by other nations. And out of all these programmes that were overheard, every one of any importance was recorded. The word " programmes " in this case does not merely mean entertainment broadcasts, which might or might not contain propaganda: it includes every speech and every announcement made by the enemy. It also includes every worth-while word sent out in morse code—both by hand and by high-speed machine. Thousands of millions of words were tuned in, recorded and digested by the B.B.C. during the war years.

Long before the war, the nucleus of the monitoring system was founded, and, to give an example of the work done by the department, every speech made by Hitler or his fellow-gangsters, from the beginning of the Nazi Party's rise to power until its final destruction, lies in the B.B.C. archives on film, on disc, or on steel tape. But the main job of the monitoring service was not to get a programme recorded for subsequent transmission (that was

taken care of by the B.B.C.'s Tatsfield receiving station) but to commit to paper the text of spoken word broadcasts.

And the war-time monitoring service was started at Evesham—the B.B.C.'s war-time country home—when war broke out. It was started at the request of the Government, and it has since served all the main war and other Government departments, and all B.B.C. news departments, with a rapid flash service and a daily report in the form of a digest of world broadcasts. It began with a few very overworked young men, struggling on their own initiative to keep a check on what the enemy was saying. In five years it grew to be a highly organized professional news and intelligence service, comprising over six hundred employees, and listening to every audible broadcast worth mentioning throughout the world. Before the German surrender it was listening to about one and a quarter million words a day in thirty-two languages. Of these foreign broadcasts, some three hundred thousand words were transcribed daily into English, of which, approximately, one hundred thousand words were published in a daily digest of world broadcasts, and twenty-five to thirty thousand a day flashed as an urgent service on teleprinter to nineteen War, Government and B.B.C. departments.



The microphones of the B.B.C. went everywhere to bring to the world the highspots and the backgrounds of a nation at war. Here, on a British airfield at dawn, a Halifax bomber contributes the throb of its engines as it returns from a raid on the crumbling Third Reich.

In addition, the daily monitoring report, giving the main slants of world radio propaganda and news, and a short daily report for the War Cabinet offices, were issued.

The monitoring service worked to split seconds. When Keren fell, the monitoring service picked up the news in Arabic from a Cairo transmission and flashed it to the Prime Minister ten minutes before the operational telegram arrived from the War Office. When Mussolini resigned, the service picked up the news in Italian at 22.51 double British summer time, and flashed it to the News Department of the B.B.C. at 22.53. In exactly five minutes, at 22.58, it was on the air in the B.B.C. news for Europe in English. At 22.59, having been written in Spanish, checked and revised, it went out on the B.B.C. Spanish service.

When Holland was invaded, Hilversum was putting out, minute by minute, "Parachutists over . . . parachutists coming down. . . ." *The monitor operators were phoning these messages through to the Air Ministry before the parachutists had touched down!*

War Reporting

Because it has formed such a large part of the B.B.C.'s war programmes, the work of the war reporters is often overlooked or accepted as commonplace. But recall this dispatch: "I've just come back from the beaches, and as I've been in the sea twice, I'm sitting in my soaked-through clothes with no notes at all. All my notes are sodden—they are at the bottom of the sea. So, as it's only a matter of minutes since I stepped off a craft, I'm just going

The Monitoring Service. The Ears of the B.B.C. By day and by night, without a break, more than fifty thousand words were taken down every hour—words that burbled from loudspeakers and headphones in thirty-two different languages. And from them, translated into English, the equivalent of half a dozen novels were written and edited each day.

to try and tell you very briefly the story of what our boys had to do on the beaches to-day as I saw it myself. . . ." That was broadcast after the 9 o'clock news on D-Day. B.B.C. men, with specially designed midget recorders and a supply of recording discs, were with front-line troops in every major operation of the war. They went out with the Navy, they stormed the beaches with front-line troops, they went across the channel in gliders, they stationed themselves in advanced posts to pick up the noise of exploding shells and mines, they flew over Germany in R.A.F. bombers by night, and in Flying Fortresses by day, watching and recording the destruction that they saw below them. They took the same risks as the troops, and they were unarmed. They did all this to bring the proof of what was going on, to the millions of people who listened by their firesides in countries all over the world. Many were injured. Several were killed. But, as a result of their magnificent work, the archives of the B.B.C. recording library are filled with first hand accounts of every notable occurrence of the war.

The B.B.C. kept the world informed of the truth, it kept the British civilian in touch with every move, military and political, throughout the long years of war. Through their receiving sets, the people of Great Britain were always in close touch with their leaders. Yet, despite the importance of all this work, possibly the most important of all the war-time jobs of the B.B.C. was to keep open the doors of Truth and Hope to the millions of oppressed people in those countries across the sea under Nazi domination. We, in Britain, will never know just how much this meant to those people

Portable recording unit. This device, more than any other, made it possible for the folk at home to hear the story of the war in faithful, dramatic detail. B.B.C. War Reporters took their clockwork driven portables and their microphones into places where no recording truck could go. The job they did was magnificent.

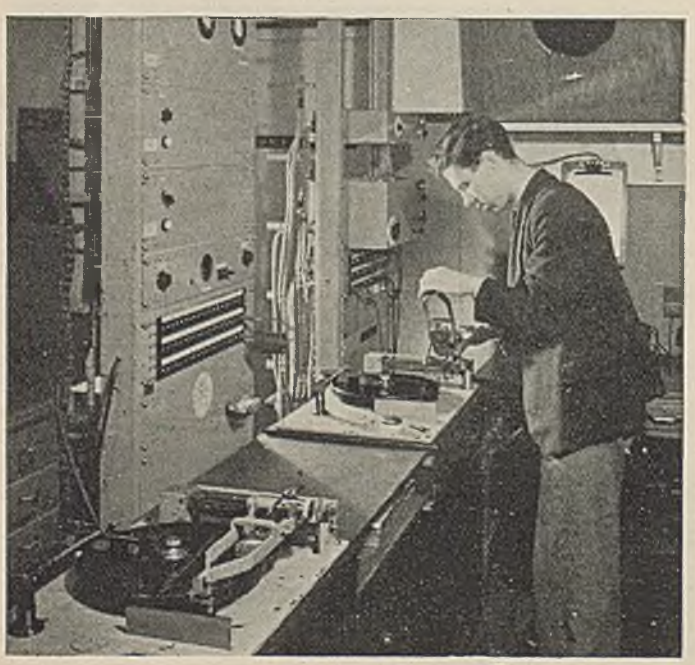
who were stripped of everything but hope—and even that ran very low at times. The nearest approach to an appreciation of what the voice of England meant, can be obtained from the words of M. Georges Bidault:

"June, 1940. In the din of armoured columns sweeping like an avalanche towards the South, the familiar voice of the French radio was extinguished. The links which united the French with the rest of the world were cut at a single blow; they had been hurled living into the grave, they had been walled up in a prison of silence where no friendly voice could ever reach them again. These were dramatic hours when one's reason refused to think for fear of doubting itself, when dawn was dusk, when one lived and wished to die.

"There were no more newspapers, no mail, no radio; there was nothing but rumour with its many confusing voices, often tainted, more often deceiving. In the disorder of rout and the confusion of retreat, our hearts ached to see a nation crumbling."

And then on June 18th, General de Gaulle broadcast his first appeal over the B.B.C. "How shall we recall," continues M. Bidault, "without emotion those evenings of clandestine listening at home, in cold rooms without fires, in the darkness of night? It is partly, indeed largely, thanks to you, dear familiar voices, that our minds stayed free while our limbs were bound."

And, as it was with France, so it was with Belgium, Holland and Norway. Night after night, month after month, throughout the war years, the voices of Hope and Encouragement flashed out from the aerials of the B.B.C. to the people of oppressed Europe. And it may truthfully be said, that when the day of liberation finally arrived, it was in no small measure due to the spirit of resistance existing in the French people, inspired by the voices of their friends in England.



"The programme you have just heard was a recording. . . ." Continuity is obtained by using two recording turn-tables. One is made ready while the other turns.

FINDING THE MEN

It is very difficult to recapture a true picture of things in 1939, looking back over six years of colossal expansion and development—and, what is more, looking back from a position of security and achievement; but it is most necessary to recapture that picture in order to appreciate the vastness of the job that has been done, and to realise what a very narrow, twisty lane divided the realms of victory and defeat. That lane might well be called "manpower alley."

"Manpower" was one of the most repeated and least understood words of the war. To get it in its right perspective, in terms of radio, consider these two facts. At the end of hostilities, there were close on 500,000 men and women serving the nation through radio. In 1939 the figure stood at approximately 75,000.

Flashback

But figures are cold and uninspiring. We know that we got the men—and trained them. Consider how nearly we did *not* get them. Early in 1939 a responsible person made a statement to the effect that *two-and-a-half radio firms could easily supply the needs of the R.A.F.*

In 1938, one radio factory was switched over to the manufacture of bombers.

By the beginning of 1940 the radio industry had already been drained of many thousands of men, as a result of the call-up and voluntary enlistments.

And, to conclude this painful summary, recall that the radio industry, still quite young, was geared up for peace-time production, and was not even in demand by the fighting forces, whose radio needs were, at that time, less than modest.

No, there is one more recollection to be made. While the industry was being drained of its personnel, and even before the realization had come that radio was to be one of our greatest sources of salvation, there was an episode in 1940 which will figure as one of the bleakest moments in British

history: "*Dunkirk*"—*and the loss of most of the equipment we had so laboriously made.*

And then, suddenly, at the most awkward of all awkward moments, everybody began to ask for radio.

The Navy wanted more radio. The Army wanted more radio. The R.A.F. wanted as much radio as the other two services put together. The G.P.O. needed additional apparatus, and so did the B.B.C.—*and* the Police, *and* all the other services, such as the Observer Corps and Fire Service. And, as the emergency grew in intensity, along came the demands for radiolocation apparatus as well.

But this chapter is not concerned with types and quantities of radio apparatus: it is written around "manpower." To *make* all the gear that was so suddenly demanded, the industry needed men and women. To *operate* all the sets which they were ordering so freely, the fighting forces needed men. To *maintain and service* the apparatus, still more men were required. *And to train all the "manpower," skilled men were needed.* Had anyone thought of that?

The Verge of Disaster

The first shock came in the summer of 1940, just after Dunkirk, in the guise of a telephone call from the Ministry of Labour to the Secretary of the Radio Manufacturer's Association in London. "The R.A.F. urgently needs 500 technicians, and it is proposed to call them up from the industry."

Where were a large number of the technicians who were so urgently needed? In the Forces, washing up dishes, peeling potatoes, driving lorries, manning sentry posts—doing anything and everything but the job for which they were most suited.

Blame no one, for no one foresaw the need that was to arise; but these are the facts.

R.A.F. radio mechanic at work . . . June 1940.

An unofficial Committee was set up, representing the Forces, the Industry and the Board of Education. The men had to be found, and trained—somehow.

And so it came about that the radio industry, sorely pressed for manpower to deliver the goods, had to stand up and fight to retain the key men it needed. How it did this forms one of the most dramatic "behind the scenes" stories of the whole war. And the story began with a visit by two or three members of the industry to the Air Ministry—to meet the man who had issued the call for those 500 technicians, and to endeavour to explain the impossibility of meeting the demand.

"If the R.A.F. needs those men (and the industry cannot spare them anyway), the Army will probably need more, and so will the Navy."

"What can we do?"

"Train them."

"But where can we find enough for our immediate needs? *Where are the men?*"

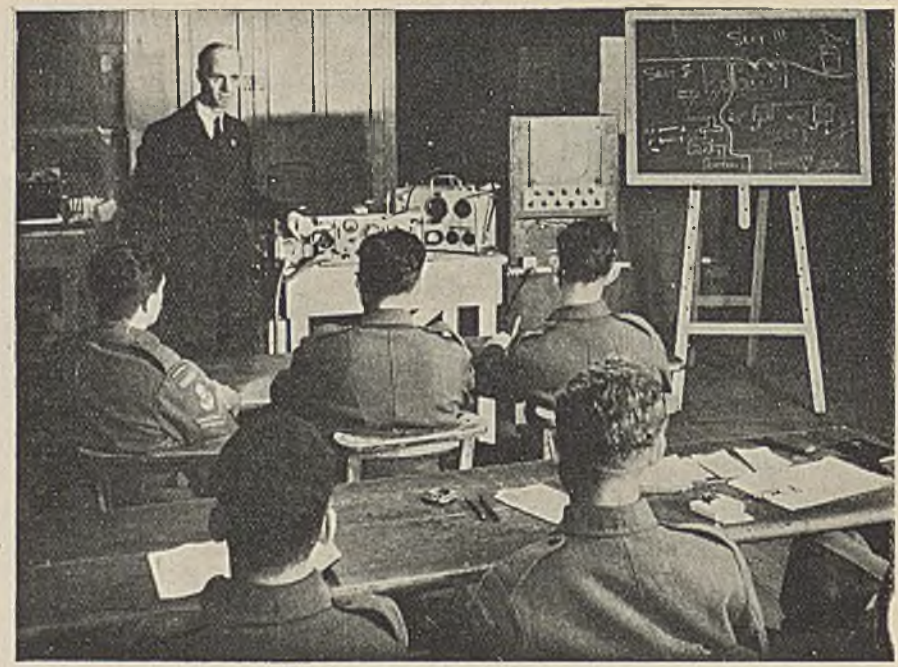
"Washing dishes—peeling potatoes—driving lorries. . . ."

That, roughly, was the line of conversation which ensued. What followed is a typical example of the way we do occasionally beat "red tape". It was decided to make an unofficial survey of the position—by direct mail—to find out exactly how many men had been "lost", and where they could be tracked down.

23,000 Unofficial Official Letters

The representative of the industry explained that he had no authority to allocate his Association's funds for posting thousands of letters. The R.A.F. officer produced, quite unofficially, 23,000 O.H.M.S. envelopes. A simple form was drawn up. "Have any of your service engineers enlisted, or been called up? Can you supply their last known addresses? Can you give their regimental numbers?"

The Radio Manufacturer's Association printed 23,000 of these forms, put them into the O.H.M.S. envelopes, and mailed them to factories, wholesalers and radio dealers all over Great Britain.



Schools, Universities and Technical Colleges were taken over. Teachers were taught, and went out once more to teach. So urgent was the task, and so energetically was it tackled that training establishments were run on a factory basis. Universities worked three 8-hour shifts!

Within forty-eight hours the answers began to flow in. Within a week there were over 6,000 cases to be followed up. Within a fortnight 1,000 men had been located in the Army and R.A.F. The immediate need was met and, within another month, a further pool of 1,000 men was available as a nucleus for the great training scheme which was to follow.

With no official blessing, but with the approval of the Ministries concerned, the work went on. An unofficial committee was set up, representing the Forces, the Industry and the Board of Education. A new syllabus for training was drawn up, and a carefully formulated "exam" was arranged for selecting entries into the radio branches of the Forces.

The Official Blessing

In December of 1940, at the inspiration of Mr. Churchill, the unofficial Committee was made official, reporting direct to the Cabinet under the leadership of Lord Hankey, and the good work went ahead with a rush. As a nation, we were at last awake to the vital role that radio was to play in the war; and, at the eleventh hour, miracles were demanded—and worked.

No poor material must be admitted. The finest men must be available for training. The available manpower must be formed as a pool—for *all*

purposes. There must be no more misplacements. There must be refresher courses for all who need them. Those were the directions.

And the results? Ninety technical colleges and thirty-one universities were made available for training. Men of matriculation standard were passed through for officer's courses. Professors taught the teachers. Even the professors "went back to school" to prepare themselves for their new and urgent job. Boys leaving public schools were sent up for two-year university courses. Hundreds of physics masters were withdrawn from schools. Men and women already specialized in other academic subjects—botany, biology —were put through six-month courses in radio. The Dominions and America were scoured for additional technical men.

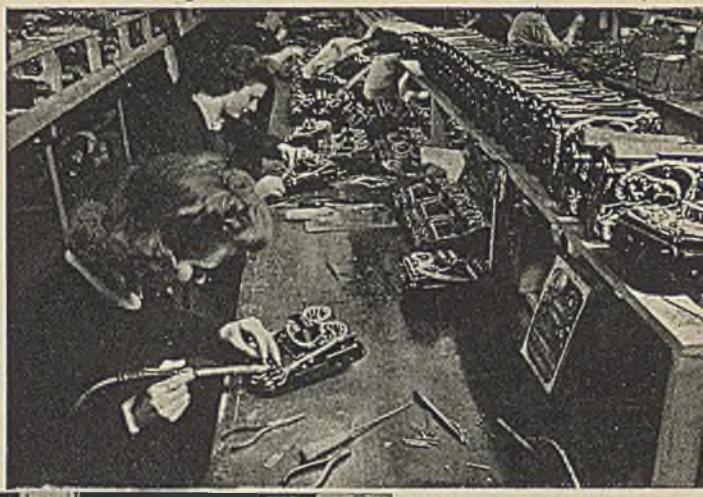
Turning the Corner

By June, 1941, the results of this thorough planning were beginning to be apparent. Skilled men trained for the operation and maintenance of radiolocation and other wireless equipment totalled 11,000. A further 30,000 were in course of training.

Most important of all, the "pooling scheme" enabled men already trained for the Forces to be loaned to industry to help to make the gear they were to use when it was ready! *Contrast this with the dark days of the Blitz, when the "back-room boys" worked all day in their laboratories—and then worked*

The most ingenious and practical apparatus was designed and produced for the lecture rooms. Trainees were taught to work with, and in, the gear that was to be their care in the years ahead.

Hundreds of thousands of pounds worth of test gear was made for the vast training programme. Millions of pounds worth was later supplied for use in the factories and the workshops of the armed forces. Nearly every new radio set called for at least one new type of testing apparatus.



Many millions of valves, in thousands of different patterns, were made for the Navy, Army and Air Force. Special test instruments were designed to examine these valves, under working conditions, before they were despatched for service in all parts of the world.

Some of the test gear was simple to construct: some of it was far more complicated than many of the wireless sets in use at the time! But whatever the designer designed, he had to make it as simple as possible to operate. That meant fewer man-hours wasted on training the people who were to use it.

half the night as operators for the equipmen they had designed. They had to do it. There was no one else who knew how.

By March, 1942, the "radio strength" of the Navy, Army and Air Force was up to 24,000. By June it was 33,000.

By VJ-Day the equivalent of a complete Army Corps of highly skilled technicians had been passed through the schools.

The Tools for the Men

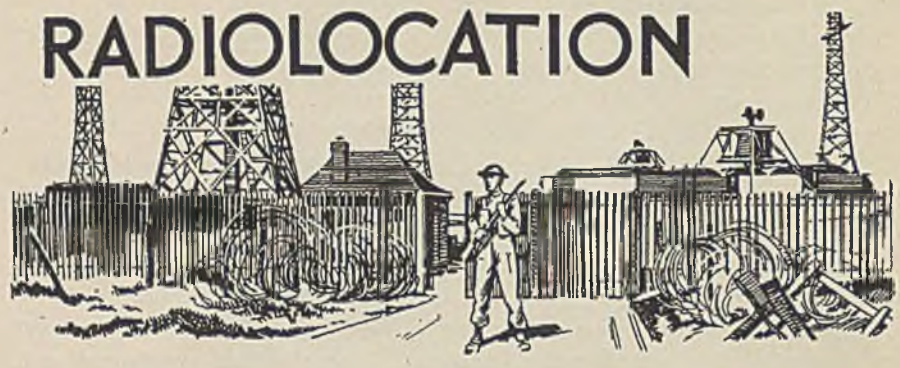
A final thought—but a mighty one. How were all these people taught the secrets of most advanced radio? How were they able to walk out from their schools and use and maintain the complicated apparatus which confronted them, *in action?* Only because their lecture rooms and laboratories were lavishly equipped with the very finest apparatus obtainable.

In addition to its almost nightmare fighting commitments, the growing industry somehow managed to keep the radio training schools supplied with experimental and test gear. Through the medium of the Radio Manufacturer's Association, many hundreds of thousands of pounds worth of apparatus was made, and delivered, in "crash programmes", to the waiting army of instructors.

In this way, man-power—500,000 men and women—was organized, trained from the raw and polished to the finest degree—trained to operate and keep in operation something that, a few years ago was virtually unknown.

This was indeed one of the greatest dramas of the war. Had not keen men foreseen the need that would arise—for men and apparatus—and pressed ahead with unofficial plans, the radio and radar sets which so largely brought us Victory, could not have been manned. They must have "gone into store". They must have lain in factories and warehouses while the enemy did his worst. And we now know only too well how bad that worst would have been.

RADIOLOCATION



WAY back in 1924, ten years before a ranting, raving corporal talked and bullied his way into the Reich Chancellery in Berlin, two British scientists, Sir Edward Appleton and Dr. M. A. F. Barnett, went to Bournemouth to carry out an interesting experiment. They wished to prove the existence of a belt or layer of gas in the earth's upper atmosphere. Years ago it had been suggested that such a layer must exist, for in no other way could the early wireless experimenters account for the fact that radio waves travelled round and round the earth, instead of vanishing upwards into space. There must be, they argued, some form of reflector which bent the waves back to earth, more or less as a mirror reflects light waves. For a long time it had been impossible to prove this theory, because man possessed neither the knowledge nor the apparatus.

Then came the inspiration which sent the two British scientists to B.B.C. headquarters, seeking permission to "borrow" the Bournemouth transmitter. They decided that, if they could transmit a certain type of radio signal nearly vertically upwards, and detect its return to earth, they would not only prove the theory that some form of reflecting substance existed, but they would also be able to measure its distance from the earth by measuring the time that the signal took to make the double journey.

Electric Tape-measure

Quite obviously such an experiment called for extremely delicate and specialized apparatus, and nothing so crude as the human ear and a stop-watch would be of any use. Wireless waves travel at a speed of about 186,000 miles a second; *and this means that an error of one hundredth part of a second would have thrown out their calculations by over 900 miles.* A number of ingenious methods were developed, capable of giving the necessary degree of accuracy; but the apparatus they finally decided to build was fashioned round what was years later to become the vital part of a television receiver

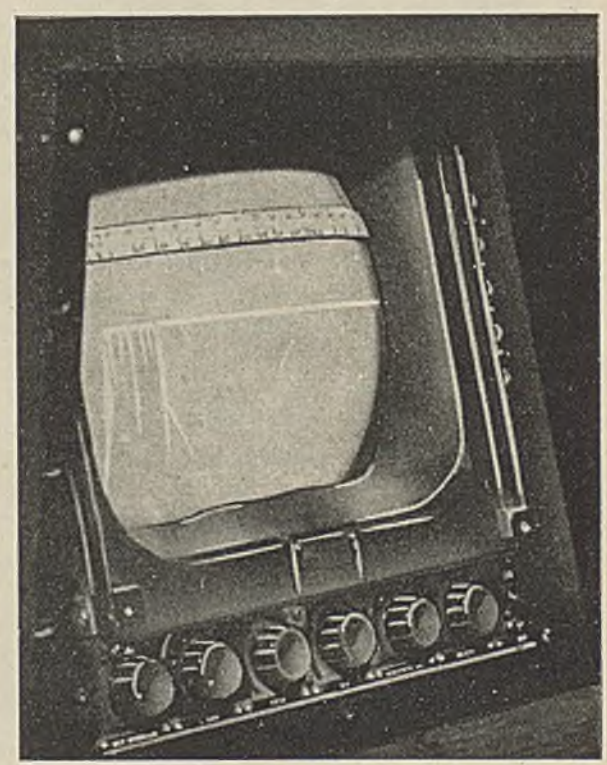
—the cathode-ray tube. By careful calculation they arranged for the spot of light to sweep backwards and forwards across the end of the cathode-ray tube in a straight line, and at a definite speed; thus, if they chose to make the spot travel once across the glass in one-thousandth part of a second, they had a thin line of light which represented a distance of 186 miles—a very useful and outwardly simple tape-measure!

Having progressed that far, the next step was comparatively easy. They connected their cathode-ray tube to a wireless receiver and set it up in a laboratory in Oxford, tuned in to the wave-length of the Bournemouth transmitting station. Then, every time the Bournemouth station transmitted its special, short signal, the spot of light on the glass tube gave a little kick—*and more important, indeed of historic interest, every time a signal was sent out, the spot of light gave a second kick a brief instant later. An echo!* Yes, the theory of the earlier scientists was proved beyond doubt, and by measuring the distance between the little bumps on the line of light, Appleton and Barnett were able to work out just how high above the earth was that long debated layer of reflecting gas. The answer was about seventy miles.

As a matter of interest, Sir Edward Appleton continued his research and later discovered yet another reflecting layer which science has named after him—the Appleton Layer—in honour of his work; but for us, in the story of radio at war, his discoveries have a dramatic significance. Little did Professor Appleton imagine, as he recorded and measured the echoes of those radio pulses in 1924, that he held in his grasp the secret that was one day to protect his country from the ravages of enemy raiders.

* * *

The setting for the next scene in the great drama, was the Government Radio Research Station at Slough, Buckinghamshire. Eleven



Far more advanced than the apparatus used by Sir Edward Appleton, this piece of R.A.F. radar equipment none the less employs virtually the same principle. It is an "electric tape measure". The line of light on the cathode-ray tube shows "kicks" when an echo is received. The spacing of the "kicks" is measured off in miles on the scale.

years had passed, and it was 1935. Four years ahead lay the biggest war in history.

But there was nothing war-like about the duties of the small group of men who were busy following up the experiments of Sir Edward Appleton. They were primarily engaged on meteorology. Using far better apparatus than Sir Edward had at his disposal, they were measuring the changing height of the layers above the earth, seeking to prove a number of theories that existed about the effect of these layers upon the weather. Under the leadership of a Mr. Watson Watt, now Sir Robert Watson Watt, these scientists were engaged upon nothing more exciting than "shooting" short-wave radio pulses to the heavens, and measuring the times that the echoes took to return.

And then one day Mr. Watson Watt noticed a peculiar thing. Unexpected echoes were appearing on the cathode-ray tube—*echoes that returned far too soon to have travelled back from the regions above the earth. There was only one explanation. Something quite near at hand—possibly trees or buildings—was reflecting the radio pulses back to the receiver.*

Fortunately for this country, Mr. Watson Watt was a man of extremely keen imagination. These sudden accidental reflections gave him an idea that was just as sudden and unexpected. He immediately re-designed his experiments to prove what he suspected, and as soon as he was satisfied he travelled straight up to London, to Whitehall.

Those Death Rays!

We know now the reason for his journey, and the nature of the discovery he had made. He has since been knighted for his great work. But in those far-off, peaceful days, it needed something very big first to claim the attention of the Cabinet, and then to persuade it to take immediate and urgent action. Sir Robert Watson Watt's message achieved both these things; it was, in effect: "Reflected radio waves were used to detect the presence of layers of gas above the earth: they can be reflected back from objects near at hand: *they can also be used to detect the presence of aircraft in the sky.*"

No one, not even among the closest friends of those scientists, was entrusted with the secret of the discovery. But in 1936 it was noted that a group of scientists had taken over Bawdsey Manor near Felixstowe, and that tall aerial masts had been erected in the grounds.

Tongues began to wag. Journalists, uncensored in those days, smelled a story. An answer had to be found. It *was* found; and what a good one it turned out to be! The news got round that, "Joe's tractor had mysteriously stopped working in a nearby field"—"that the engines of motor cycles and cars were being affected by some unseen ray." The stories grew and multiplied. Many readers will recall them. "It was almost impossible to drive along certain stretches of road without one's engines being affected." Unwitting victims of the great hoax, the newspapers played up these

stories, and so helped to keep secret one of the greatest secrets of the age—"Death rays"—"Mysterious rays that stop car engines". And motorists, eager to be in on the mystery, helped, too: for they blamed "the rays" for even the slightest ignition trouble!

And so, safely screened behind the scent of a red radio herring, Sir Robert Watson Watt and his colleagues pressed on with the great idea. More and more wireless masts grew up, and, by the end of 1938, a chain of radio-location stations was in existence around the vital stretches of the coast line of our islands.

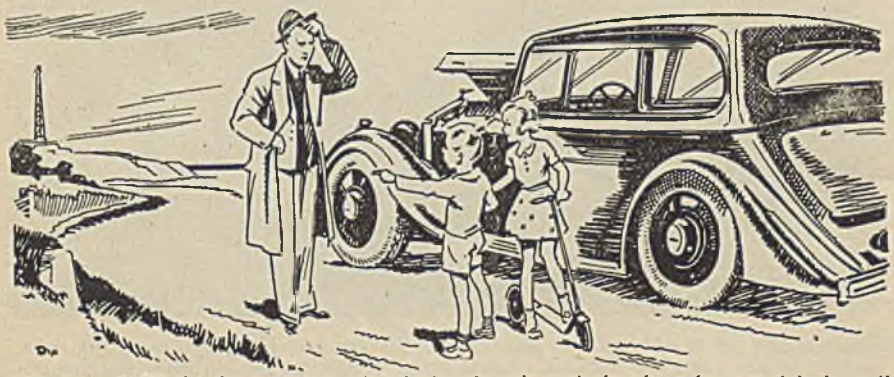
* * * * *

The third and final act of the drama was seen by thousands of people at the time, but even to-day, few of those people can have guessed that they were front-stall observers. The event was the beginning of high-definition television from Alexandra Palace in London.

The cathode-ray tube is the heart of a television receiver, and it is also the main component around which the whole science of radiolocation is built. Until the advent of high-definition television, there was no great demand for cathode-ray tubes, nor for the many components that are needed to work with them: and, *most important of all*, there was no ready-made industry, with all its designers and engineers with their brains and ideas from which to draw what was wanted for large-scale manufacture of radiolocation apparatus.

But the rapid success of television as a form of entertainment soon changed all that. The public wanted television; the makers of television sets placed orders with the component makers and the manufacturers of cathode-ray tubes; every branch of the radio industry began to speed up research; every workshop and laboratory started to specialize in the new ultra-short-wave technique; every factory trained workers to make the parts that were in demand.

To those who did not realise the full significance of all this, it seemed a pathetic wail to boast, at the outbreak of war, that *Britain led the world*



"Death rays! That's what it is! I was just driving along the road when the engine stopped dead——."

in television. To those who were in the know—and they were very, very few—that fact was a godsend. With the closing down of Alexandra Palace on 1st September, 1939, *Britain led the world in radiolocation.*

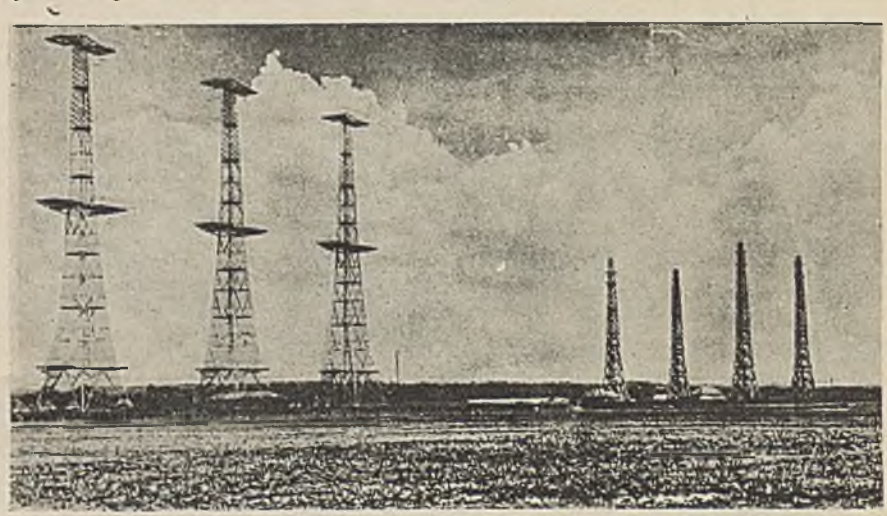
Thousands of components, from switches to lengths of special cable, were urgently needed: machinery for producing them was in existence. cathode-ray tubes and special valves were wanted in a rush: the valve-makers were well advanced in the science of their manufacture. Specialized engineers were urgently needed by the Government for training operators for the new apparatus, as yet unnamed: this personnel was to be found in the industry's laboratories. And, finally, thousands of workers were wanted to man the machines: there were already many hundreds with good experience.

The television industry died overnight. And when morning dawned the wheels began to turn for radiolocation.

What Is Radiolocation?

The British public have known of the existence of this mysterious thing called radiolocation ever since June 1941, and early in 1942 an intriguing poster appeared on the hoardings, calling for volunteers to work the apparatus. But comparatively few people know, even to-day, exactly what radiolocation is.

To complicate matters, when our American allies joined us in the war, another name, *radar*, was introduced. Both words mean one and the same thing; and radiolocation, as we prefer to call it, may be summed up as meaning *the science of detecting and locating the whereabouts and range of any object by means of radio waves.*



General view of a C.H. (Chain Home) radar station. The transmitting towers are on the left, and the receiving aerials on the right. Hundreds of chain stations provided an unbroken radio fence around the British Isles.

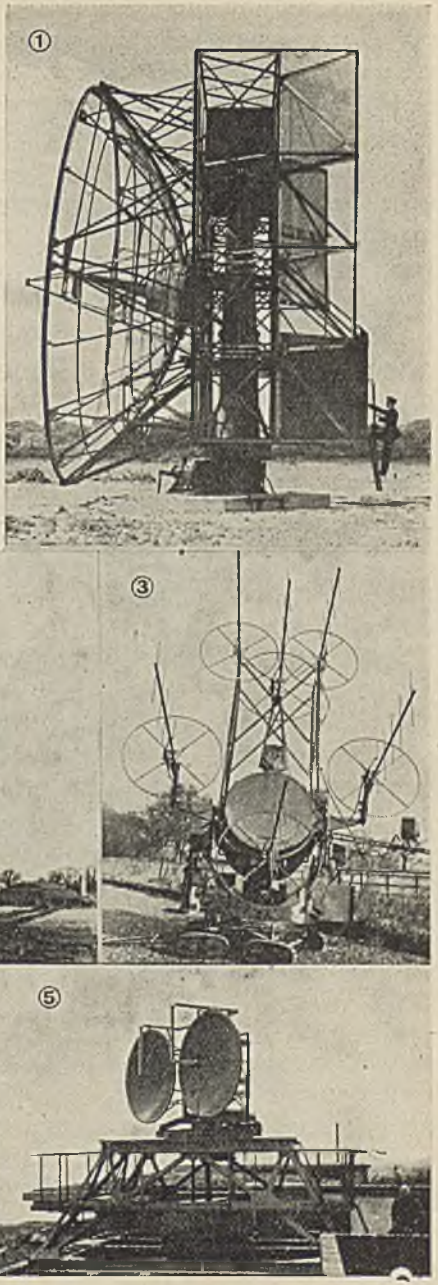
(1) *The aerial of a Fighter Director station in its outsize bowl-fire type reflector. The "reflecting" surface of the bowl is wire-netting.*

(2) *G.C.I. (Ground-Controlled Interception) aerial system.*

(3) *The radar aerial array of "Elsie", or Searchlight Control apparatus.*

(4) *One form of P.P.I. (Plan Position Indicator) radar aerial and reflector.*

(5) *The radar aerial system which spotted the targets for the Dover guns.*

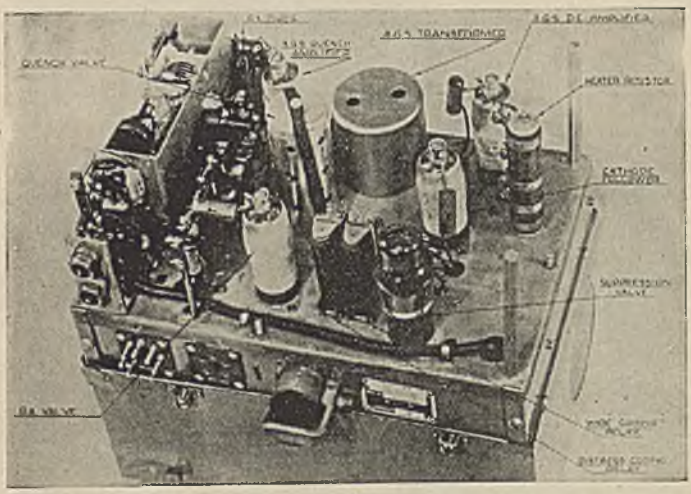


Radar aerial systems. These queer and fascinating structures puzzled many people who saw them from afar during the war years.

But in case this simple definition, following the equally simple description of radio pulses and echoes, suggests that radiolocation merely involves the use of a standardized piece of radio apparatus and a cathode-ray tube—or is much ado about nothing—here are just one or two examples of the many, many developments of the science. The *principle* remains the same in each case—reflected radio waves—but the *adaptations* of the principle are varied and complicated in the extreme. Some of the adaptations have taken months of concentrated, war-time research to perfect; some have taken years of research and are not perfected yet.

Long Distance Warnings

Taking first things first, the tall masts that were erected round the British coast, starting at Bawdsey, represented the earliest and simplest form of radiolocation. They were known as C.H. or "Chain Home"stations. They radiated a wide and powerful beam of wireless waves out to sea — towards the enemy, and they recorded the presence of any aircraft in the sky while it was still many miles out of sight.



I.F.F.—one of the first "Hush-Hush" radio sets of the war. And this is what they look like inside—nothing spectacular—almost the same kind of bits and pieces that are found in a modern, short-wave receiver.

And, here followed one of the first and most ingenious of all the adaptations, or improvements, of radiolocation. The whole idea of an early warning system was to avoid the need for keeping a fighter force in the air, waiting for an enemy that might, or might not, be on the way. To be able to detect the presence of approaching aeroplanes was, therefore, only half the answer. *It was necessary to be able to find out whether those aircraft were hostile—or our own.*

Who Goes There? Friend or Foe?

To this end, a small piece of equipment was designed and fitted into all British aeroplanes—a silent,. radio voice, which would automatically answer the challenge of the distant radiolocation sentries. Until the air-

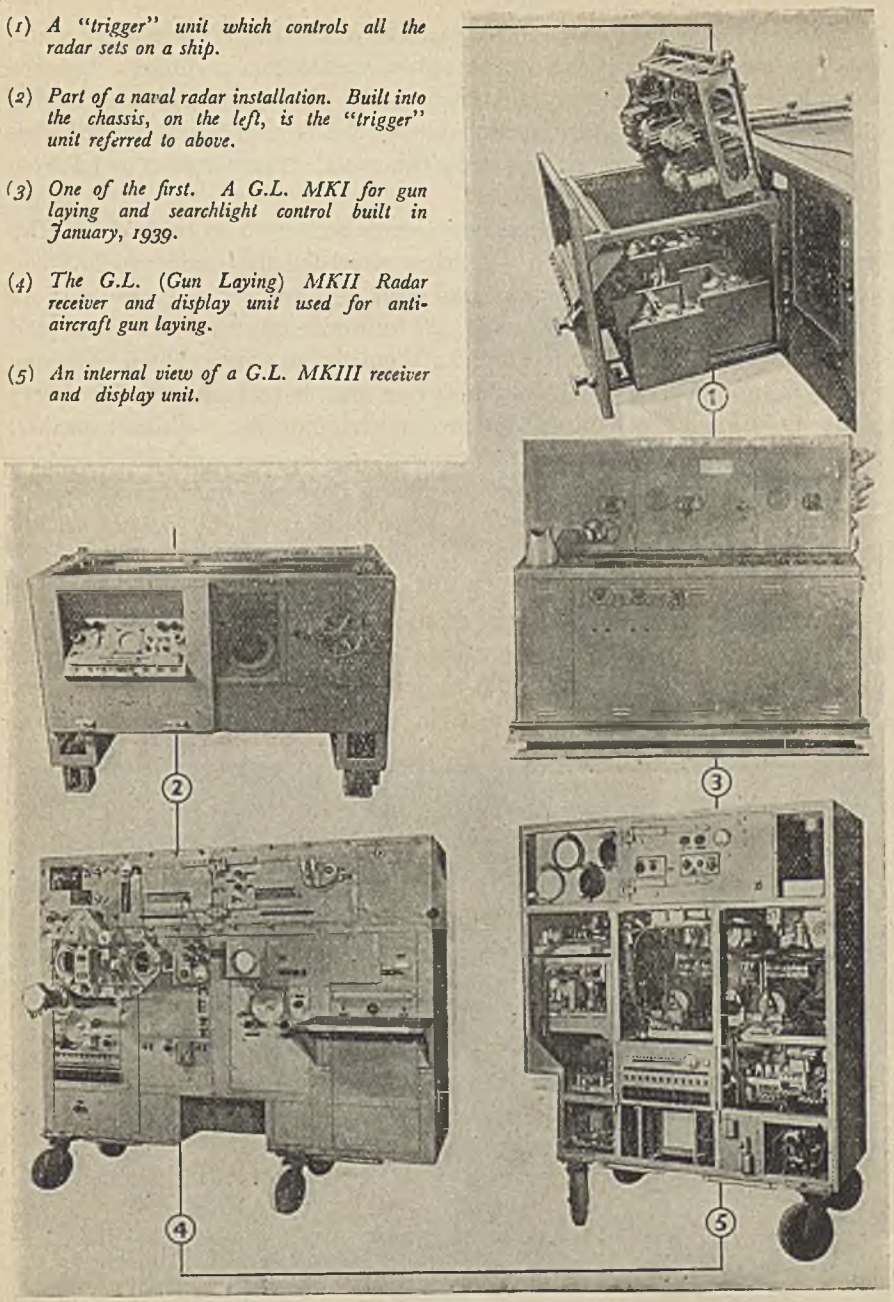
(1) *A "trigger" unit which controls all the radar sets on a ship.*

(2) *Part of a naval radar installation. Built into the chassis, on the left, is the "trigger" unit referred to above.*

(3) *One of the first. A G.L. MKI for gun laying and searchlight control built in January, 1939.*

(4) *The G.L. (Gun Laying) MKII Radar receiver and display unit used for anti-aircraft gun laying.*

(5) *An internal view of a G.L. MKIII receiver and display unit.*



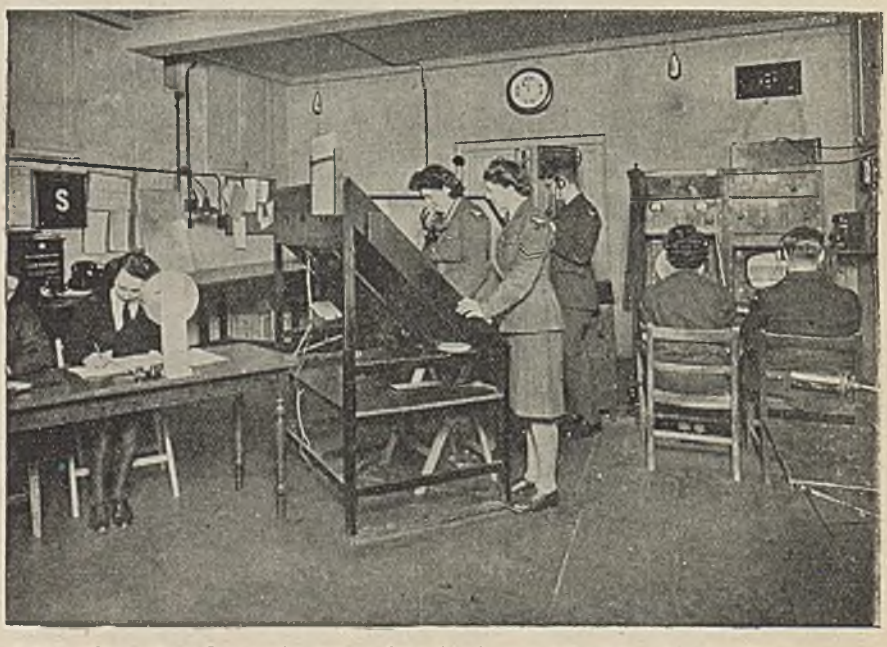
Some of the radar apparatus used in the war was not only highly complex, but weighed several hundredweights. Here are five views of some of the big fellows.

craft flew into the radiolocation beam, this little radio set remained mute. But the moment the groping, invisible, radiolocation fingers hovered around the allied aeroplane, unknown to the pilot, the apparatus sprang into life, flashing back an unmistakable wireless signal which identified it as "Friend" to the operators on the British coast. It was known as I.F.F.—"Identification, Friend or Foe".

A perfect example of the need for extreme secrecy is to be found in this development. It only needed a careless word for the enemy to find out this trick, and to use it against us. And then, with our radiolocation stations receiving the identification "Friend," the fighter force would have remained on the ground until it was too late for them to have intercepted with any success. Indeed, so secret was the device that it was protected in every plane by an explosive charge, designed to detonate if the aircraft crashed on enemy territory. In many cases the explosive charge went off, wrecking the apparatus, after a heavy landing during normal flying duties! But it was better that way.

The Enemy Finds a Loophole!

It has often been said that every weapon of war has its counter-weapon: and that is very true of radiolocation. As soon as the Luftwaffe chiefs suspected that we were using radio to detect the approach of their planes, they fitted some of their aircraft as flying laboratories, and sent them over



C.H.L. (Chain Home Low) radar stations detected and reported low-flying aircraft. This picture was taken in a C.H.L. receiver room.

to find out exactly what we were doing. We expected this, of course, and we shot a number of them down; but some got through, and they were able to detect the presence of our radiolocation beams by means of their apparatus. More serious, by flying up and down the coast, at varying heights, they discovered that there were blind spots not covered by our beams.

The first hint we had that the enemy had discovered this flaw was the arrival of raiders without previous warning. The beams from our C.H. stations were "pointed" at a fairly steep angle from the earth. Gaps existed beneath them. The Germans were sneaking in by flying low over the sea, *under the beams.*

So our scientists got to work, and provided the answer with a second set of radiolocation stations, high up on the cliff tops, with beams at a lower angle. These were known as C.H.L.'s—Chain Home Low.

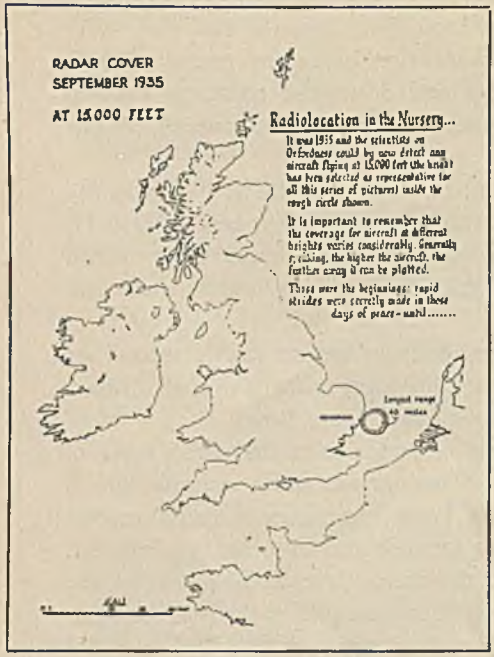
But by this time the spark of the radiolocation idea had fired some of the best brains in the radio industry. The various radio manufacturers, who were busy with the production of large quantities of radiolocation apparatus, also produced idea upon idea for new and improved equipment. Working in the closest harmony with the research establishments of the Navy, Army and Air Force, they developed and simplified the most complicated pieces of apparatus to such a degree, that even a semi-skilled operator could manipulate it successfully. This was undoubtedly the biggest triumph of all, for Britain was desperately short of trained men, *and someone had to work every piece of wireless equipment that the factories turned out.*

Radio on Searchlights and Guns

Radiolocation had put up an invisible barrier to prevent the unheralded approach of the raider, but the German pilots still had a loophole—the darkness of night. The next step was to apply radiolocation to check them in that element. As late as the autumn of 1940, with the big Blitz but a few months distant, the searchlight crews and the batteries of anti-aircraft guns were dependent upon sound locators and mechanical predictors to detect the presence of raiders, and to calculate their position in the sky. But sound travels comparatively slowly through air, and by the time the throb of a raider's engine had been located, and turned into mathematical information by the predictor machines, the pilot in the sky above could have changed course, speed or height—or all three. It seemed an impossible problem to solve.

And then came the ingenious answer . . . in radio.

If a stream of invisible radio pulses could be "fired" into the sky, in a very narrow beam, so as to be reflected back from the aircraft to a receiver close beside the transmitter, the enemy pilot would be unaware of the fact that he was "spotted." Furthermore, since the stream of radio pulses would be "fired" in the direction that the aerial was pointed, any "echoes"



These four maps show the amazing growth of Britain's invisible defence weapon—Radar. Within three years of the beginning of practical work, radar coverage was extended sufficiently to take in part of the continental coastline. A year later, when war came, our Eastern coasts were protected. By 1941 a double ring had been built up.

received would at once indicate the bearing, the elevation *and* (by the time taken for the echo to arrive) *the exact range!*

The scheme was tried, and it worked. Radiolocation again. A searchlight was fitted out with experimental equipment, with its aerials pointing along the direction of the beam. The testing of this latest development was practical and dramatic. When the fresh apparatus was ready a telephone call was put through to the nearest aerodrome: "Please send over a bomber." The bomber droned overhead, and the cathode-ray tube of the receiver showed the tell-tale hump in the line of light. Frantically the radio factories went to work. Time was short. Even while experimental work was proceeding, a telegram arrived from the Prime Minister, Mr. Churchill: "*The first six equipments must be ready for the next moon-phase.*"

They were ready, and they were successful. The apparatus went into mass-production—apparatus that would have been a problem for a hardened expert to operate in the pre-war days, and yet which was so simplified that teams of A.T.S. girls could handle it with ease. *Ten thousand sets of equipment were made and delivered in two years.*

Those who stood in their gardens at night to watch the distant raiders soon saw the difference. No longer did the probing beams of light swing about all over the sky. The operators picked up their targets by invisible radio waves—and then switched on. *But they never switched their lights on to allied aircraft, for once again the clever scientists had thought ahead, and the invisible beam felt out the unseen target, telling the operators, faithfully, "Friend" or "Foe".* I.F.F. had found yet another job.

Similar forms of radiolocation apparatus were designed to operate with the gun batteries, and the old sound locators and predictors became obsolete. The gun muzzles, like the searchlight reflectors, were pointed accurately at their targets in the darkness, guided by radiolocation. It was a triumph of inspired thought on the part of our designers, and tireless, painstaking work on the part of thousands of factory workers. The German raider was half beaten, and he knew it. The numbers of bombs that he wasted in fields and woodland was proof of his defeat. How still other forms o radiolocation put the finishing touches to his discomfiture is told later in the book. So far, radiolocation has only been discussed in terms of defence. But even while the factories were turning out the detecting devices for searchlights and guns, the research workers were putting the finishing touches to the first forms of radiolocation apparatus for attack.

THE English-speaking peoples love names; and they have always excelled at choosing them. From the humorous to the heroic, and from the serious to the tragic, the names they bestow upon almost all things nameable always seem to fit. Witness the "Flying Bedstead" for Henry Ford's famous T-model—the "Moth," the "Hurricane," the "Typhoon," and the "Mosquito" for aircraft. And wherever initial letters are used, as they often are in matters governmental or military, it is a safe bet that they will be coined into a word. The G.P., or General Purpose vehicle became a Jeep—and will probably find its place in the dictionary. Fido originally covered the secret Fog Investigation Dispersal Operation—but was soon adopted by the "boys" to stand for "Fog, Intense, Dispersal of". Pluto stands conveniently for "Pipe-line Under The Ocean" (even though the ocean *was* the Channel!) Radar, the American name which is winning hands down over our original but overlong Radiolocation, stands for "Radio Detection And Ranging".

And when the British go to war they have a most effective trick by which they maintain secrecy around a product or an operation. They give it a code name. The idea is as simple as it is clever. The fewer times an operation is mentioned, the less chance there is of the enemy getting to know of it; and it was much *easier* for people to talk about "Mulberry" than it would have been to refer each time to Prefabricated Harbours!

Radio has had more than its share of humorous, cautious and perfectly-fitting names during the war years—beginning with "Beetle," "Banquet Light," and "Pip-Squeak" in 1939-40, and ending with "Oboe," "Lucero," and "Rebecca-Eureka" in 1943-45. The stories behind some of these names are not only interesting, but they throw up several stages of the radio war that might otherwise be passed over in a book of this necessarily condensed nature.

Pip-Squeak, described in detail in the chapter "R.A.F. on the Air," was one of the first automatic radio devices to be fitted to the fighter air-

craft. The pilots gave it that name because it "pipped and squeaked." The name *Beetle* concealed an emergency radio warning system, worked out by the Army Authorities in 1940 at the time of the fall of France. Transmitting stations in each of the Home Commands sent out hourly test calls, and operators at all aerodromes, Army units, and important depots were on their toes throughout the day and night, listening for the warning . . . "*Beetle Calling.*" Fortunately, that call never came except in exercise. It would have meant enemy landings. But the name stuck to such an extent that the portable radio receivers issued to the listening posts—a popular, pre-war domestic type—are still referred to as "*beetle sets.*"

Banquet Light covered an operation of the most desperate nature that was planned to greet Adolf Hitler's legions as a last resource. We were so terribly short of aircraft in those dark days of 1940, that a scheme was worked out, whereby our trainers—"Tiger Moths"—would join in the battle, flying with Army Co-op squadrons, some even carrying small bombs. A radio network was arranged so that every training aerodrome in the country came under the control of one of the Army Co-op squadrons; and every day, at an appointed hour, the wireless operator at each training station made morse contact with his control station. The actual words *Banquet Light* were never used. They would have signified "*The operation is on*"; and, had they been flashed out, hundreds of our instructor pilots

This diagram, prepared by the Ministry of Aircraft Production, shows the uses of many types of radar apparatus, and the names by which the apparatus is known—from C.H., the Chain Home stations which guarded our coasts against surprise attack, to Oboe, which introduced a new and deadly technique of pin-point bombing attack.

Every hour, during the most urgent days of invasion fears, operators—R.A.F., a few trusted civilians, and Army—switched on the hastily distributed portable radio sets and listened for the code word, "Beetle Calling". Fortunately that call never came.

would have flown to what would have been almost certain death in light training aircraft, armed with nothing more than a revolver or a pistol—for only a few of the aircraft were fitted with bomb racks.

Darkie was a minor name in the radio war, but it marked an important stage; for *Darkie* stood for an emergency landing scheme for bomber pilots in 1941—we were, at last, at the turning point; our bombers were beginning to strike back.

Odd Radiolocation Names

As the development of radiolocation devices proceeded, many dozens of strange names began to be heard in the radio factories up and down the country; for these devices were "*most secret*," and it was important for factory workers to get so used to a meaningless name that they would not think of speaking of their work in any other terms. "Elsie" was one of the earliest radiolocation names to be uttered, and it was derived from two letters in the words SearchLight Control—L.C. The name covered the complete radio equipment that was fitted to searchlights to enable their operators to point them, still darkened, at an unseen target.

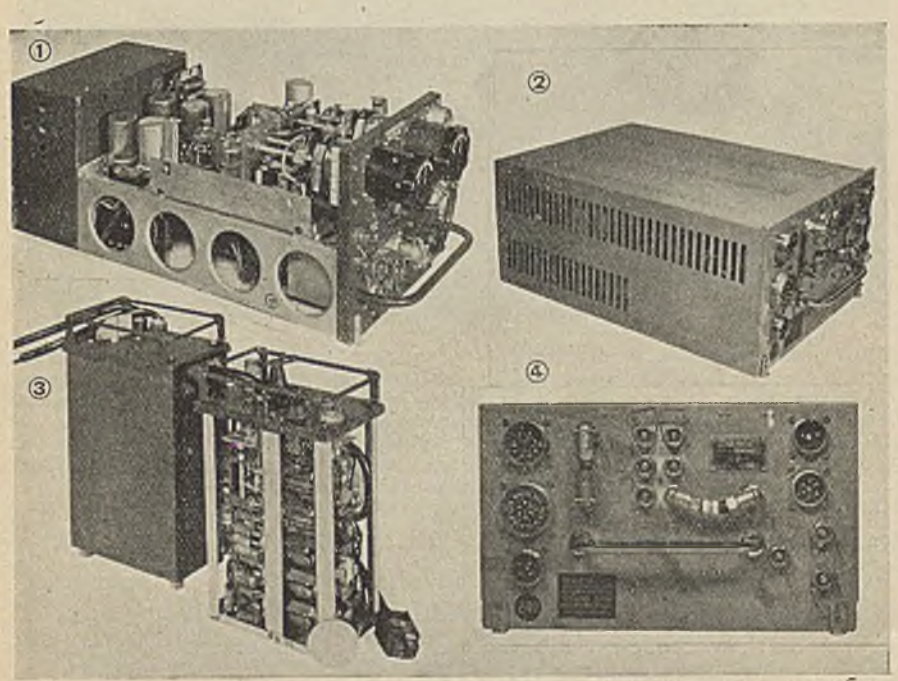
Lucero was one of the enquiring gentlemen of the Spanish Inquisition, and it was a subtle stroke to attach his name to the inquisitive, probing radio apparatus which enabled aircraft to locate their bases in bad weather or darkness, and to land safely on a radio beam. *Oboe*—or Observed Bombing Of Enemy—was the almost magical system by which pin-point attacks were made by aircraft whose bombs were released by radio control from a base in England.

Rebecca-Eureka, one of the most secret of all the secrets in the vocabulary of hush-hush radio words, concealed the mass-production of thousands of

airborne radiolocation sets for use on D.Day. *Rebecca*, a light-weight but complex piece of apparatus was installed in Allied glider-tugs. *Eureka* (I have found it!) was dropped by parachute with the advance airborne troops. *Eureka*, when assembled on the ground at predetermined points, responded automatically to the inquisitive signals transmitted by the airborne *Rebecca*, telling the glider pilots where to make for, and where to land.

The manufacture of *Rebecca* and *Eureka* was spread out among several radio factories, and only one or two trusted people had an inkling of what each part was to be used for. *No one*, outside S.H.A.E.F., knew what the *whole* equipment was to do—or when it was to do it. The manufacturers merely knew, to their loss of sleep, nerves and tempers, that it was priority A.1 plus, and that *it just had to be ready by the contract date.* So well was the *Rebecca-Eureka* secret kept, that few of the factory workers making *Rebecca* knew there was a piece of equipment called *Eureka*, and they learned what they had been making only when they read it in the daily papers after the defeat of Japan—more than a year after the apparatus had been used so successfully.

Gee stands for "Grid", the marvellous grid radar system of aerial naviga-

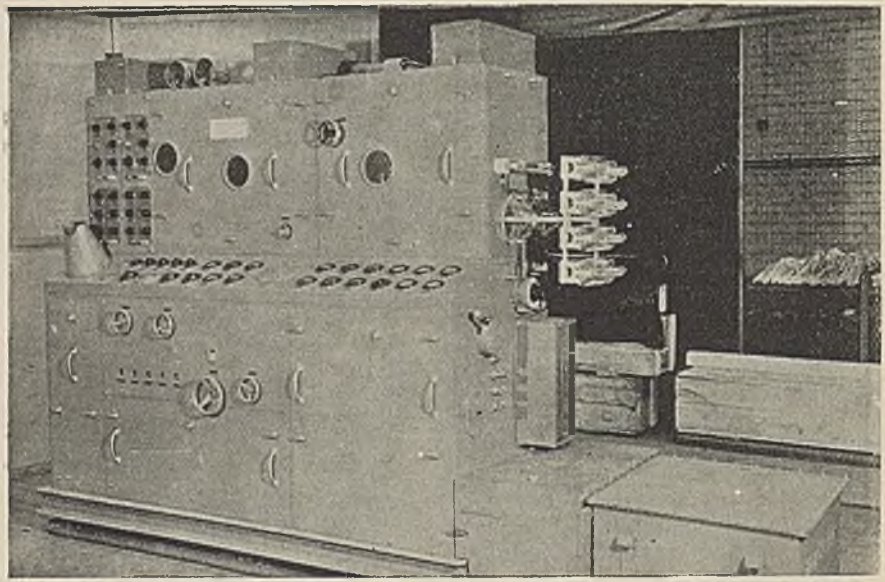


Rebecca-Eureka was one of the big radar triumphs of the war. It was largely responsible for the successful allied airborne landings on D-Day. Here are four pictures of Rebecca-Eureka apparatus.
(*1*) *A version of the airborne* Rebecca *transmitter-receiver removed from its case.*
(*2*) *Another form of airborne* Rebecca.
(*3*) *The light weight* Eureka *carried by paratroops to guide* Rebecca.
(*4*) *A view of the front panel of* Rebecca.

tion which enabled hundreds of aircraft to assemble for the accurate, saturation bombing attacks that resulted in the obliteration of all the major target towns in the Third Reich.

Monica was the name given to the radar equipment fitted in the tails of our bombers for detecting the fighters which had detected them.

"A.I." were the letters covering the most secret Air Interception. "P.P.I." covered Plan Position Indicator. "G.C.I." hid the words Ground Controlled Interception. And so on, seemingly without end, through a string of initial, numbers and names, from "Boozer" and "Grocer" to "Walter"—the



This is a Gee *transmitter, the complicated piece of radar equipment developed as a navigation aid for aircraft.* Gee *stands for "Grid Navigation". Three transmitters are used—a master and two slaves. The master sends out a series of regular pulses, and also triggers the two slave stations, which send out similar pulses. These pulses from the three stations are received on a cathode-ray tube in the aircraft, where the positions of the transmitting station are known. By comparing the visible pulses, the navigator can "fix" the position of his aircraft with a greater accuracy than any existing map can give. It was* Gee *that made possible the mass raids on Germany.*

highly ingenious, automatic radio set with which the lifeboats of the Royal and Merchant navies were subsequently fitted. "Walter", on the pressing of a button, sent out radio signals which appeared as glowing spots of light upon the cathode-ray tubes in the "A.S.V." equipment of all Air-Sea Rescue machines, and in all surface craft within range.

Why "Walter"? Why "Monica"? Why "The Dark-haired Lady"? Just secrecy, ingenuity, humour and deadly purpose. Just another very subtle British secret weapon.

No one will deny that radio is a fascinating subject; and there are few who do not wish that they knew a bit more about it. But those who know least can console themselves with the fact, that, *even those who know most are continually confronted with new developments.*

We speak cheerfully of wireless waves, and the knowledge of the schoolroom brings back a picture of waves on a pond, with a cork bobbing up and down on the path of those waves. But in practice we know that radio waves are nothing like the waves on a pond. They flash outwards from an aerial *in all directions*—rather like the skin of a rapidly blown-up balloon; and they travel with the speed of light—about 186,000 miles a second. It might be a bit easier if we did not drag in "*light*" as a standard of comparison, for light waves and radio waves (*and* heat waves *and* X-rays), all belong to the same family, and obey the same laws. The family is known to science as the spectrum of electro-magnetic waves, beginning with grandfather waves measuring several miles in length, and ending, somewhere, with waves too short to imagine—(a fraction of a millionth of an inch long!).

Droitwich. One-Mile Waves

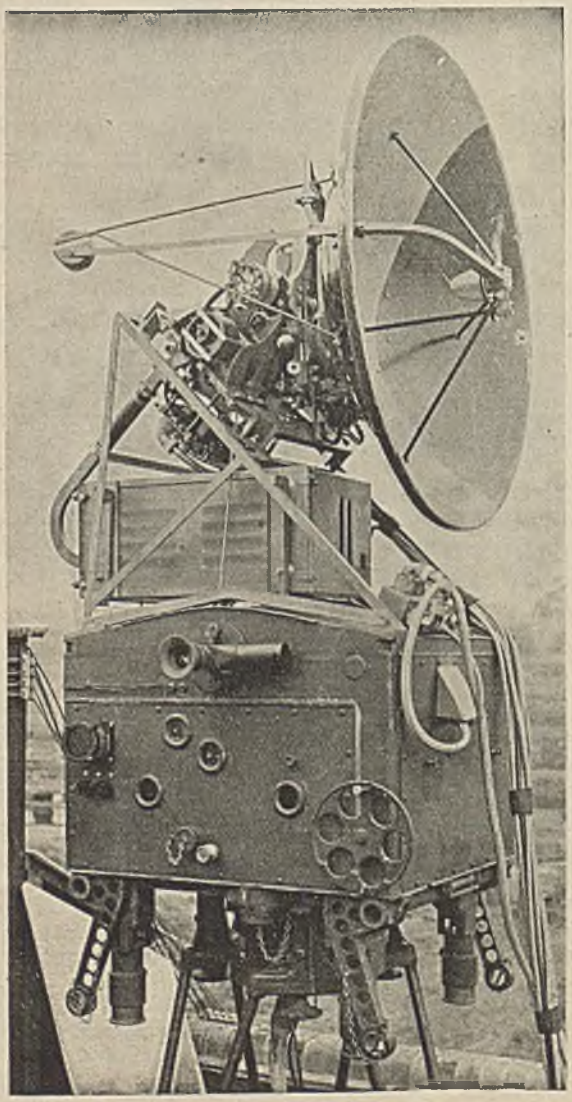
Scientists know nearly all that is worth knowing about the very long waves of the family; and radio engineers have been using them for morse and telephone conversations for many years. It has been found that the longest waves of the family that are of real practical use for radio measure about ten miles. Droitwich uses waves of about one mile in length. The waves used for the *medium*-wave range on broadcast receivers lie between the limits of approximately 200 yards to 600 yards in length.

For years it was thought that waves of about 100 yards in length were about the shortest that could be conveniently used for radio, because it was known that the shorter they were, the more they tended to shoot away from the earth and to vanish into space. *This was unfortunate, for it looked as though there could only be a very limited number of wavelengths available.*

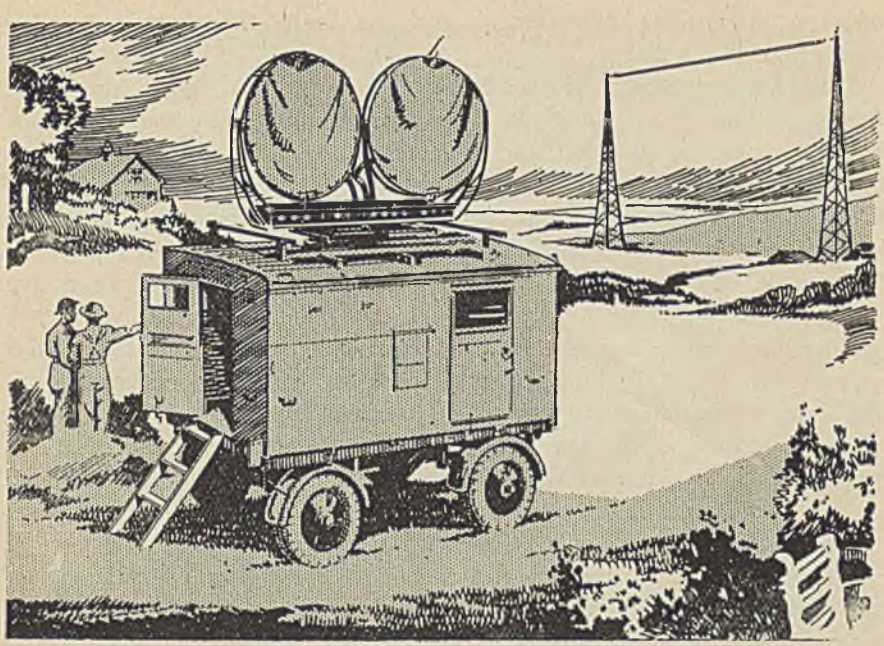
And then, suddenly, it was discovered that something beyond the earth

reflected the waves back to the ground (the gaseous layers that Sir Edward Appleton investigated), and it was at once realised that it would be possible to use a huge new slice of the wave family for radio purposes. In fact, to-day, most broadcast receivers fitted with short-wave ranges have wavelengths as short as fifteen metres (about twenty yards) marked on their tuning dials. And the television pictures were transmitted from Alexandra Palace on a wavelength of under ten yards.

There are two tremendous advantages to be gained by the use of shorter and still shorter waves. The first is that the size and expense of the necessary apparatus decreases; and the second is that more and more "channels,"



"CUPID"—another highly ingenious radar device which revolutionized gunnery. Cupid, using the centimetre waves, was mounted directly on the gun predictors. Other forms of radar detection having supplied the warning of approaching aircraft, with their heights, speeds, etc., and this information having been passed on to the gunners, the guns were pointed in the direction of the targets. Then Cupid took over. As soon as radio echoes flashed back to its aerial (in the centre of the "bowl-fire" reflector), Cupid went into action with the predictor and the gun. In other words, Cupid "selected" its target and followed it automatically, holding it in its radio beam. It was particularly effective against flying bombs at high speeds and low altitudes. Used in conjunction with Bonzo, the radar-fused shell which exploded itself as it came within range of the target, Cupid did not give the doodlebugs much chance.



The "No. 10 Set" uses centimetric waves for telephonic communications. Its "bowl-fire" aerials and eflectors are in marked contrast to th long wave aerials.

or stations, can be fitted in, side by side on a tuning dial, without interference. An inch of tuning dial on medium waves may "hold" half a dozen stations; but, as short-wave enthusiasts know, the same inch on the short waves will bring in maybe ten times that number of stations.

Radiolocation One-inch Waves

The great *disadvantage* of the short waves (which may well turn out to be the biggest advantage on grounds of non-interference), is that the shorter they are, the shorter their range for receivers on the ground. Indeed, many of the wavelengths used for radiolocation are so short that they cannot be picked up at all by receivers placed beyond the visible horizon. *But that is just what is wanted for radiolocation; for the objective is to obtain reflections back from "solid bodies" anywhere within visible range; and an aircraft or rocket flying one hundred miles high, is still within visible range.*

This "visible-horizon" limit obviously applies to *all* waves in the family, no matter how short, since light waves themselves travel to us from the furthest stars, taking hundreds of years to make their journey. And this, in turn, means that there is an untold amount of work ahead of the research workers; for it has taken nearly fifty years to learn the art of creating and using waves as short as *half an inch* for radio—and the longest of the light waves (red light) measures only one-sixty-thousandth part of an inch! There is, indeed, a long way to go, and no one knows what discoveries lie

between present-day achievement and the limit—the shortest possible wavelength of the family.

However, the research worker has already gone a long way, and one of the biggest developments of all was the perfection during the war of an entirely new type of valve, the "Magnetron." Until the day that the "Magnetron" became a practical proposition, the "back-room boys" were at another of the dead-ends that so often appear in research. One of the most helpful developments of all during the war was the High Frequency Magnetron. Though its principles had been known for some twenty-five years, it was not until intensive research had perfected its high frequency performance that certain advanced types of radar were made possible. A few years ago, waves of one hundred yards in length were the lower limit—until the secret of the reflecting layers above the earth were discovered. In 1942, waves of an inch or so in length were the limit for Radar, because it seemed impossible to manufacture valves that would operate successfully, or which could be produced in reasonable quantities, for such high-frequency (or short-wavelength) work, using the high power that was needed.

The urge that drove the research workers on was the fact that, the shorter the waves they could produce, the more nearly they behaved like their smaller brothers, the light waves; in other words, they could be more and more easily condensed into narrow, accurate beams. No matter how beautifully they "condensed" the longer waves at the transmitting aerial, at a distance of a few miles they spread outwards like a funnel; and that meant that reflections would be echoed back from an aircraft or a ship anywhere in that funnel. What was wanted was a *beam* of waves that did not spread, but which would still be a narrow beam at a distance of miles—*so that anything "picked up" by that beam could be plotted to within a yard or so.*

And with the "Magnetron" came the answer, and away went the research workers once more, building apparatus to transmit waves of a few centimetres. And, as an immediate result, up went the accuracy of British radiolocation—*until, at the end of hostilities, it was possible to transmit such narrow beams that the position of an object could be accurately detected to within one yard per mile distance.*

It was the gift of science of these "centimetre waves" that put the final touches to the whole range of radiolocation apparatus in use. It was through them that "Gee," the wonderful grid system of radio navigating, became so accurate. It was by means of them that "H2S," the television map in the bomber, obtained its fine detail. In the early days of "H2S" the outlines, though invaluable, were comparatively fuzzy on the screen—simply because the scanning beam from the transmitter spread as it travelled outwards and back. But with the narrow, hard beam provided by the centimetre waves, quite small objects on the ground produced clear reflections. Railway tracks, for instance, which had once appeared as smudgy streaks, showed up as two distinct lines!

Two valves developed to a high pitch of perfection by British scientists during the war, making centimetre radar possible. Left, *the Reflex Klystron and,* right, *the air-cooled Magnetron.*

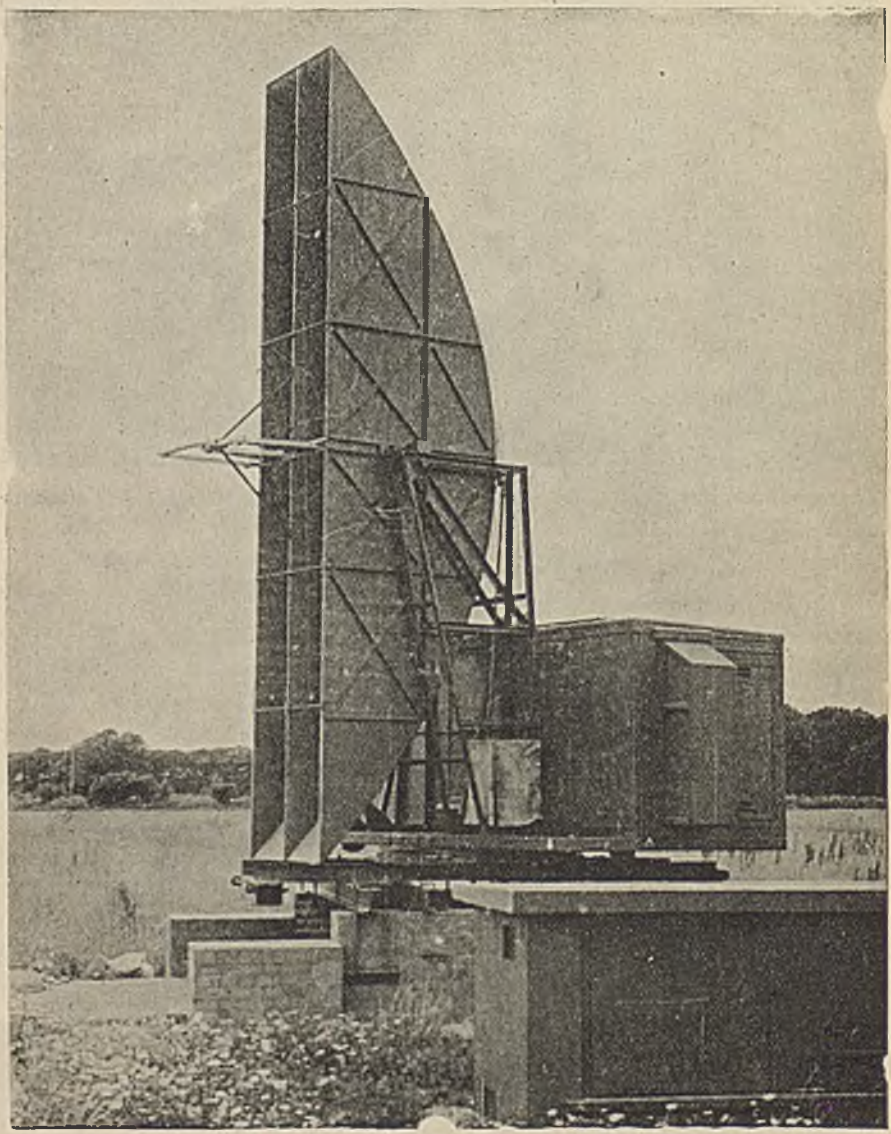
Micro-waves in Peace-time

The centimetre waves are often spoken of as micro-waves, but both names are likely to appear very frequently in the Press in the next few years. Watch out for them, and remember the battle of the war-time research workers who harnessed them to such good effect. Micro-waves, unlike their bigger relations, are not transmitted from large aerials, but from short metal rods, and the rods are usually placed in the centre of metal reflectors—exactly like the reflectors and elements of bowl fires. The waves, too, behave in nearly the same way as the heat waves from a bowl fire. Stand in the beam of the fire, and you will feel the heat: move outside the beam, and the heat is lost. Place a receiver in the beam, from a micro-wave reflector, and you can detect the waves, move the reflector, and the beam misses the receiver.

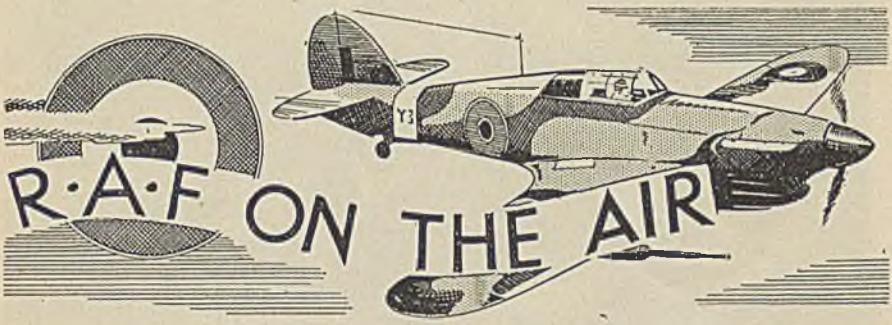
From this it is easy to foresee one of the most straightforward peace-time uses for micro-waves. They can be "beamed" across country, from point to point, carrying telephone communications with complete privacy. They may even be used to carry television programmes from one part of the country to another, with freedom from interference, and without interfering with any other transmission. Micro-waves have already proved their value for direct beam telephone transmission over short distances. The "No. 10" set was installed in mobile units and was used to provide eight simultaneous

conversation channels between different centres in Europe, where the line system had been destroyed.

We began the war with "meter-waves". We enter the post-war years with "centimetre waves"—and with untold possibilities for the "back-room boys" of industry to explore.



Like a giant slice of cheese, this is the aerial and reflector of the latest British centimetric radar height-finding equipment. It is swivelled by remote control until it points in the direction of an approaching aircraft, and tilted up and down until returning radar echoes indicate the target.



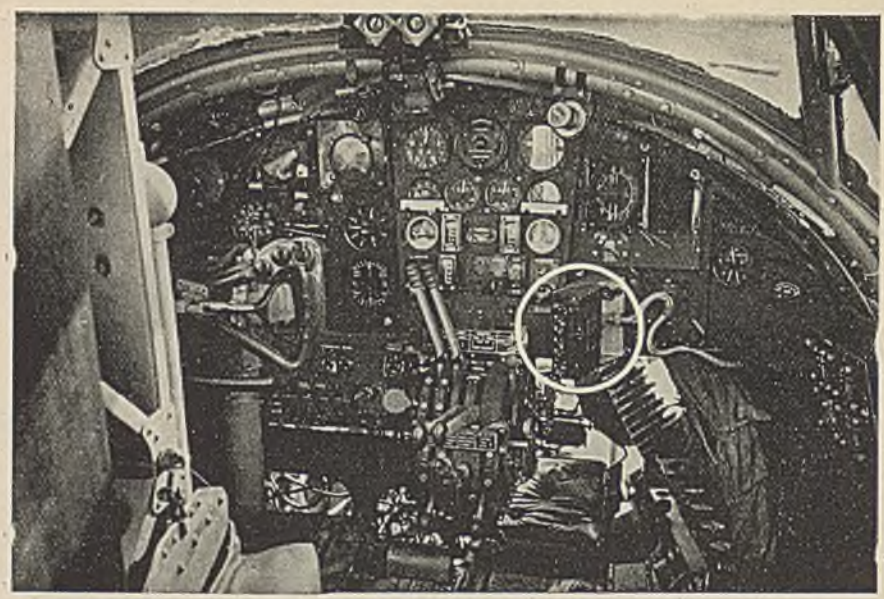
UNTIL war came, radio in the R.A.F. was used merely as a means of communication and direction-finding. Pilots used their wireless sets as a link from plane to plane and from plane to base, and the navigators of bombers obtained radio bearings from the modest number of wireless beacons that were dotted about the British Isles. With the exception of a few sets of an experimental type, and not in quantity production, the total airborne radio requirements of the R.A.F. consisted of two types of general equipment—a transmitting and receiving set for bombers, and a similar but smaller installation for fighters.

To-day, by way of contrast, a single aircraft of R.A.F. Bomber Command may carry as many as eleven different radio sets, weighing a total of half a ton, and worth about £10,000.

The above example is, of course, an exception, and it applies only to aircraft equipped for special duties; nevertheless, it serves to give an idea of the enormous development that has taken place, and to show just how vital is the job that radio has been called upon to do in the air war. Every modern bomber that leaves the production line is fitted with nearly two and a half miles of electric cable, to carry the current for its various electrical devices, from radio to bomb-release gear. Which, for those who like crazy statistics, means that the aircraft engaged on a large scale saturation attack on the late "Third Reich" carried enough electric wire between them to reach from England to America!

Why All This Radio?

The first addition to the aircraft's comparatively simple pre-war radio installation was the little black box of secrets, fitted just before the war, to give the automatic answer, "Friend," to the inquisitive radiolocation beams from the coastal stations. It had a small aerial to itself, and, provided that the pilot remembered to switch it on, it worked quite happily on its own, with-



The cockpit of a modern fighting aircraft. No matter how many clocks, levers and gauges are fitted, there is always room, somewhere, for a few more vital knobs when the need arises. In the circle, conveniently placed at the pilot's right hand, is the control box for his radio telephone. But he has no dials or tuning problems to worry about. Just a row of buttons, each one providing him with a different wavelength.

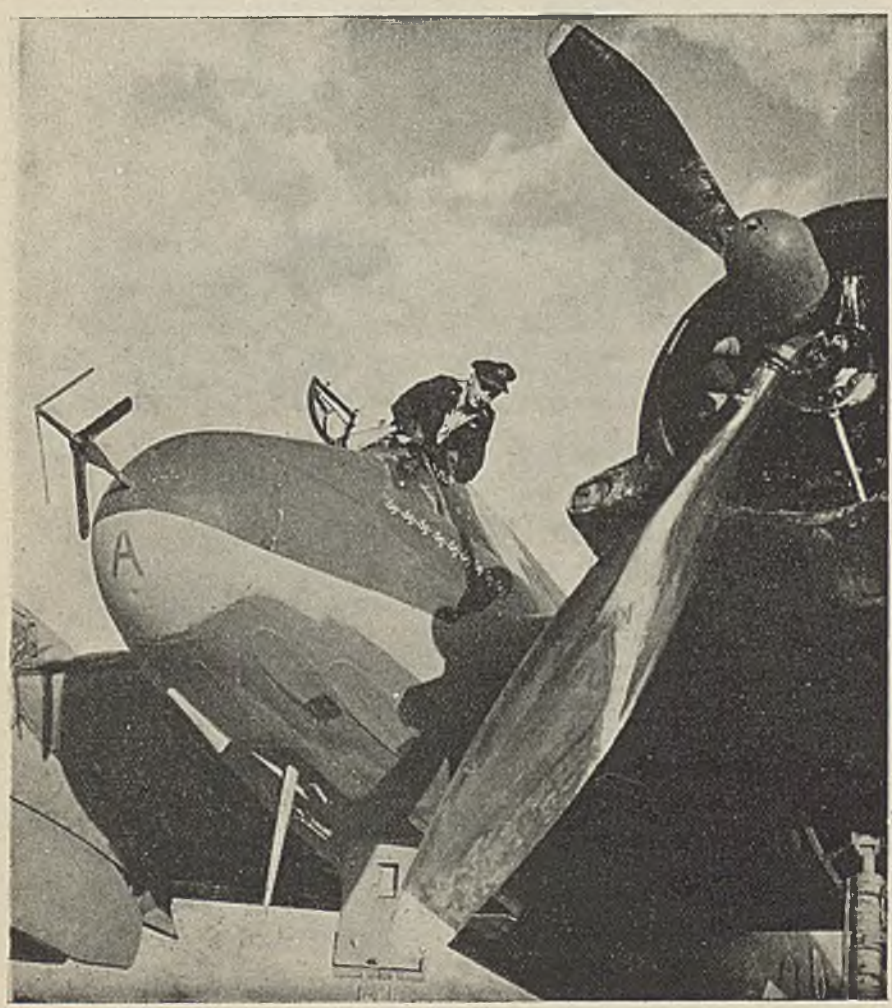
out any further attention. If the pilot *did* forget, then an A.A. shell, or a rude radio message from a hastily despatched fighter, usually jerked his memory.

The next addition to the fighter aircraft's radio equipment was the "Pip-Squeak," and this was one of the first of many ingenious devices which helped to knock the Luftwaffe from the sky in the Battle of Britain. It was a gadget which made one radio set do the job of two, in the small space available in Hurricanes and Spitfires, and which also did a job that could only have been done by an extra man in the plane—an impossibility.

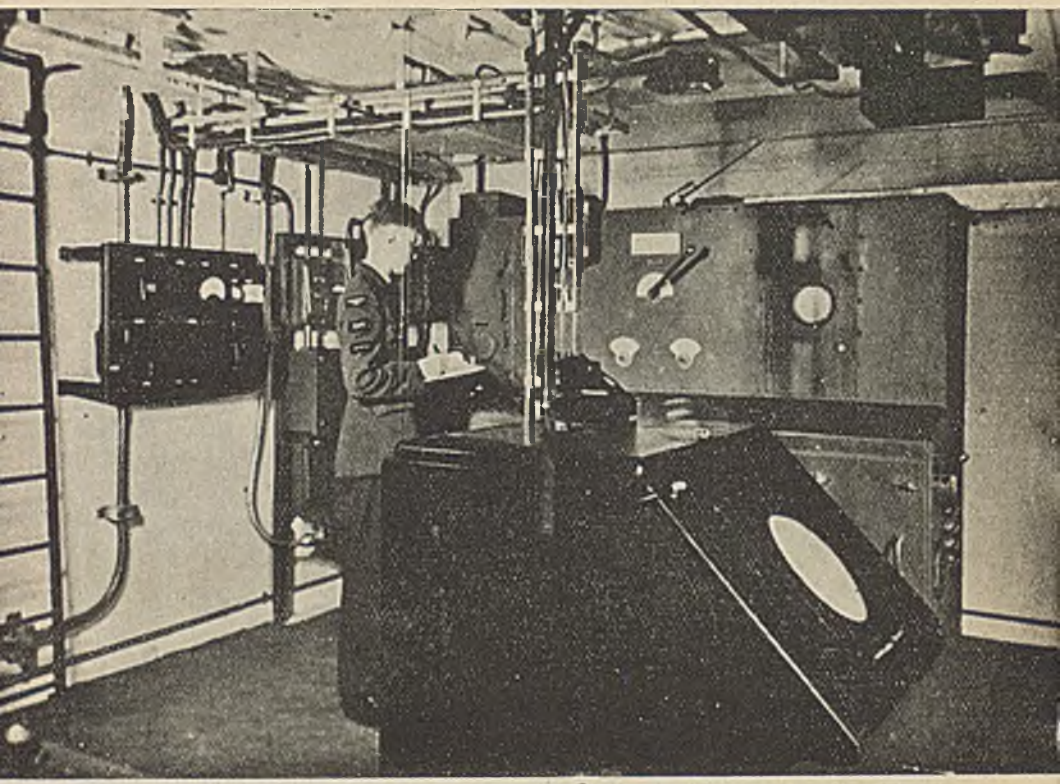
When radiolocation picked up the tell-tale signs of approaching raiders, the news was flashed to Fighter Command H.Q., and passed on to the Fighter aerodromes. The pilots took-off, directed by radio, to intercept. But there was a gap in the plan that had to be filled. In order to keep the pilots of a dozen fighters posted with the latest information about the enemy aircraft they had yet to find, it was necessary for the ground staff to know exactly where each fighter was at any given moment. The pilots could not be expected to cope with this additional job, with a life and death matter on hand—maybe right behind them. So the answer had to be found in an automatic device. The radio factories supplied it, in "Pip-Squeak."

"Pip-Squeak" was a clock on the dash board which automatically switched the pilot's radio set to a special wavelength for a few seconds every minute, and which warned the pilot—rather like the 30-mile limit warning on a speedometer—that he was temporarily "off the air." And, as

the radio set was switched over, the transmitter automatically sent out a short *pip—pip—pip* signal on the special wavelength. This was picked up by the ground staff on their direction-finding apparatus. Thus, as the pilot flew along, the men "back at base" were able to plot his position by these regular, automatic, signals. And, by arranging a squadron's dash-board "Pip-Squeak" clocks to switch over all the different fighters' radio sets at different times, the ground staff received a continuous stream of information minute by minute from every fighter in the air. And so, by radio-phone, "C for Charlie" could be told to fly vector 340, towards a bandit over Maidstone, while "T for Tommy," who was nearest to another hun over Tonbridge, could be diverted to deal with him. All that the pilots



Radar was used first for the Defence of Britain, but soon became the greatest weapon of attack. Nine Swastika's on this R.A.F. Beaufighter show how effective airborne radar can be.



G.C.I. (Ground Controlled Interception) radar stations made it possible for men on the ground to follow on the cathode-ray tubes, the position of raiders, and to direct our fighters towards them by telephone until the pilots "made contact". This picture shows an underground G.C.I. transmitter and receiver.

had to do was to watch their "Pip-Squeak" clocks, and to break their radio conversations while the clock hands swept over a short, red-pointed section of the dial: for during those few seconds their radio transmitters were in use by the robot *pip—pip—pipper*.

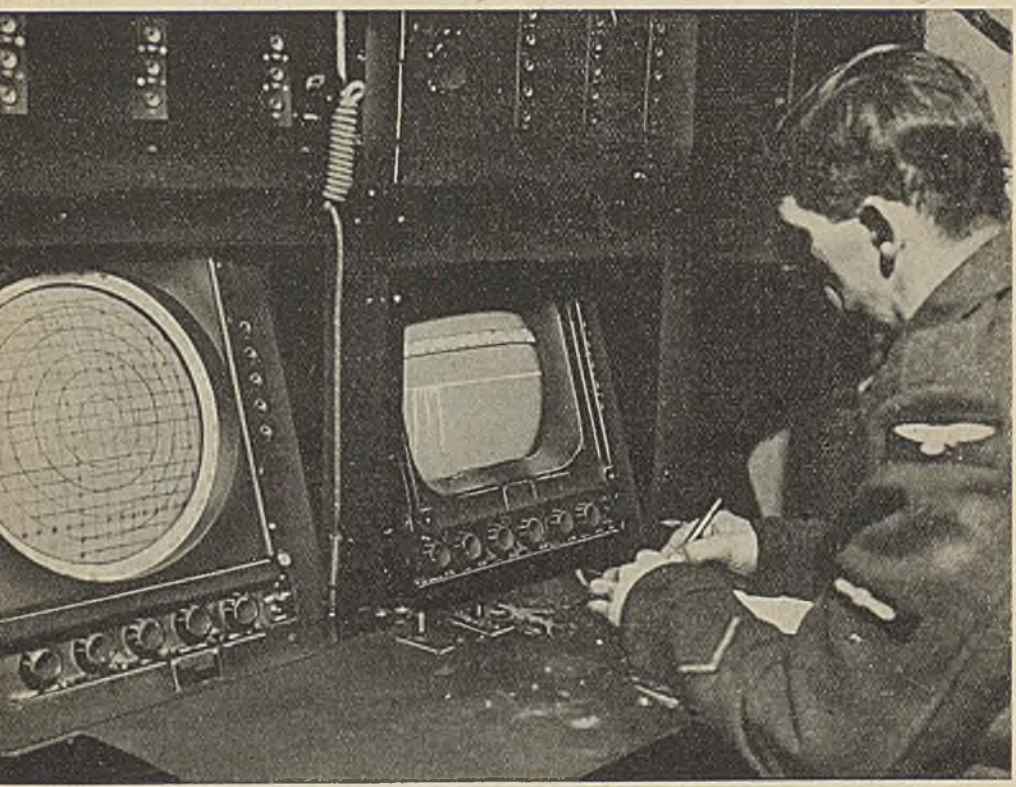
Radiolocation Grows Wings

The next important development in the R.A.F.'s radio equipment for fighter aircraft was radiolocation. Many keen observers of aircraft were puzzled by the appearance on certain types of fighters of short metal crosses which projected from the extreme ends of the leading edge of the wings. In other types of aircraft they stuck out from the nose as well. A few of the more observant noticed that, as a rule, the aircraft so fitted, were painted black—for use at night. But only a handful guessed the secret, for it represented an engineering miracle. The small metal crosses were radio aerials—a transmitting aerial in the nose, and receiving aerials on the wings—and their presence meant that the radio "back-room boys" had succeeded in cramming into the incredibly small space available in a fighter all the

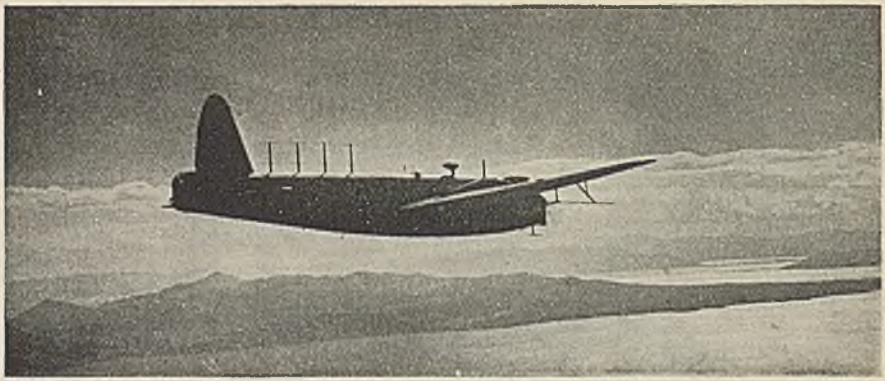
paraphernalia of radiolocation which had hitherto weighed hundreds of pounds and which had measured several feet in each direction.

* * * * *

At the beginning of the war the night-fighter pilot had to rely upon his eyes to pick up his quarry in the sea of darkness that was his element. On the ground, awaiting the call that would send him aloft on his nocturnal chase, he sat in darkness, keeping his eyes accustomed to the conditions in which he would soon be flying. It was no fable—in the early days of night-fighting—that he ate raw carrots. The nick-name, "cats eyes," given to more than one outstanding night-fighter was no mere leg-pull at first. Later, it was deliberately encouraged to conceal the fact that we had "other means of detecting aircraft". The most that the Operations Room staff could do for the pilot, in the early days, was to keep him informed of the enemy's constantly changing position, guiding him by radio-telephone to the approximate area of the sky in which he must hunt. From then on, it was up to the pilot.



An R.A.F. radar operator on duty at a G.C.I. (Ground Controlled Interception) station. The cathode-ray tube on the left is the P.P.I. (Plan Position Indicator) and has a map of the appropriate section of England drawn upon it. Aircraft appear on this map as starry blobs. The tube on the right gives the range, which is measured off in miles against the scale.



A peaceful picture at first sight, but the Wellington is on no peaceful errand. It is fitted with A.S.V. (Air to Surface Vessel) radar, and is on the prowl for enemy submarines.

But even while the night-fighters roamed the dark skies on their seemingly hopeless quests, below them, in the blacked-out factories, hundreds of men and women were at work, producing the latest radio marvel that was to change the whole conception of night combat—a radiolocation device that would indicate the presence of the German raider, and mark his whereabouts on the end of a cathode-ray tube mounted on the fighter's dashboard. No longer had the pilot to strain forward in his seat, eyes almost pressed against the windscreen in an instinctive effort to peer more closely into the blackness all around him. Instead, his observer concentrated his gaze upon the screen of the little cathode-ray tube. The radio waves, streaming out from the little aerial in the nose, probed the darkness ahead of him. As he turned, climbed or dived, so the invisible beam was projected along the direction of his flight—until, suddenly, the tell-tale "blip" of a returning echo showed him that an aircraft was in his beam.

By watching the position and the pattern of the "blip" of light he quickly found out the direction of his quarry's flight. Banking and accelerating, he adjusted his own course, manœuvring so as to come up astern. Eyes on the screen, thumb on the machine-gun trigger, the pilot waited as his observer watched the spot of light as they raced up through the darkness towards the raider. . . .

Now! A slight pressure of the thumb. A shudder through the aircraft as the guns fired. A sudden burst of flame in the sky ahead. A lightning turn to avoid the cloud of wreckage.

Fantastic—terrible—but true. The actual experience of the first night-fighter pilot to make a kill with the aid of radio eyes. The day had arrived when men could locate, chase, and destroy a target they could not see. And until the bullets raked his doomed machine, the enemy had no intimation of the danger that lurked behind him.

But, terrible as this British secret weapon was, it was only one-half of

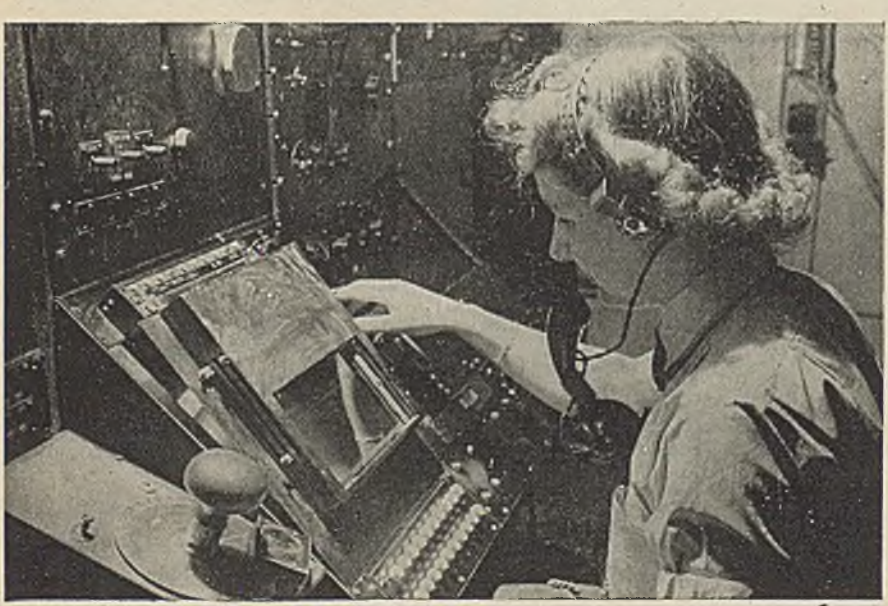
the story; for now, on the ground below, were increasing numbers of an equally deadly radiolocation weapon to work in conjunction with the airborne apparatus of the fighter.

The heart of this ground equipment was a large cathode-ray tube, mapped out to represent the circle of the countryside about it, as seen from the air. *Turning silently and slowly beside it, the radio aerials swept that celestial circle with a stream of waves, and on the face of the cathode-ray tube appeared a glowing blob for every aircraft in that circle of sky. More than that, each blob moved like a glow-worm on the screen, showing its position in the sky, and the course it was flying.*

There, in the north-west corner of the cathode-ray tube, move two British fighters. Easy to distinguish them, because they are flashing back their automatic I.F.F. recognition echoes. And down in the south-east corner of the screen are one—two—three—four—five more starry spots, moving westward. Germans.

Now follows a gruelling battle of wits between Nazi pilot and British Ground Controller, assisted by a team of highly skilled operators. It is a battle which may last half an hour—a series of lightning calculations of vectors, speeds and heights which are passed to the fighter by radio phone. And, as each fighter follows the directions, the glow-worms in the north-west corner of the screen move southwards, closing with the enemy glow-worms as they move westwards.

Finally, when the Controller decides that he has placed a fighter close enough to a raider for the aircraft to pick him up on his own radar, he tells



An airwoman plots a raider on a cathode-ray tube. Over 4,000 W.A.A.F. personnel were on radar duties during the war.

High frequency transmitters on test in a British factory. These transmitters, installed on aerodromes all over the world, were the vital telephone link between ground and fighter pilots.

the fighter observer to "flash" his A.I. (Air Interception apparatus). If the observer fails to get a "contact" he phones back to the Controller for further assistance.

If he gets a "contact"—well, it's all over bar the shooting.

Wonder followed wonder in the world of airborne radio. Just as it seemed that the limit of ingenuity had been reached, along came another idea to pale everything that had gone before it. And, as is often the case with invention, accidental discoveries cropped up to aid the research workers.

In the same way that rotating aerials were adopted for sweeping the sky from the ground, in order to provide a complete radiolocation picture of the heavens above the ground station, so it followed that aircraft were fitted with this device in due course. The advantage was that the pilot's aerials "swept" a whole area of the darkness ahead of him, instead of just that line of the sky beyond his nose. Thus, if any aircraft flew ahead of him, whether above, below, or to either side of his line of flight, its presence *and position* were revealed to the pilot.

Here, however, came the beginning of something new and big. And a strange twist if ever there was one. Radiolocation came into being as a result of radio echoes being reflected back to earth from the sky. *As soon as pilots began to use radiolocation in aircraft they were bothered by the reflections—or echoes—from the earth back to their receivers in the air!*

At first this was serious, for when a night-fighter was nearer to the earth than to its unseen enemy, the reflection from Mother Earth blotted out

any tell-tale echoes that might have been received from a potential Nazi victim. This fact is quite easy to follow when it is realised that reflections—or echoes—from the earth not only continued the whole time, but were naturally stronger than echoes from a more distant object.

This bother was rapidly overcome when the research workers got busy with it, but in the meantime it resulted in a most fascinating discovery. *It was noticed that the echoes which came back from the earth below varied according to the nature of what was beneath the aircraft.*

For instance, as the rotating aerial of the aircraft swept the area ahead with its stream of radio pulses, those pulses which were reflected back from the sea were of a different strength from those which came back from dry land. In other words, *by looking at the screen of his cathode-ray-tube receiver, an observer found that he could tell when he was passing over the coast towards the sea!*

This was indeed a new and exciting line for the research workers to follow. And follow it they did, with such success, that, before long, they had designed super-sensitive apparatus which would not only show up border lines of land and water, but also rough details of the ground over which an aircraft was flying. First, the outlines of towns became visible, as reflections were received from buildings and then the outlines of the streets and buildings themselves came as the next prize, as improved equipment was produced. The value of this amazing development will already have occurred to the reader, just as it occurred to the men who were wrestling with the problem at the time. *NIGHT BOMBING!* Equip a bomber with such a device, and the bomb-aimer would have a plan of the ground right beside him as the aircraft flew along—with all the details of his target plain to see.

And that was precisely the outcome of the discovery. Quantities of this super-clever radiolocation apparatus were made and installed in Allied bombers, providing their crews with radio eyes that peered through darkness and the densest cloud to scan the secrets of the ground below.

This was one of Britain's greatest secret weapons. As secret as only Britons know how to keep a secret. A deadly landmark in the history of aerial warfare. And it is of ironic interest that, at the very time that British brains and skill were ripping aside the veil of darkness, German effort was concerned with the indiscriminate launching of their blind, robot projectiles, the doodle-bug and the rocket.

* * * * *

Cat and Mouse Game

But the Germans were not complete fools. We caught them napping in radio matters, we took the lead from them in the early days of the war, and we held our lead until we turned it into a decisive factor in their defeat—nevertheless, we had to be on our toes continually, in order to stay ahead. The German reaction to our radiolocation weapons—when he discovered their existence—makes a grim story.

We were many months ahead of the Germans with Air Interception (or "A.I." as we called our system of airborne radiolocation). But it was inevitable that we should have this same weapon used against us; and in due course it happened. There came the night when our bomber losses suddenly increased, and we, with our experience, knew why. The Germans had discovered the secret of probing the sky with radio, carried by their fighters; and they, too, were creeping up unseen, to shoot down targets that they could not see.

The First Answer

The immediate British reply was as ingenious as it was simple. Bombers were fitted with radiolocation apparatus (*Monica*)—in the tail! And with this device, our bomber boys were able to detect the German fighters who had detected them, and to wait for them, rear guns ready, as they closed in from behind to attack. The deadly cat-and-mouse game was on. Neither opponent saw the other, but each knew that the other was near—and drawing nearer. *And neither one knew that the other knew.* It was a case of who pressed the gun trigger at the most vital moment—Nazi fighter or "Tail-end-Charlie".

So ended phase one. But almost immediately there followed a dreadful counter-action. Our bomber losses jumped up to the level of some thirty per night. Three hundred fine, perfectly trained crew, killed or prisoners—three million pounds worth of aircraft lost—three hundred thousand pounds worth of radio apparatus lost—every night. The money, as money, meant little; but in man-hours it meant everything. The bombing had to continue; the losses had to be cut. How? What was the cause?

The Germans had discovered that we were using radiolocation detection in the tails of our bombers. Their fighters were picking up the radio waves sent out to locate *them*, and they were following those waves to their source. In other words, they were using our bombers as radio beacons to guide them in to the kill. The cause was discovered, but where was the cure? We could not dispense with our "tail-end" radiolocation sets. That would have been disastrous.

Inspiration came when it was most urgently needed; and the answer was produced, once again, by the radio research workers. Since the German fighters were sending out radiolocation waves to detect our bombers by *their* radiolocation waves, *we* in turn should have to use the Germans telltale waves to *their* disadvantage. We did, in a beautifully simple manner. We modified our "tail-end" equipment so that it switched itself off automatically, as soon as a German radiolocation wave "discovered" it.

And so, the grim game of "cat-and-mouse" went on; but beyond this point it is impossible to follow with clarity in written narrative form, for the tricks and counter-tricks are too bewildering. In carrying the story even to this stage, the human element has long since been left behind.

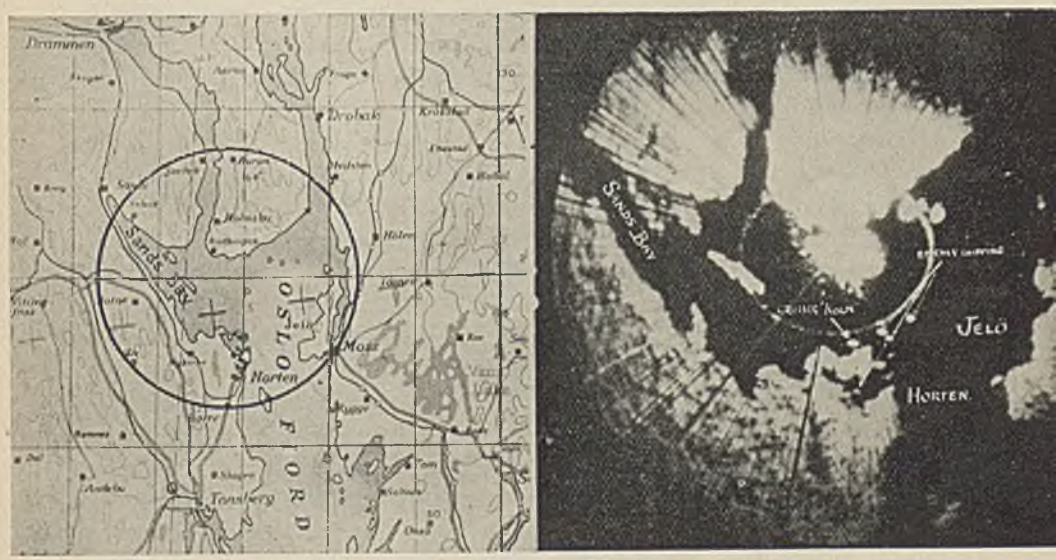
Radio set discovers radio set, and discovered radio set turns radio set off. It is as bad as trying to catch one's thumb with itself and its neighbouring finger. It is but a step from there to straw in the hair.

The marvel of it is that radio engineers usually look—and nearly always are—quite normal, everyday people.

* * * * *

One more story will make a fitting end to this chapter of radiolocation and the R.A.F.; for it shows the tremendous strides made in the technique of radio, and the absolute mastery held by British scientists at the end of the European War in the air. The story is best told by first outlining the job that was done, and then explaining *how* it was done. It is a perfect example of the deadly accuracy of precision instruments, and a pre-view for the imaginative mind of what marvels lie at the disposal of man in the next few years if only he turns them to good account, instead of to his own destruction.

One night towards the end of the war in Europe, a British pilot took off from his aerodrome with a load of bombs. His destination was a small building in Holland, which was being used for the manufacture of war material. He flew eastward until one of his radio receivers picked up a special radiolocation signal, and, thereafter, his sole duty was to fly his aircraft in such a way that he never lost that signal. After flying that way for twenty minutes, he suddenly felt the aircraft grow light in his hands. *His bombs had gone.* He turned and flew home.



The work of H2S—radar's magic eye—described in this chapter. The map on the left is part of a chart showing Oslo Fiord, with Sands Bay just cutting the circle in the North-East corner. The picture on the right is what the navigator saw on the screen of his cathode-ray tube at night. Enemy shipping, including a large blob caused by the cruiser "Koln," is clearly visible to the observer.

That pilot had done nothing but fly his aircraft according to automatic radiolocation instruction. No one on board had so much as pressed a button or pulled a lever. All that had been done from a small room, way back in England, over one hundred miles distant.

Two specially constructed radiolocation stations are used to perform this miracle—amazing pieces of apparatus which each employed about 120 valves. The first station is sited in, say, Kent, and it transmits a peculiar type of radio signal of unmistakable dots and dashes. By very precise calculations this signal is "beamed" so that the pilot, on switching on his receiver, hears a series of dashes when flying *beyond* a circle passing through his target, and a series of dots when flying on the inner side of that circle. *When dead on the circle—or dead on the line of flight that will take him over the objective—he hears a continuous note.*

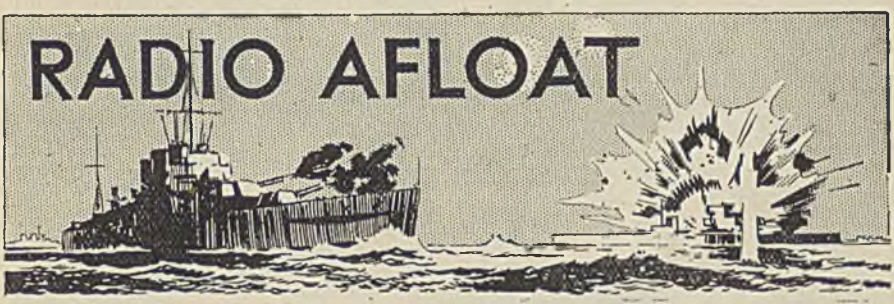
On taking off, the pilot flies into a pre-arranged waiting area, until station number one in Kent—the "Tracker Station"—is ready for him. He then switches on another of his sets, which shows Tracker Station where he is. Tracker Station sends him signals of dots and dashes to guide him on to the automatic beam—the beam with the continuous note area sandwiched between the dot area and the dash area. He now knows that he is flying along the edge of a circle that will lead him bang over his target.

So far, so good. But he is not the only person who knows that. At special radiolocation station number two, sited in, say, East Anglia—Releaser Station—an operator is looking at the screen of a cathode-ray tube, and on the screen of this tube is the outline of a large-scale map of a part of Holland. There is a circle drawn on the map, and a little white starry blob is creeping round the circle. *Yes, it is our bomber pilot, and he is getting very close to a cross marked on the circle.*

The operator in East Anglia places his finger on a button. As the white star reaches the cross he presses. A radio pulse flashes out from the aerial. Another radio set in the bomber jumps into life. There is a click as the bomb release gear is automatically moved, and away go the bombs—just early enough to allow for the speed of the aircraft, and perfectly timed to allow for the distance they have to fall.

The pilot has nothing to do with all this. His job is just to fly. And it may not be so very long before a radiolocation-controlled robot will do that job for him, too.

"Oboe" is the name of that cunning device, and "Oboe" did amazing service in the accurate dropping of target markers during the mass raids on Germany. The actual releasing of bombs by button from England was one of the very latest developments. But before that final touch was added to deadly "Oboe", the Navigator in the bomber was able to drop his markers, slap over the target, by acting upon a series of radio signals sent out by Station Number Two.

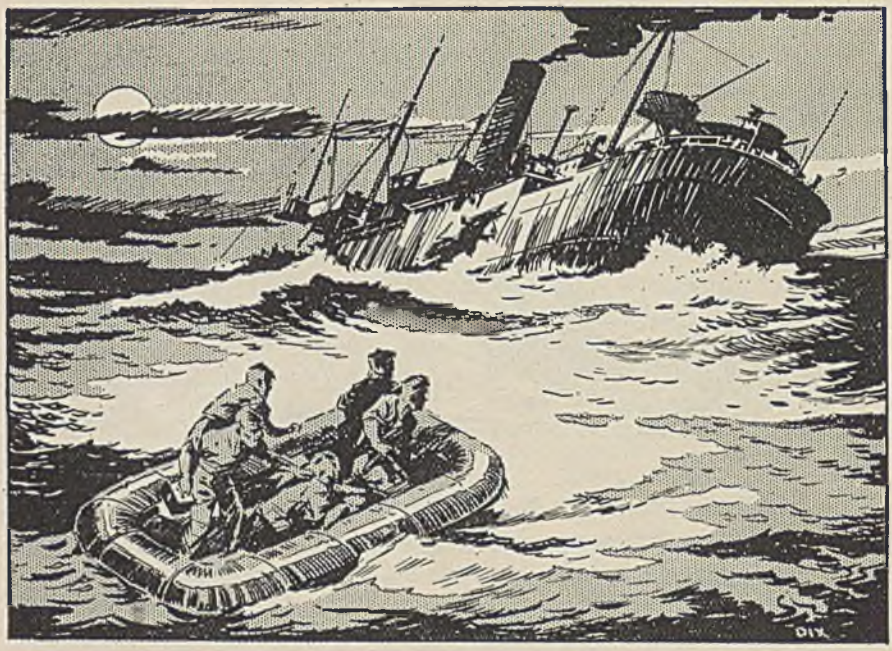


THE traditional title of the Navy—"The Silent Service"—has been well maintained in the recent war, and particularly in the world of radio. This is very reasonable and understandable, because our battleships do not fall into enemy hands. If they are lost, they go down fighting. On the other hand, radio sets in use by the Army must inevitably be captured by the enemy sooner or later, if they are in operation at the front line; and airborne radio apparatus will eventually give up its secrets to the enemy after sufficient pieces of crashed aircraft have been re-assembled. Nevertheless, the fighting ships of the Royal Navy have been amongst the biggest users of every type of radio apparatus, from the most simple form of receiving set to the most complicated radiolocation equipment, specially designed to operate with gun-laying machinery.

The Navy has used radio for an increasing number of purposes since shortly after the turn of the century. When wireless was first proved to be a practical proposition, seafaring men were the first to recognize its potentialities as a life-saving device. Until radio came into being, a ship was a world of its own, without any form of communication with the shore, from the moment it left port. If it came into collision with another vessel, or became seriously damaged by storm, it was at the mercy of the elements; and its crew were entirely dependent upon their own efforts and stamina for survival. But the day that the first radio message flashed out from the aerials of the first ship, all that was changed. It is history that many lives were saved when the *Titanic* struck an iceberg in the North Atlantic as long ago as 1912.

The Early Days

In those early days of radio, though bulky in the extreme, naval radio equipment was very simple indeed. The transmitter consisted of no more than a set of huge coils, an enormous condenser, a morse key, and a rotary



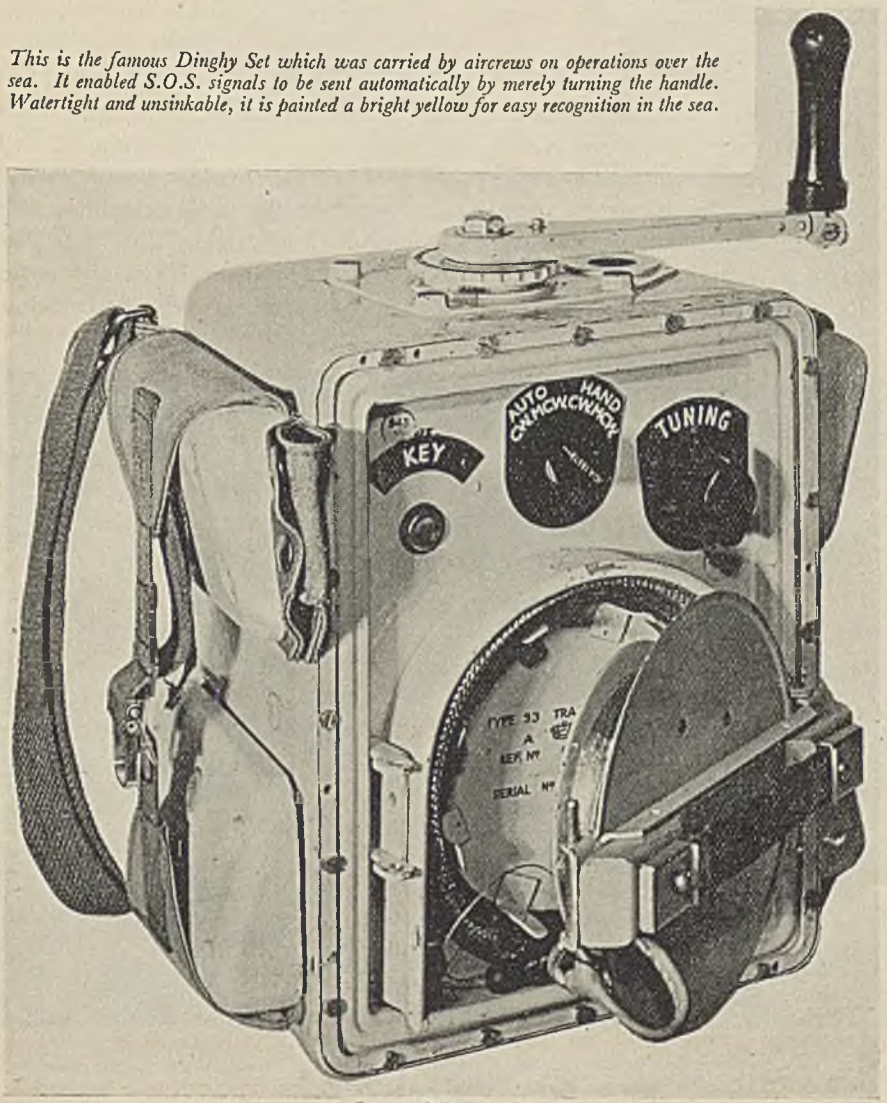
Torpedoed! But, as their ship goes down these survivors have comfort in the knowledge that an automatic waterproof radio set is in their boat—a link between them and other men.

spark gap across which jumped a stream of vicious, crackling sparks, driven by a pressure of many thousands of volts. The more power, the greater the range—and that was all that mattered. But the Navy, though sometimes slow in welcoming big changes, is never lacking in initiative when it has decided that those changes are for the better. Accordingly, it was not many years before ships of H.M. Navy were fitted out with a radio-telephone device, making it possible for the commanders of ships to speak to each other, and from ships to shore. It was largely this stirring on the part of the naval authorities, coupled with the growing appreciation by commercial companies ashore of the value and almost unlimited possibilities of radio, that founded the British radio industry as we know it to-day. The orders which came from the Admiralty, and from telegraph companies, were the first demands made upon the British electrical industry for a new type of apparatus—which came under the heading of "wireless." The call for valves, which came as soon as it was realised that the human voice could also be flung out on radio waves from transmitting aerials, provided the first orders for the electric lamp-making industry, that was one day to build up colossal manufacturing plants for the production of this "new-fangled" device.

The Navy took up wireless in a big way, and even founded its own wireless department in H.M. Signals School. At the Signals School, men were

trained as wireless operators, and the first of the radio "back-room boys" set about the improvement of existing apparatus and the creation of new equipment. From this school came orders for the growing industry, and through its good work during the next thirty years, many new radio ideas saw the light of day. Indeed, one of the most useful books yet produced upon the theory and practical use of radio emerged from the Admiralty Signals Establishment. It is known as the *Admiralty Handbook of Wireless Telegraphy*, and has long been the "bible" of nearly every student, inside and outside the services, who takes up radio as a career.

This is the famous Dinghy Set which was carried by aircrews on operations over the sea. It enabled S.O.S. signals to be sent automatically by merely turning the handle. Watertight and unsinkable, it is painted a bright yellow for easy recognition in the sea.



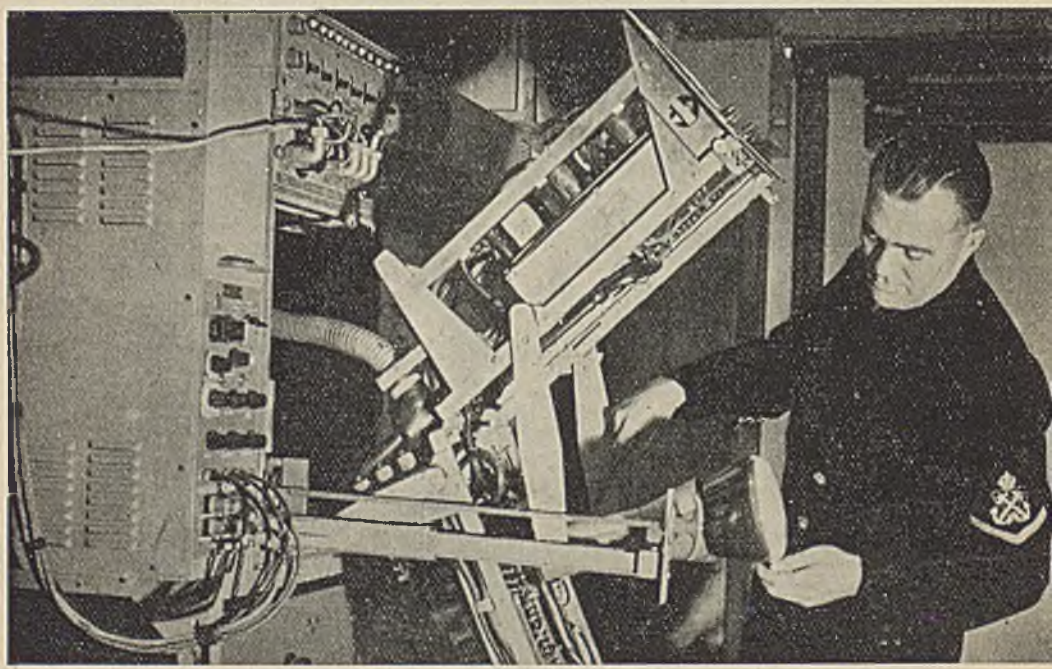
Radio in the Lifeboat

Both radio and radar also came to the aid of seamen and airmen in distress during the war, and it is likely that the ingenious devices which were created for their safety will at last end the long chapter of stories of misfortune and suffering in open boats after shipwreck. The "Dinghy Set", a picture of which appears on page 71, and "Walter", a clever radar device, have saved scores of lives that might otherwise have been lost.

"Walter," driven from a simple dry battery, is a small transmitter which flashes out its signals as soon as a switch is pressed. These signals automatically appear on the cathode-ray tubes of radar receivers in all Coastal Command aircraft and surface vessels within range.

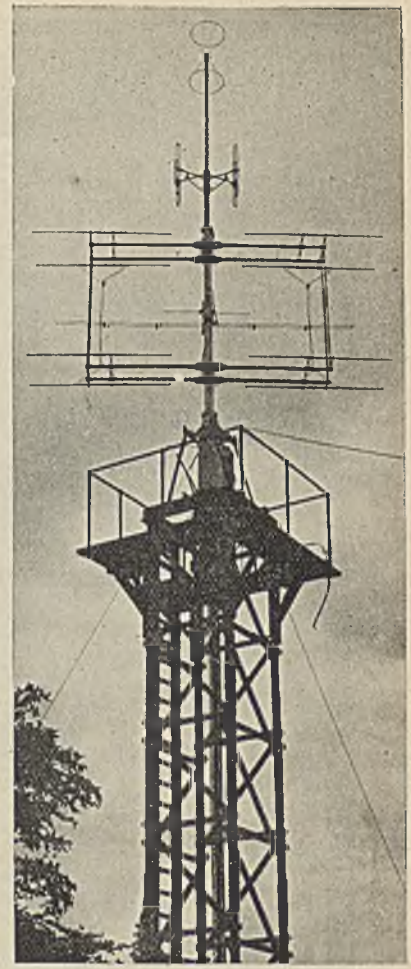
Trawlers on the 'phone

When war came to the modern Navy for the second time in a generation on September 3rd, 1939, H.M. ships were more than well-equipped with radio apparatus of the very finest design. Even the trawlers, which were to play such a large part in naval affairs, were on the radio telephone, and most members of their crew were accomplished operators. The "new" line in radio that had not been considered seriously by the Navy was radiolocation. It was, strangely enough, through the experimental work done



One of the greatest radio triumphs was that the design of even the most complicated radar sets allowed for simple, rapid maintenance. Vital seconds saved meant lives saved, too.

between the R.A.F. and the "back-room boys" at T.R.E. (Telecommunications Research Establishment), at Bawdsey Manor, that radiolocation was introduced to the Navy. The introduction came through the letters *A.S.V.* (Aircraft-to-Surface-Vessels). R.A.F. aircraft fitted with A.S.V. apparatus were obtaining pin-point positions of surface vessels which were out of sight. This was big news to the Navy, for the problem of hunting down and destroying U-boats was a grave one, and it was obvious that radiolocation had much to offer in this direction that was impossible by any other known system. But, even so, when radiolocation arrived on board the ships it was looked upon as a rather peculiar gadget, and nothing more. However, this stage did not last very long. The potentialities of the new equipment were soon recognised. It was first fitted in ships for the purpose of providing a warning of approaching enemy aircraft, but it soon became apparent to everyone who had occasion to use it that it might well change the whole science of navigation.



More strange radar aerials—and this time out of their element. These are naval aerials for use on ships, for the different types of apparatus on board. Here they are mounted on a tower for experiments.

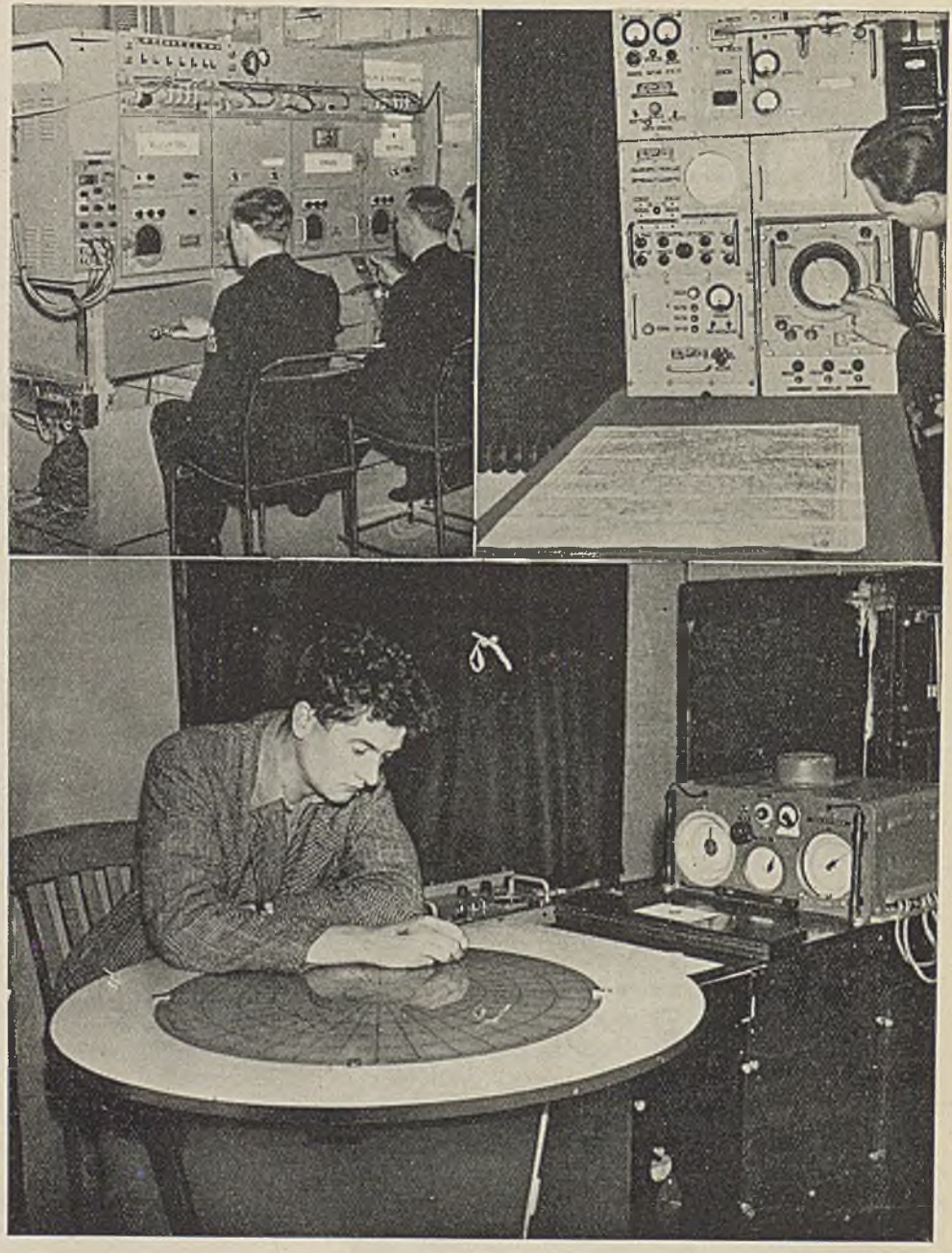
The Biggest Thing Since Steam

As one seafaring man summed it up, "The arrival of radiolocation is the biggest thing in the Navy since the change-over from sail to steam." There could be no better tribute than that to radio.

The Navy at once considered all the possible ways in which radiolocation could be used, settled its requirements in definite terms, and set about the design of the necessary apparatus. Within a matter of months the first orders were being placed with the many companies of the radio industry.

One of the greatest worries of any navigating officer is the nightmare of keeping station in a convoy consisting of a hundred or so ships in fog, in darkness, or in bad weather. But, in a flash, this worry was cut by half with the arrival of radiolocation. At once the position of every ship in the convoy was recorded instantaneously and accurately upon the cathode-ray tube screen of the radiolocation apparatus.

But no sooner was radiolocation installed than it began to create new



Three pictures of some of the latest Naval radar apparatus. Top left, *is a "centimetric" installation for Ack-Ack gunnery. The first operator records elevation, the one in the centre, range, and the one on the extreme right, bearing.* Top right, *is a lightweight "centimetric" radar warning set.* Bottom, *the wonderful Skiatron apparatus for tactical plotting.*

uses for itself. For instance, by scanning the surface of the sea ahead, the radiolocation aerials brought back echoes of anything that was likely to be a danger to the ship—another ship, a rock, or even a large piece of wreckage. Buoys, whose lights were invisible to ships in fog, and whose bells required a keen pair of ears to pick them up, were located in a second, and at great distance by the searching radiolocation beam. And, later, when the Navy adopted "H2S"—the bomber pilot's televised map of the country below him—ships' navigators were able to "see" an outline of an unseen coast.

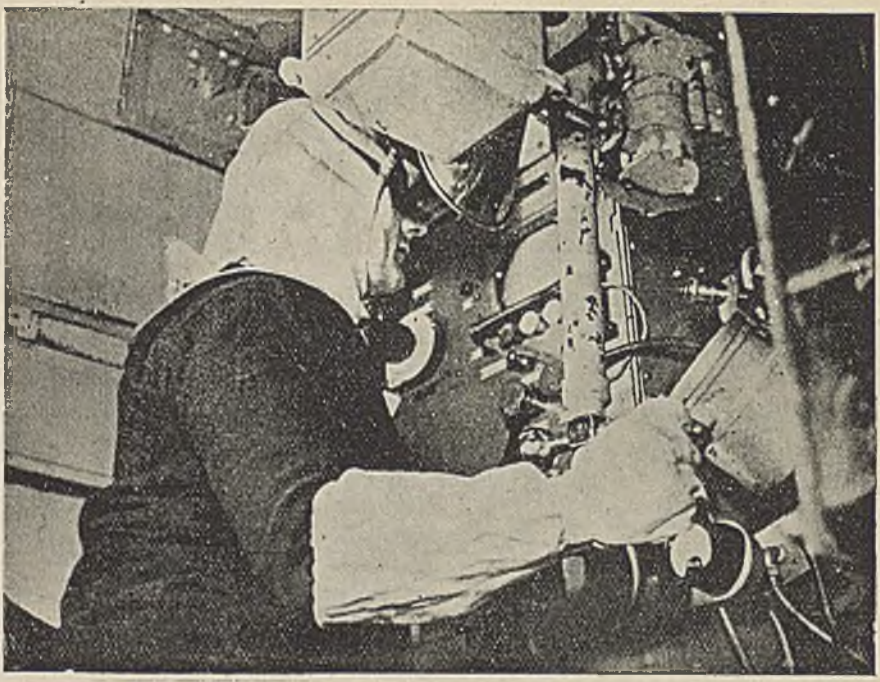
Assault Landings in North Africa

At the time of the landing of troops in North Africa, much comment was heard about the miracle of seamanship which enabled so many boats to arrive safely and with such accuracy at predetermined points after such a long voyage. A large part of that operation was, we know now, due to the magic eyes of radiolocation. Guess-work was gone; the possibility of errors in navigation was eliminated; the effect of bad weather was greatly reduced.

Most significant of all, however, the art of radiolocation changed the whole science of naval gunnery overnight. On the screen of his cathode-ray tube, the gunnery control officer received the tell-tale "blip" of all the enemy ships ahead. By the mere turning of a knob he was able to pass on to all guns the exact range and bearing of the target, and to keep track of the smallest changes of speed and course. *Most fantastic of all, as shells from the guns fell wide or short, the probing radiolocation beams were reflected back from the water spout, showing the gunnery control officer exactly how wide or how short the shells were falling! The enemy had not much chance.*

To the person who has not seen these miracles performed, the idea of watching a distant shell-burst appear on a radiolocation screen may seem far-fetched. But it should be remembered that the pulses of radio energy hurled out from the transmitting aerials of a radiolocation set are reflected back from any *solid* body. They come back, from many miles distant, reflected by such small objects as thin submarine periscopes, rain squalls, *and even floating boxes!* It is giving away no secret now to recall the excitement that was once occasioned by a strange echo received on the cathode-ray-tube screen of a shore station during the war. There was fog over the water, and no one knew exactly what was causing the "blip" on the screen. There was no friendly I.F.F. indication with the "blip"; it must, therefore, be an enemy craft of some sort. A destroyer was sent to investigate—*and the target proved to be nothing more than a drifting buoy!*

Though this story has its funny side, it shows with great emphasis the accuracy of the equipment in use—a destroyer now able to be guided through fog, dead on to such a ridiculously small object.



Radar revolutionised naval warfare when guns were fitted with radar range-finders. Here, the operator at his action station passes range and bearing by voice pipe to the bridge.

The Battle of Matapan

The Italian Fleet off Matapan was quite big game compared with a floating buoy. Steaming towards it through the Mediterranean at night, the officers on board the British ships had before them a complete plot of every enemy vessel. The Italians did not know until the last few fatal seconds the danger that was approaching. Then suddenly, at close range, the searchlights were switched on, and when H.M.S. *Warspite* fired her opening broadside, it was noticed that the enemy guns were still trained fore and aft. Five out of six of *Warspite's* 15-inch shells scored direct hits. In the engagement which followed, three Italian cruisers and two destroyers were sent to the bottom. The battle was a decisive one. It prevented the Italian Fleet from hindering the withdrawal of our forces from Greece and Crete. It relieved the Malta convoy situation entirely, so far as surface action was concerned, and it had the effect of turning the whole war in the Mediterranean, at the very moment of our greatest peril.

"Scharnhorst" and "Bismark"

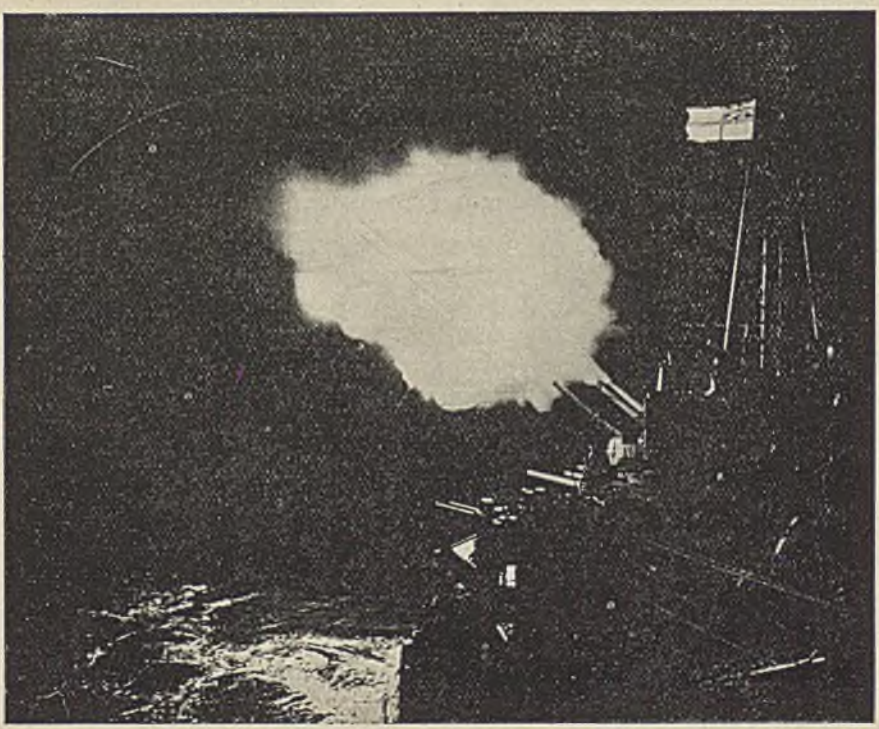
It was radiolocation which detected both *Scharnhorst* and *Bismark* before the actions in which they were sunk. *Scharnhorst* was first detected by the British cruiser *Belfast* at a distance well beyond gun range. *Duke of York*

also picked up the enemy at an even greater range, and closed that range to 12,000 yards before opening fire.

Fleet Air Arm

There are far too many naval uses of radio to be mentioned here, still less to describe. The Fleet Air Arm Barracudas, originally designed to carry one, or at the most two radio sets, now carry seven! Radio is vital to the successful operation of aircraft from carriers, and also for the safety of their pilots and crew. It is one thing for a shore-based aircraft to stagger home and to make a landing at almost any point along the coast; but it is quite another matter for an aircraft to find its sea base—a mere spot in the huge ocean—and an ocean that is often swept by clouds or blanketed by fog.

Radio and radiolocation devices enabled the crews of Fleet Air Arm machines to keep track of their carriers at all times, to detect and close with their targets, to enable them to detect and report back to base the approach of hostile aircraft, to obtain instant and accurate bearings from radio beacons ashore; in addition, the pilots are able to talk to one another in the air, and from the air to their carriers. And, further, they are even equipped with a marvellous radio altimeter which tells them, by means of warning lights, whether they are flying too high or too low.



Night action. Radar has so revolutionised naval gunnery that enemy ships can now be detected—and sunk—in total darkness, without a sight of the target.

ARMY RADIO

One of the big attractions at Radiolympia 1939 was an exhibition of Army wireless equipment, operated by members of the Royal Corps of Signals—now "Royal Signals". It was a very simple piece of equipment, but it created enormous interest because it represented a side of radio that was completely unknown to the general public. Radio, then, was a piece of furniture—an attractive cabinet with a built-in speaker, push-button tuning, coloured lights and a tuning scale marked with the names of broadcast stations. Anything beyond that spelled "mystery".

The piece of radio equipment on show was a mobile transmitting and receiving set, of which the Army possessed but a few hundred. They were used for morse and telephone communications between units up to ten miles or so apart. The only other radio equipment in use by the Army at that time consisted of a set of high-power transmitter-receiver stations, through which the War Office could maintain contact with outposts abroad; a set of medium-power mobile stations for use between the various Commands and Whitehall, and sets for communication between armoured fighting vehicles. All other signals were made by line, flags, lamps—and, in some cases, by heliograph mirrors.

Compare this picture with the radio-equipped British Army of to-day and you are left wondering just how it was possible for so much to be done in such a short time by one section of British industry. For to-day the infantrymen use nearly a quarter of a million portable radio-telephones; all aircraft co-operating with the Army carry special communication radio sets; every type of vehicle, from the jeep to the biggest tank, carries radio; gun and mortar positions are plotted by radio; micro-wave radio-telephone sets keep Army Headquarters in constant touch with one another; radio-location apparatus keeps nocturnal watch for Army gunners and guides the crews of searchlight and anti-aircraft weapons; glider troops and para-troops carry radio as a standard part of their equipment; and patrols in

the loneliest parts of the world are provided with sets with their own portable generators. And that is but a sketchy outline of the whole picture.

The change-over began in a very small way; for the British Army was quite a small force at the beginning of the war—and we had lamentably few tanks. At that time, no one had thought seriously of giving the P.B.I. their own radio telephones. The Army's requirements were, at first, modest —a mere increase in the quantities of the types of wireless sets then in production.

The First Innovation

But even as these extra sets were being made, the Army authorities decided that something new was required to make communications more flexible. Radio gave them a link between Whitehall and the Command Headquarters; smaller, mobile sets provided a further link between H.Q.'s and Brigades: but the chain had to be extended. What was needed was a light, portable transmitter-receiver station that could be carried and operated by two men, so that patrols could keep in touch with their own bases while on the move.

Three sets of this type were produced by the radio industry and went

Contact with ships during landing operations. This picture was taken at Anzio. The Beachmaster's signaller dug a hole in the sand for himself and his "46 Set", and from this point he transmitted the Beachmaster's messages to the ships in the bay.

A lightweight portable radio telephone used by Airborne troops. The "38 Set", made in its tens of thousands.

into production. But one was still-born, another died on the production bench—because it was made almost entirely of aluminium, and an episode—"The Battle of Britain" —was going to drain every available scrap of aluminium for aircraft production. The third, however, was lucky; and thousands were delivered to the troops within the first two years of war. The set was an instant success. The orders went up—and continued to flow in right through the war, until more than 10,000 of these "portable radiophones" were in use in all parts of the world.

Long before the first thousand of these sets had been delivered, however, the War Office, through the Ministry of Supply, had "required" a new type of transmitter-receiver for use in Army vehicles—something that could be used on the move, but whipped out and installed on the ground in a few seconds, possibly to be operated by a soldier hidden fifty yards or so away, up a tree or in a ditch. This set, too, was delivered in its thousands—as were at least half a dozen other types of receivers for picking up the "traffic" between the many stations now in operation.

Two Amazing Sets

And then, as the armed strength of Britain began to grow, as the nation recovered from the shock of Dunkirk and began to think in terms of attack, two more big demands were made upon the already over-worked radio industry. The first was for an even smaller portable radio-telephone: the second was for a really robust transmitter-receiver to work in the tanks that were beginning to roll from the production lines. Both these sets—the most amazing "best sellers" of the war—conceal a fascinating story of development.

It was just about the time when the Commandos were first blackening their faces, and when the first hundreds of our future invasion army were learning to glide and to drop by parachute. A representative from one of the radio-manufacturing companies called upon "Airborne H.Q.," taking with him a pair of radio-telephone sets which could be carried and operated

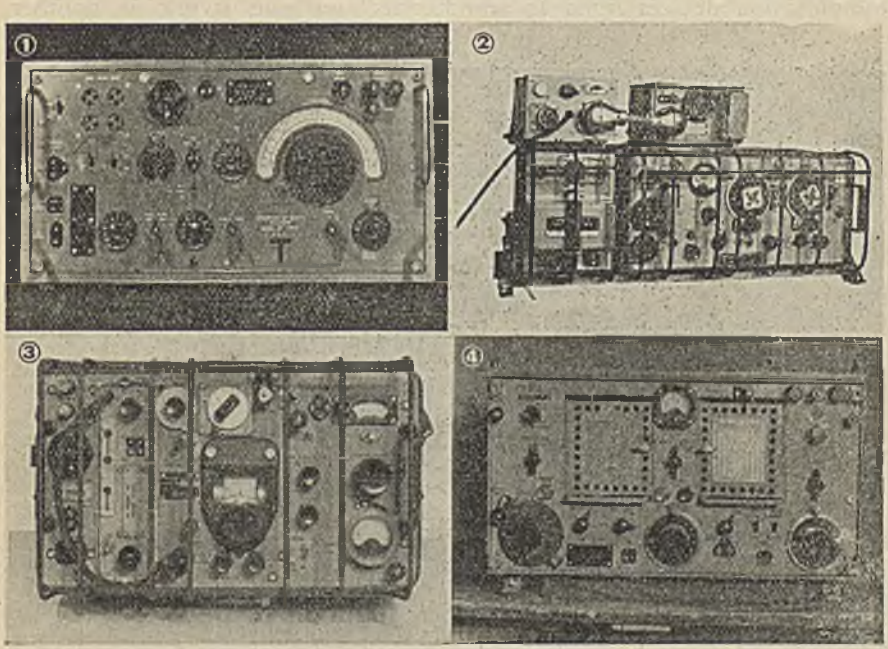
by one man. It was the view of his company, he said, that airborne troops might find such a device useful. The sets could be manufactured very cheaply, and could be thrown away if they went wrong. Little did he know what he was starting!

The first order, which came almost immediately, was for 2,000 sets. It was increased to 10,000 before production was under way, *and it was stepped up and up until three factories were turning out about two thousand a week, trying to cope with a total demand of over three hundred thousand sets.* That was the "38-Set," used by infantrymen on patrol, by commandos on lightning raids. by the Home Guard—and even fitted into tanks, for direct communication between fighting vehicles and troops in action.

The second set was the "19-Set," which was designed primarily for use in tanks, but which also "ran away with itself," ending up by being used in almost everything on wheels, on small ships, and even in aircraft co-operating with tanks. The first orders placed for this set totalled a few thousand. *By the end of the war it was being manufactured in three countries, and nearly two million were delivered for service.*

Two and a quarter million sets of two types alone !

But this was only the beginning of the Army's appetite for radio sets. The Army wanted special vehicles fitted up with as many as six different types of set. The Army wanted special devices for locating and ranging



Four more types of Army radio sets, made and delivered in huge quantities for troops in all parts of the world. (1) The "R.107 Receiver". (2) The "19 Set", fitted (on top) with a special version of the "38 Set" for use in tanks. (3) The "21 Set", a medium-power transmitter-receiver for use in vehicles. (4) The "12 Set", a transmitter of greater power.

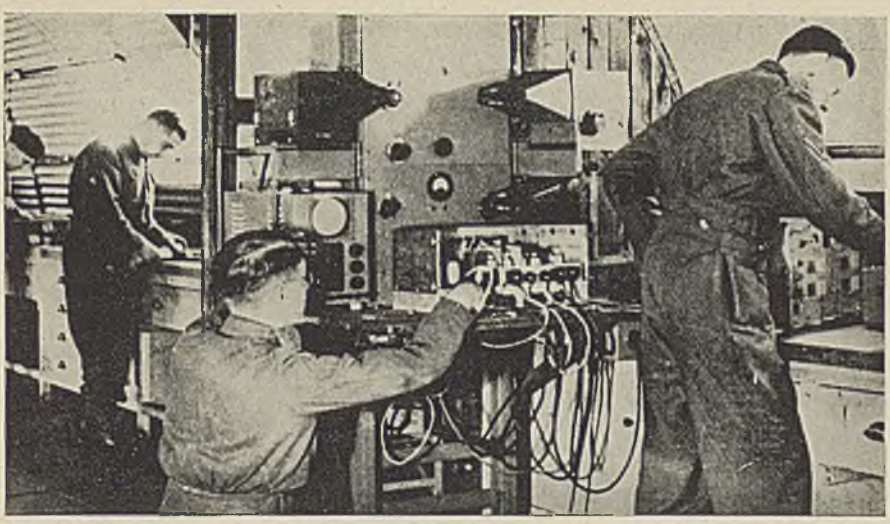
the enemy's gun and mortar positions. The Army also had a little problem with mines, and demanded thousands of mine detectors. The Army also wanted radiolocation apparatus.

But the Army's demands for sets were always accompanied by another demand—for spares. And this, of course, was the same when the other fighting forces ordered *their* equipment. And the word "spares" in this story, hides another tale all of its own. The provision of spares meant the provision, in quantity, of every component in every set—from valves to finished parts of a set which could be replaced as units by skilled R.E.M.E. technicians. To the actual set maker, the item "spares" on a contract meant, more or less, the manufacture of anything up to fifty per cent more sets than the figure in the contract; for he was, in fact, called upon to deliver not only the finished sets, but also a catalogue of parts for rebuilding damaged sets—*and the Army had to organise the storing and delivery of all the spares in all parts of the world where a set might become damaged.*

At least four spare valves—and often as many as ten—had to be available for every valve in every set. And that explains why, in the difficult days of the war, the local radio dealer was forced to say: "Sorry, but we haven't got that valve!"

The Army got all this—somehow—and more besides. The story of the radiolocation devices fitted to searchlights and guns is told in another

One night's bag for the Dover Guns—eleven enemy ships out of eighteen—sunk at a range of twenty miles, and in darkness. Operators in the Battery fire control room stand by.



R.E.M.E. at work. Thousands of men were trained to service and maintain the radio and radar sets in use by the Army. Many of these men, in specially built mobile workshops, were right ahead with the front line troops, ready to whip out, mend and replace any damaged apparatus.

chapter, so are details of some of the radio sets produced for special jobs; over and above all this the Army found it could use the eyes of radiolocation in a surprising number of different ways. And each of these ideas meant just one more scheme to work out, and just one more job to be tackled—by the radio industry.

Radio for the Dover Guns. The Battle of the Robots

There was, for instance, the problem of increasing the accuracy of the guns for the Dover Defences, and other coast artillery. When radiolocation was adapted to work with coastal gunnery the whole art was revolutionized; and it will be recalled that the Dover Defences ended the war in a blaze of glory when, on the last *night* of the German evacuation of Boulogne, they sank eleven ships out of eighteen—*at a range of twenty miles, and without seeing one of them.*

It had been discovered, too, that radiolocation beams could detect the presence of unseen enemy infantrymen, as they crawled along the ground many yards away. So the Army called for—and received—special radiolocation apparatus to cover this need. Another trick of the enemy's (and ours), was to hide away convoys of vehicles until darkness fell, and then order them to creep along vulnerable and exposed roads when they could not be observed by the gunners. This trick worked with us, but not with the Germans; for we used radiolocation. Our gunners trained their artillery to bear accurately upon a cross-road, and then, while it was still light, also trained a narrow radiolocation beam upon the same spot. Then, when the huns came creeping along the road, a tell-tale "blip" on a cathode-ray

Three more pictures of apparatus designed and delivered for the Army by the radio industry. Top, *a portable receiver.* Centre, *a transmitter-receiver planned for use by patrols in isolated parts. A pedal-driven generator does away with the need for batteries.* Below. *Mine detectors in action. The enemy has fled. The British wait to advance. A path of safety has to be cleared.*

tube showed the passing of each vehicle; all the gunners then had to do was to fire.

One of the last big jobs of the war which the Army called upon radio to perform was the destruction of flying bombs. On the first day that these missiles began to cross the Channel, it was found that they could be plotted accurately by coastal radiolocation stations, from the moment they left their launching sites. A courageous decision was at once taken to transport a large proportion of the mobile searchlight and "A-A" guns towards the coast, and to utilise their radiolocation apparatus for pin-pointing and attacking the bombs. This counter-move was so successful that, by the summer of 1944, eight were being destroyed out of every ten which came within range.

If the world were so foolish as to countenance another war and if, as would be likely, that war were to be waged with long-range robot-weapons, what occurred on the coasts of "Southern England" in 1944, will be recorded by historians as a perfect pre-view of the unpleasant but fantastic things which lay ahead. For there one saw the opening round of the battle of the robots. On the one side were the blind, soulless machines which coughed and rattled their cargoes of explosive towards their targets; and, on the other side, the muzzles of radio-guided guns moved like deadly fingers, following what they could not see, until the correct split-second arrived for them to fire. Add to that picture the shell ("Bonzo") which explodes itself by means of radar as it nears its target, and the story is complete.

Five years lie between that strange battle and the simple demonstrations given at Radiolympia in 1939; and in that period the British Army adopted radio as one of its major weapons. It required, demanded, and obtained from industry, apparatus of almost every type and size, in twos and threes and in millions, from sets of equipment employing a hundred or so valves, and weighing several tons, to midgets that barely bulge the pocket of an overcoat.

WOMEN JOIN IN

It is doubtful whether the women of Great Britain have anything like a true idea of the value of the work they did in radio during the war years. To say that they did a truly magnificent job is quite inadequate. They did fifty per cent. of the whole job, and the world is only just beginning to understand the magnitude of the job. Without the women of Britain, it could not have been done. They left their homes and their families to work in the radio industry's factories; they gave up promising careers to swell the ranks of the Government's army of inspectors; they went straight from their schools to join the women's sections of the Forces, to operate the apparatus and to repair it; and not a few of them, with special scientific training, became the counterpart of their menfolk—"back-room girls"— in the research laboratories of the industry.

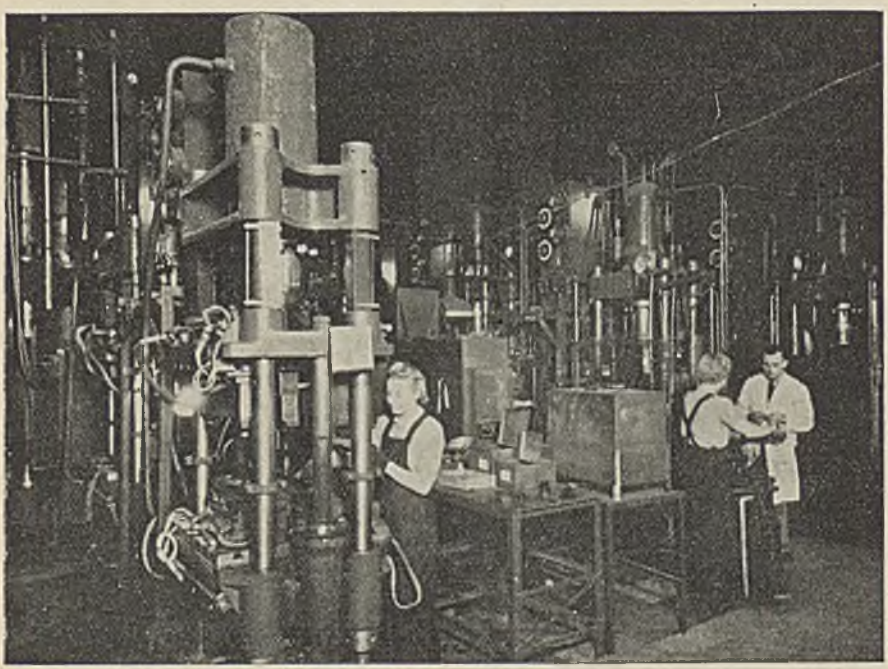
As already mentioned, the industry's manpower problem became acute quite early in the war. The first drafts of men to be called up had already eaten into a reserve of workers whose experience was to be sorely missed, and the Forces had first claim upon many more who might have been trained to take their places. So the nation called upon its women. They came from all over Britain. Until the call went out, they had been making stockings, confectionery, dresses, cigarettes—anything, in fact, that was *not* radio. They were given screwdrivers, odd lengths of coloured wire, nuts and bolts, and soldering irons—and they set about the business of making radiolocation apparatus.

To most of them, the work must have been bewildering to say the least of it, for radio is unlike anything else. No matter how odd-looking or insignificant a mechanical part, it is possible for a worker to see what it does on the finished job—to see it *working* in a car engine or an aeroplane; and that means a lot to a person on routine work. But there is nothing to see in a radio set, unless one has a fairly thorough knowledge of electricity. Nothing *moves*. And many a woman who spent four years before a coil-winding machine will never know why she had to wind exactly thirty-six-

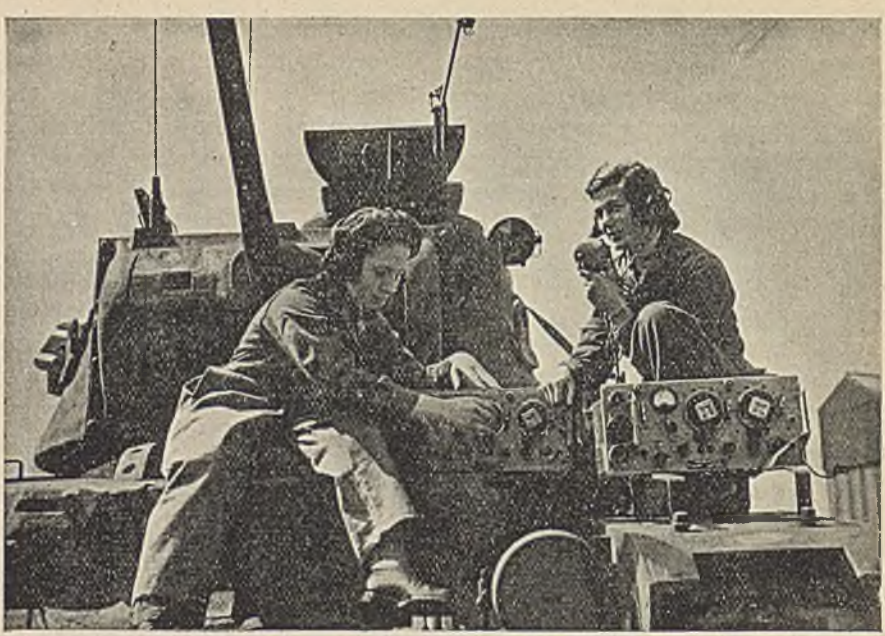
and-a-half turns of wire at one end of a bobbin, spaced exactly half an inch away from another coil of ten-and-a-half turns of different wire. If asked to cut rods two inches long, she could have seen at once if they were too short. A gauge would have guided her. But only the electrical tester could tell her that her coils were good or bad—too long or too short, and he could not explain *why* they would, or would not, do the job.

"Dry Joints"

Many a woman, now sitting at home relaxing after endless months of soldering, will smile at a reference to "dry joints." Having gripped her hot soldering iron for the first time, and run a hundred or so beautiful blobs of silvery solder in just the right places, fixing wires to metal tags with every outward appearance of perfection, *she could not understand why the inspectors rejected the work.* Not enough soldering flux; an iron too hot, or too cold; a wire moved a trifling amount as the solder was setting—all these things show up when the apparatus goes to test. Dry joints. And, if a dry joint slips through inspection, a pilot, or tank commander, or submarine "sparks" finds a "silent" radio set at the vital moment. But the women workers learned the technique of soldering, just as they mastered the art of winding coils of exactly the right length, and spacing funny metal plates exactly so



Picture of girls in overalls working press. Radio and radar sets for the war demanded many millions of plastic components. These were formed from raw plastic material in huge presses, working twenty-four hours a day. Just one more job for the women who joined in the battle to keep the troops supplied with vital apparatus.



A.T.S. girls test "No. 19 Sets" before installing them in tanks.

many thousandths of an inch apart, and mounting incredibly fine wire to form the filaments of millions of valves. In the factories they were superb; and they kept right on the job, despite "moaning minnie", despite the swish of falling bombs, despite the coughing doodle-bugs, despite the warningless crash of rockets—and the shopping queues, uncomfortable billets, anxieties about their men, homesickness and everything else.

Many of these women workers have already left the industry to re-establish old homes or to found new ones, or to go back to their original jobs; but many more have fallen in love with this strange work which demands such accuracy, but which does not show why. These women are even now winding the coils, making the glass bulbs, and soldering the joints for the thousands of broadcast receivers and television sets so badly needed for the home and overseas markets.

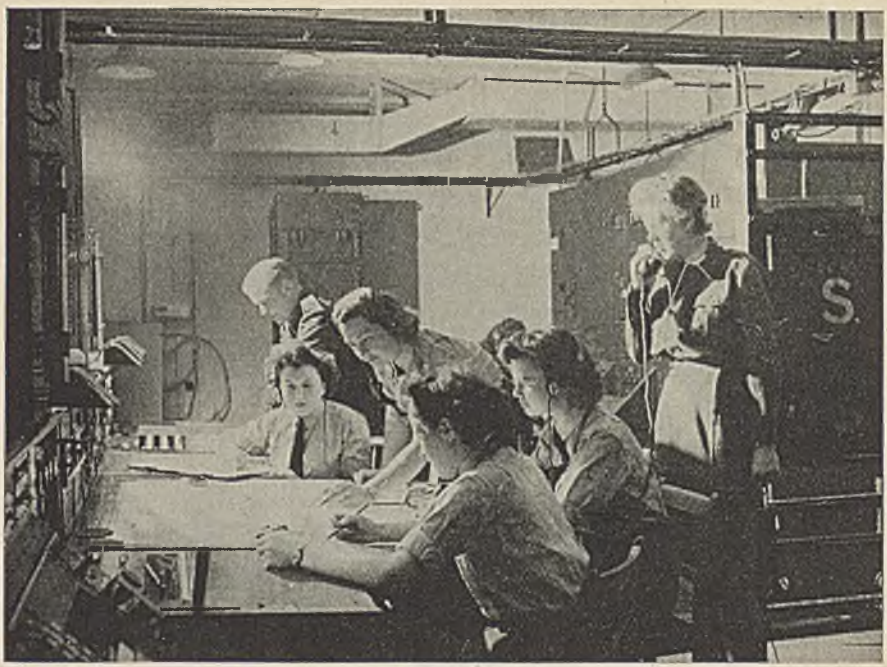
W.R.N.S.—A.T.S.—W.A.A.F.

In those far-off days before the war, it was not an uncommon belief that the man about the house was the person best able to tune-in the broadcast, or bring the clearest picture on the television screen. With very few exceptions, the world of radio amateurs was composed of men. *They* were the morse-key tappers who played with the short waves, and who pulled in the distant voices of foreign amateurs to their earphones, answering them through the microphones of their transmitters. Not for women, this work. And as for the idea of women repairing faulty radio sets, well———.

But to-day, in almost every town and village, one can meet women who have been on the operational side of radio—working morse and telephony sets, and radiolocation apparatus, on wavelengths shorter than many pre-war amateurs had considered; women who are capable of tracing the most elusive faults in the most complex piece of radio gear, and capable of stripping that gear down and replacing it. "Wren" radio mechanics, barely out of their 'teens, traced the faults which developed in Fleet Air Arm radio sets, repaired them, and flew with them to test them. On more than one occasion the aircraft in which they were flying were directed by radio against the enemy. It was routine work, for some of them, to draw from stores six or seven radio sets and yards of electric cable, and to instal those sets in aircraft newly delivered from the factories.

Thousands of A.T.S. girls "manned" the radiolocation apparatus fitted to the searchlights and anti-aircraft guns in Great Britain. Thousands of

Wrens undertook much highly skilled work, including the servicing of radio equipment. These two Leadine Wrens are installing a set in a Fleet Air Arm plane. When the sets are fitted, the Wrens test them, on the ground and in the air.



"Waafies" worked for six years among the secrets of radar. This picture shows a team of them in a plotting room.

W.A.A.F. girls were "on the air," night after night, operating the short-wave radio-telephone service between bombers and their bases.

Sealed Feminine Lips!

Where did all these women come from? And how did they do it? The answer to the first is—from everywhere. From every branch of life. From shops and offices. From schoolrooms and university courses. From factory benches and from home life. How they did it is one of the wonders of the war. No single word can frame the answer; it is to be found in a combination of words—tenacity, ingenuity, adaptability, loyalty, *and a sense of responsibility that has rarely been equalled.* And, finally, let it never be said again that women cannot keep a secret! From 1937, when radiolocation was still an unweaned infant, to 1945, when the enemy crumpled and collapsed, women held the secret of Britain's greatest secret weapon. Not all the natural inquisitiveness of the gossiping landlady, the trust of the family circle, or the intimacy of marriage, could make them let that secret out.

BACK ROOM BOYS

THROUGHOUT the war so much emphasis has been placed upon the work of "the back-room boys" that many people have come to regard them as a race apart—as a mysterious group of people who work alone, surrounded by secrecy, and cut off from the normal happenings of daily life. But there is also an unfortunate reaction to this mental picture; and it is, simply, that the layman has come to regard "a back-room boy" as a war-time special—something vaguely connected with the Government, or one of the Ministries; whereas, in actual fact, the specimen is a perfectly normal human being, who may be of either sex, and is as likely as not the person who sits opposite you in the train on the way to work. *He—or she—is an integral part of British Industry.* He is the person who designed your kitchen cabinet, your fountain-pen or your refrigerator, when such things were obtainable; and he is the person who will help to put British Industry back on the map, bringing prosperity back to these islands of ours by his genius.

Pre-war, no one heard of the "back-room boys"; but they were very real and active, none the less; they were the research workers in the drawing offices, laboratories and design departments of every worth-while industry. They were, and are, and always will be, of the same stock as the men who invented the steam-engine, the spinning-jenny, the steel ship, gas lighting and chloroform.

In the days of war, their energies were diverted towards the creation of offensive weapons—prefabricated harbours, liberation of atomic energy, propulsion, radiolocation.

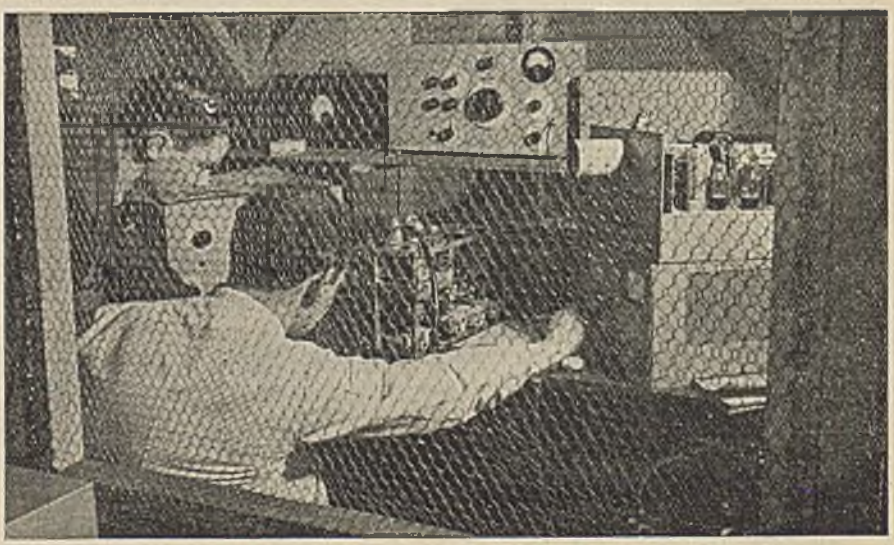
In order to guide industry into the road of common effort, the Government wisely picked a goodly proportion of the modern generation of these clever people, and set them up in Government departments, where they could think, invent, and develop as a body. And, then, the ideas that they produced were shared among the various branches of industry—adopted,

modified and improved as a result of consultation and co-operation with the remainder of the "back-room boys"—the research workers in the laboratories of the industries in question. These methods were applied to almost every section of industry directly engaged in the production of weapons of war. Radio is the perfect example.

Ministerial "Back-Rooms"

The Navy needed specialised radio apparatus for ship and shore stations, and for aircraft of the Fleet Air Arm. The Army needed quite different types of radio apparatus for infantrymen, fighting vehicles, such as tanks, and airborne troops. Similarly, the R.A.F. required a host more apparatus for aircraft, ground stations and homing beacons, etc., etc.

Quite obviously it was necessary for each branch of the fighting forces to maintain a specialized department, where all its needs could be properly sorted out by people who understood radio. And, accordingly, the Navy used its own research organization—*Admiralty Signals Establishment*, at Haslemere—for this purpose; the Army relied upon similar establishments—*Signals Research and Development Establishment*, at Christchurch and *Radio Research and Development Establishment* at Malvern; and the Royal Air Force maintained two further departments—*Telecommunications Research Establishment*, at Malvern, and *Royal Aircraft Establishment*, at Farnborough. (These names, each a mouthful, were condensed in the modern manner to A.S.E.,—S.R.D.E.,—R.R.D.E.,—T.R.E.,—and R.A.E., and the initials are now so universally used that many people who visit the establishments have to think twice before they can remember the full titles!)



Back Room Boys at work, testing a V.H.F. (Very High Frequency) transmitter-receiver. The wire-netting "room" acts as a screen to prevent radio interference with, and from, other apparatus.

One of the Back Room Boys of the Radio Industry at work among high precision instruments.

Each of the establishments has, of course, its own set of "back-room boys"; and these men and women are responsible for sizing up the job that has to be done, planning it out, and, in many cases, producing a prototype working model.

The "Back-Rooms" of Industry

This done, the industry is reviewed as a whole by the establishment, and a list is made of those radio manufacturers who are best suited to develop the job and to make it in quantities. From then on, the apparatus—more often bare plans and specifications—is placed in the hands of "the other half of the team," composed of the research workers in the laboratories of the actual manufacturers. There were many occasions during the war, too, when one company was ideal for the laboratory development of an idea, but was so loaded with work on the production side that it could not undertake to make what its own "back-room boys" were asked to develop. In which case the work was "farmed out" still further, to other factories whose benches were more free.

A good example of this is to be seen in the drive to produce radiolocation apparatus. Early in 1940, when it was realised that searchlight and gun crews were going to need the help of radio, Ministerial "back-room boys" were asked to work out an idea for radiolocation control. This they did, and then called in the "back-room boys" of three large manufacturing concerns to develop the ideas into a useful, reliable form that could be mass-produced. This, too, was done in double-quick-time, and, finally,

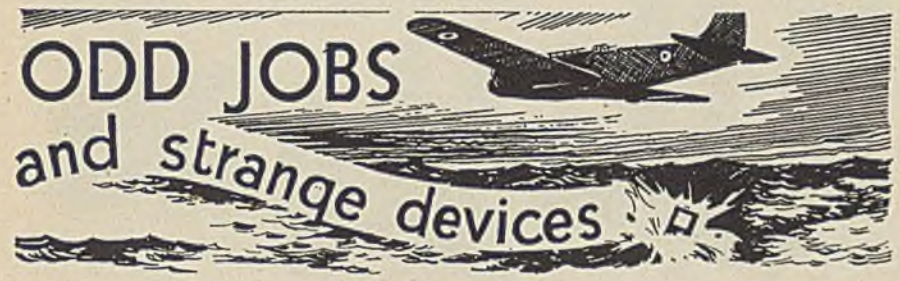
four or five manufacturers were supplied with full sets of drawings and specifications. The result of this team-work was the production of over twenty thousand sets of highly complicated apparatus within two and a half years from the word "go."

But the "back-room boys" are not merely to be found in the laboratories of the Ministerial establishments and the manufacturers of radio sets; they are at work in *every* worth-while factory which serves the final manufacturers. And the placing of a contract by A.S.E. for a new piece of apparatus for a submarine means, probably, that research workers in small electric motor factories, switch factories, wire factories, and so on, have to pull out their pencils and slide-rules and set about the design of something quite new.

The "back-room boys" of Great Britain, employed by both Ministries and Industry, have been responsible for some of the finest team-work of all time. And there is not one of them who would seek to say: "The credit is mine." They worked wonders and they performed miracles; and they did what they did because they all worked together.

Where did they come from? From the laboratories of the industry, from universities and from the classroom. Mr. Smith, B.Sc., Dr. Brown, and plain Mr. Jones, with a store of honest-to-goodness intelligence and practical experience.

And where will they go, now that the emergency is over? Some of them back to their blackboards, others to finish interrupted university courses, and still more to the laboratories of the industry, to think out and to develop ideas some of which you will probably not even notice in your broadcast or television receiver, but which will make reception ever and ever more simple and more perfect.

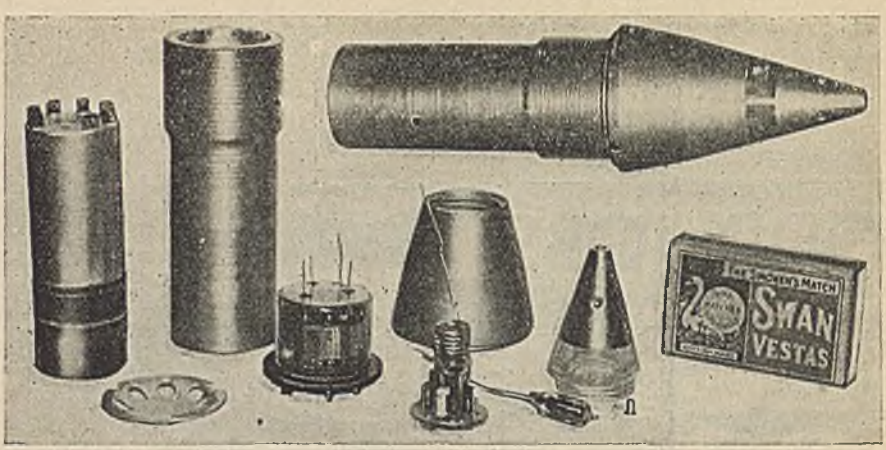


NEVER again laugh at the crazy inventor who designs a mousetrap with a bell to warn the mouse, or the crank who patents a robot-to-bring-in-early-morning-tea. At least, if you laugh, laugh kindly, and be thankful for that inventive streak which runs through the British Islanders. Imagine the smiles that would have followed the man who, pre-war, claimed to have invented a shell that could explode itself when it saw its target. Ridiculous of course.

But there is such a shell, to-day—"Bonzo"—and it was designed and developed by British brains. To look at, it is so like an ordinary shell that the casual eye would see nothing strange about it. But take a peep at its innards. In the nose-cap, in place of the customary fusing device, are batteries, valves and a miniature aerial—in short, a complete radiolocation station.

It was often remarked, by people who knew a little of what was going on behind the scenes, that the weak link in anti-aircraft work lay in the shell itself. Radio on searchlights could pick out the raider in darkness; radio on guns could locate the target with extreme precision—but if the fuse in the shell burned for a fraction of a second too long, or too short, then all the good work of radiolocation would be wasted, for in a fraction of a second a shell may pass out of range of its objective.

This was, to a large extent, true; and, although the critics did not know it, the research workers were already busy with the problem of installing radiolocation in shells. As may be imagined, it was not an easy problem. In the first place, the apparatus had to be squeezed into a ridiculously small space: and, secondly, it had to be so robust that it would withstand the terrific shock that occurs when the big gun is fired. The idea behind the scheme was easy enough to follow—a tiny radio transmitter in the nose of the shell was to send out a continuous stream of radio pulses, and any aircraft within a predetermined distance would reflect them back as echoes. These echoes would be picked up by the midget receiver in the shell's nose and, by means of an ingenious little gadget, would be made to explode the



"Bonzo", or, in technical language, the Proximity Fuse. This was one of the most ingenious British Radar developments of the war—a shell which exploded itself as it came within range of its target. When our Industry's back-room-boys had put the finishing touches to "Bonzo," we handed it over to our American friends for mass production. "Bonzo" brought down doodle-bugs like flies.

shell. But if the scheme of things was easy to follow, so are some of the difficulties that had to be overcome before the shell was even safe—let alone a practicable weapon.

If the shell's radiolocation apparatus caused it to blow itself up upon the receipt of radio echoes, the gunners would obviously not be too happy to have to handle it. So an even more positive gadget had to be designed, which made sure that the radio set would not switch itself on until it was many thousands of feet away from the gun and the earth. Quickly all these problems were solved and the shell went into production. An odd job for radio, if ever there was one; but it was "Bonzo" which put the final spanner in the "doodlebug's" works. When used in conjunction with "Cupid", and other radar devices, in the bad phase of the Flying Bomb attacks, forty-one out of forty-seven were destroyed in one day, in a single area, before they even reached our coast!

Death to Submarines!

Going to the opposite extreme, the radio industry did an equally odd job in another element—water. As every submarine commander knows, very often the only hope of survival after being spotted by the enemy is to dive, to switch off all machinery, and to lie silent and motionless as far beneath the surface as possible. In such circumstances, even the careless dropping of a plate or cup might give a clue to the sensitive ears of the sound-locators. The U-boat commanders were well versed in the technique of emergency dives and strict silence, and some trick had to be thought out for their damnation. The device that the radio industry produced was as clever as it was simple. Coastal Command aircraft were supplied with small, specially constructed radio transmitters, which they dropped into the sea

as soon as they spotted a U-boat. These transmitters were waterproof, and they worked from dry batteries that lasted several hours. Using a wavelength reserved for them alone, they began to send out code signals as soon as they were released.

And, as the U-boat crew sat in grim silence in their metal hull, far below the surface, waiting patiently for the time when danger should have passed, *that danger itself was being brought nearer and nearer, summoned by the submerged radio beacon which lay in the water close by, flashing out its recognition signals to the warships which raced towards it.*

Beacons for D-Day

Very often the research workers did not even guess the reason for the apparatus which they were asked to design. In April, 1944, a manufacturer received an urgent call from the Ministry of Aircraft Production for a special type of radio beacon. The first twelve sets were wanted within eight weeks.

They were delivered within the appointed time, and on June 5th a number of rowing boats moved through the darkness across the Channel, and men stole silently into the fields of France with these radio sets upon their backs. They set them down and concealed them in previously selected places, switched them on, and then left as silently as they had arrived.

Then, on D-day, warships moving into position off the French coast sent out special radio signals. As soon as these signals reached the aerial of one of the concealed sets, the set sprang into silent life. It switched itself into a transmitter and automatically flashed back a code message

As our troops swarmed ashore on D-Day, gliders swept overhead, guided by radar beacons. Many offensive enemy points had already been silenced through the help of radar beacons.

to the ship. One by one, as the inquisitive, probing signals from the warships reached these hidden sets, different code messages came back. From one came the letters "AXJ," from another came "BCD," from another "YMP," and so on. But on board the ships were men who knew exactly where radio sets "AXJ," "BCD," and "YMP" were hidden. Their whereabouts were accurately marked on large-scale maps, and so the men on board who knew the secret were able to obtain immediate and precise bearings of targets on shore—and to turn their guns upon them.

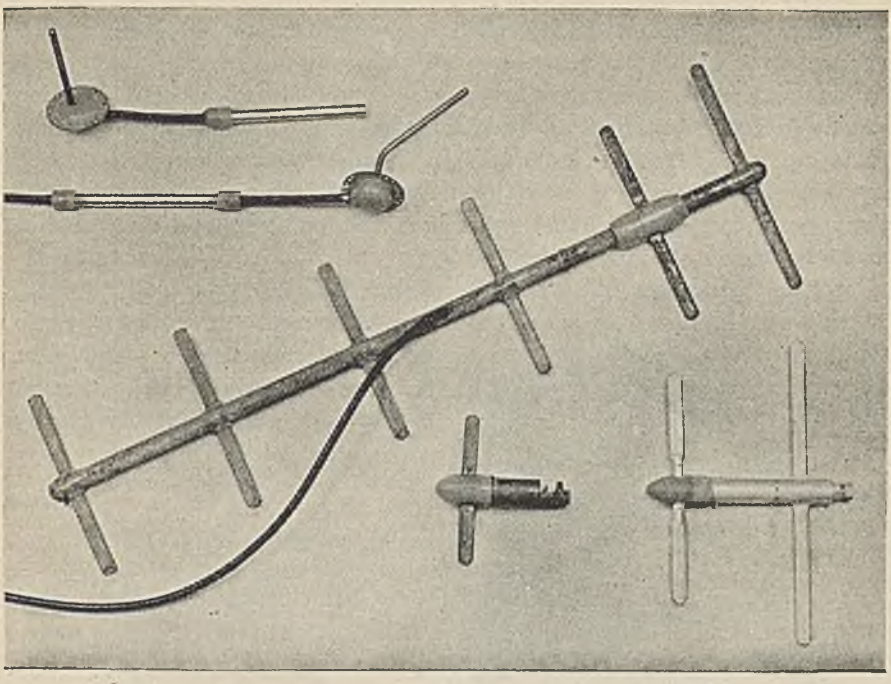
These secret, automatic radio beacons were a brilliant idea; for unless someone chanced upon them by accident they were impossible to detect by radio—*because they were merely receiving sets until a special signal converted them into transmitters; and then, when the special signal from the sea passed on, searching for another beacon, they reverted once more to a receiving condition, until the next inquisitive signal brought them to life again.*

After D-day, when the waters of the Scheldt proved such a nightmare to navigators, these radio beacons were placed along the river at predetermined points, and provided "information on demand" to all ships fitted with the necessary apparatus to make them respond.

Flying Laboratories

One of the most important jobs in the radio war was to keep in touch with the enemy's progress. If he were developing some new form of radio-location weapon for defence or attack, it was imperative that Allied scientists

The first Liberty ship arriving in the Scheldt estuary. The navigation of stretches of this river was greatly simplified by the use of special radar beacons originally built for D-Day.



Most secret. Each of these little radar aerials could have told a useful story to the enemy if he had been able to obtain advance details of them.

should know of its existence at the earliest possible moment, in order to enable them to get to work on a counter-measure. Up to a point, our agents, or spies, were able to pick up valuable scraps of information, but the surest method of confirming the existence of something new was to detect it at work. Looking at it from the enemy's point of view, his most reliable way of finding out the secrets of our radiolocation beams was to fly around in the areas where they were reported to be, and to measure their wavelengths, their power, etc. This, as we know, he did; and in doing so he found loop-holes in the system through which his bombers could creep.

One of the greatest problems our scientists had to solve was the puzzle of "where to look." Imagine sitting in front of a broadcast receiver, and attempting to tune in the single word, "yes," without knowing at what time of the night the word would be uttered, or on what wavelength it would be spoken. That would present a sufficiently formidable puzzle for a person of quite extraordinary patience. Yet the medium-wave tuning scale of the average broadcast receiver covers only enough space of the ether to accommodate about 100 broadcast programmes.

By comparison, the scientist in search of strange signals was faced with the task of exploring the possibilities of a tuning scale which had room for some 3,000,000 "programmes."

This, as may be imagined, called for some exceptionally complicated apparatus; and, to make matters worse, that apparatus had to be carried, with the scientists, over enemy territory. There was no question of sitting quietly in front of a laboratory bench, tuning and searching the ether. The radio equipment that the enemy might be developing would probably be specially designed to have a very limited range. So it was necessary to take the apparatus right to the spot—wherever that might be, and that was hit-and-miss, too.

"Flying Laboratories" were therefore constructed—special aircraft, packed with intricate electrical apparatus for detecting any type of radio signal on any one of many thousands of possible wavelengths—and these aircraft were flown over Europe, from north to south, from east to west, at night and in all weathers, and with enemy action a probability at any moment, while the men on board went patiently through their seemingly impossible task of finding the unknown.

The Value of Secrecy

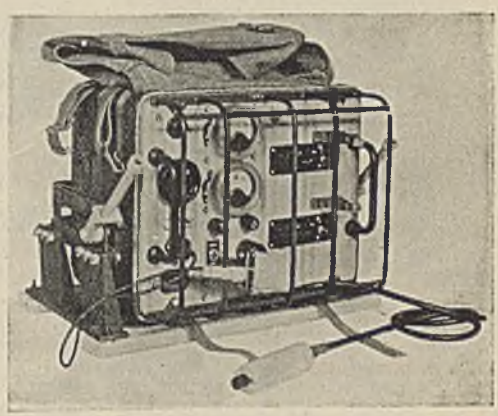
When it is realised that "finding the unknown" was the research worker's greatest difficulty, it will also be realised why such close secrecy was enforced upon all workers in the radio industry during the war years. A radio transmitter needs an aerial of a length which is directly proportional to the wavelength being used. For instance, if a radiolocation transmitter is designed to operate on a wavelength of one metre, its aerial would probably measure half a metre from end to end—or about eighteen inches. Therefore, if a factory worker happened to mention that he or she was painting "*funny little rods—about eighteen inches long—aerials I think,*" the enemy agent at the next table in the café or cinema could know in a second that it would be worth while tuning-in to a wavelength of about one metre; and by passing that information back to the right quarter, might save his Government weeks or months of vain searching.

Many people were puzzled by the strips of silver paper which fell from the sky when raiders were about. Many German civilians were probably just as puzzled, for Allied aircraft dropped tons of it, too. Its purpose was to confuse the operators of radiolocation detectors. Each strip of silver paper was half as long as the wavelength then in use by the radiolocation transmitters—*which meant that each strip would act as a little aerial of the correct length for reflecting back the strongest possible echo.* So, instead of receiving one neat little echo on the screen of his cathode-ray tube, the operator was plagued by hundreds of little spots—any of which might be the aircraft which was trying to escape its pursuer. It was a clever trick and it gave the research workers a headache.

Radio Detects Gun Sites

Two very ingenious types of special equipment were built for the Army, to enable our gunners to detect and locate the enemy's gun and mortar

sites. They utilised the speed of sound for their successful operation. Three people standing at different distances from a gun will hear the sound of the shot at different times. The research workers made good capital out of this fact by placing microphones, in small excavations, at predetermined points along a line facing the enemy's front. All these microphones were then connected to a complicated piece of radio equipment which could record the times at which a gunshot noise arrived at each microphone. Thus, by converting the different times into yards, and by drawing lines on a map, from the position of each microphone to a point where they all met, the exact location of the gun site was plotted. And then, by concentrating enough allied gunfire on to that spot, the said gun-site was duly liquidated.



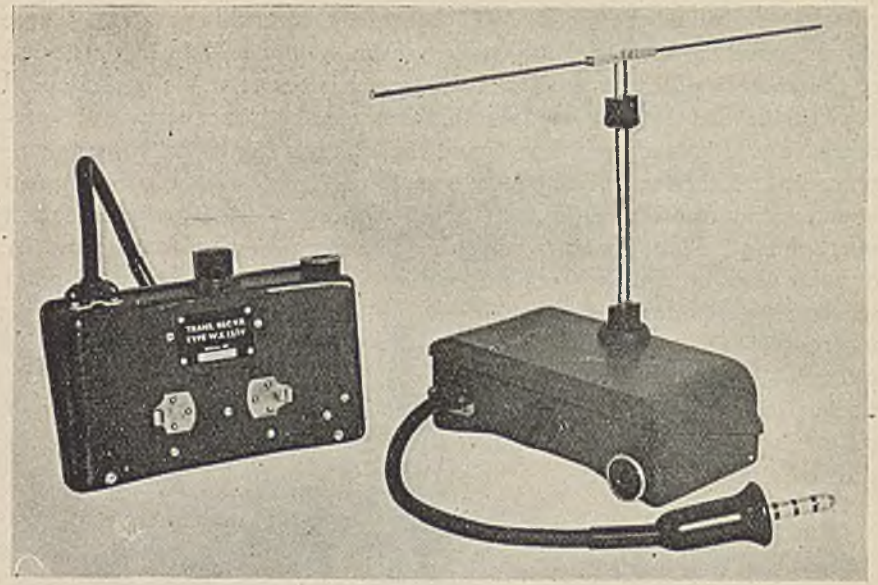
"Mortimer"—an ingenious radio device which was designed to locate enemy mortar positions by their sound waves.

Radio Sets for Spies

So many and varied were the specialised jobs which radio was called upon to do, that an account of them all would become tedious, no matter how fascinating the individual items on the list. There is, however, one very specialised job which the radio industry tackled, and which cannot be omitted. This job was the provision of secret radio sets for spies and patriots.

In 1940, when France and the Low Countries fell to the Nazi aggressor, it was at once apparent that a form of radio communication would have to be built up between the "Intelligence" departments in England and the "Resistance" movements across the Channel. Accordingly, a team of research workers was called together, and these men soon produced half-a-dozen or so experimental sets which could be carried secretly, and which required a minimum of radio knowledge to operate them. The best points of all these experimental models were incorporated into one design, and within a matter of months large quantities of *Special Spies' Radio Sets* were rolling off the production lines.

Unlike the clumsy affairs captured from German spies who were caught in Britain, the British sets were beautifully designed; they were no bigger than a miniature camera; they were worn on a belt round the waist, curved to fit the outline of the body; and they were worked from batteries, also carried snugly on the belt. These sets were supplied in hundreds to the men on the Continent who were bravely waiting for the chance to use them, and they were taken into the heart of enemy territory by British "agents,"



Beautifully designed transmitter-receiver sets, mass-produced for "agents". Little bigger than a miniature camera, they were worn on a belt round the waist, and worked from small batteries.

and by patriots of different nationalities, who were put ashore at night by boat, or dropped by parachute from bombers.

Death; and often worse, was the penalty for those who were caught; and many paid that penalty. It is significant that a special "kit" was issued to the unknown heroes who undertook this dangerous work; and this kit included a phial of a drug which would keep them going for several days without sleep or nourishment—a phial of morphia which would put them out of misery for twenty-four hours—and a capsule of poison which would put them out for good if the need arose. This capsule was to be slipped into the mouth upon capture, and it could be bitten if the peculiar methods of Nazi torture became unbearable.

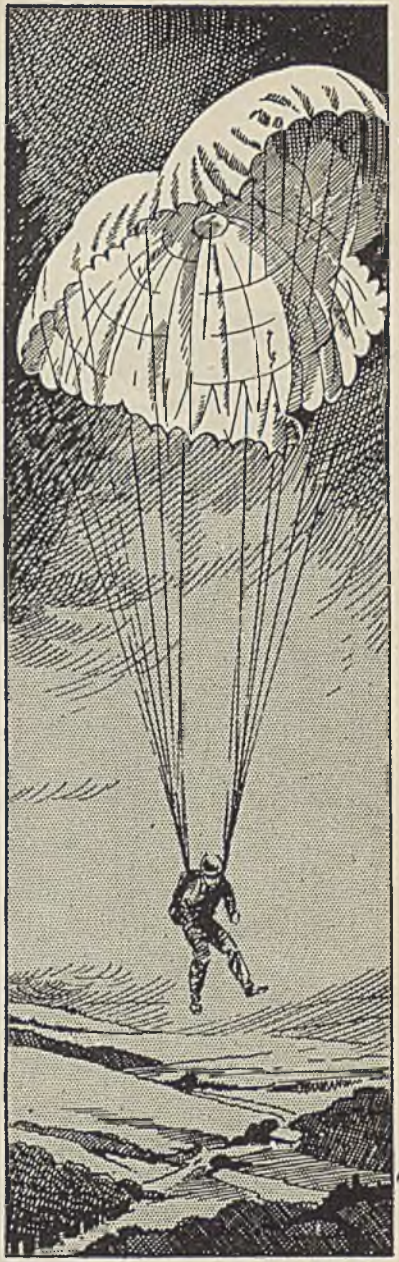
These men, when they arrived in enemy territory, were on their own, and the fate of many will never be known. With their little radio sets they made their way to the points where they hoped to pick up vital news. For weeks the voice of an operator would come by radio from the darkness; and then one night that voice would fail to come on the air. Night after night, bombers carrying special short-wave equipment flew over France, Czechoslovakia and the Low Countries; and from the ground below came the voices of the brave, invisible army—from men crouching in ditches, standing in the corners of fields, or lurking in the outskirts of towns that were being bombed, speaking into the microphones of their miniature radios, giving valuable data and information to the airborne operators who would carry the messages back to England.

One can well imagine the sensations of a spy, as he fell from a British bomber to take up his hazardous work with what was virtually a passport to the firing squad strapped around his waist. But at least he had the blessing of a radio set that was easy to conceal, that was simplicity itself to operate, and that was reliable enough to ensure that his dangerous efforts were rarely wasted.

Stranger than Fiction

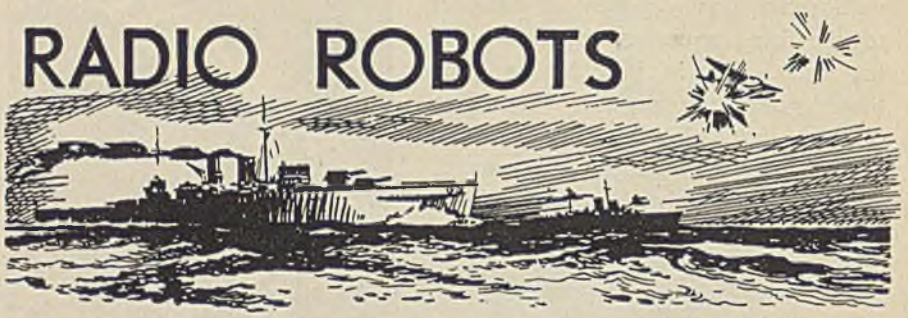
Some of the adventures of these radio-equipped agents are so amazing as to be almost beyond belief. One was arrested and sent to a concentration camp—*and he smuggled his radio in with him.* The men back home in England knew this because he continued to send his messages from the camp! But, one day, the messages ceased, and it could only be deduced that the inevitable had happened.

In bygone days, tales of espionage have always held first place, in fact and fiction. Secret cupboards, disguises, invisible writing and ciphers have enthralled readers of all ages; and now the addition of the radio device to the agent's list of tricks has introduced a new and fascinating subject for authors to exploit. There will doubtless be many such stories written in the next few years, and some of them may appear far-fetched. But it will be an imaginative author indeed who goes one better than some of the real-life characters of the recent underground war.



Some of the bravest deeds of the war were done when men, courting death, went into enemy territory to explore and to report back by means of the radio sets they carried.

RADIO ROBOTS



RADIOLOCATION has formed such a dramatic part of the radio industry's war effort that the many other uses of radio tend to be overshadowed by it. But it should not be forgotten that, many years before the war, one of the most "magical" affairs of the day was the radio-controlled "Queen Bee". This was none other than the famous little "Tiger Moth" on floats fitted with a special control system, and coupled to an ingenious radio receiver which faithfully obeyed the wireless signals transmitted to it by an operator on the ground several miles away. "Queen Bees" were launched by catapult and flown out to sea without anyone aboard them. They were directed automatically around the sky, turning banking, climbing and diving, to act as targets for our anti-aircraft gunners undergoing training on the beaches below.

Radio-controlled aircraft were a British idea and a British development. Being "the real thing," they provided the gunners with a target that was just a little better than that possessed by any other country. A set of ten buttons—or sometimes a telephone dial—formed the simple control for the ground operator. By pressing the buttons, or by dialing a number, he could make the aircraft perform any of the evolutions that a gunner would expect to encounter when dealing with a real, enemy target. So perfectly was the "Queen Bee" developed by the outbreak of war that the ground operator was able to bring it down to a safe landing in quite choppy seas.

It was obvious, when war broke out, that radio-controlled targets could perform a most useful service in the training of gunners. The "Queen Bee" was further improved, and became the "Queen Wasp." But an even more revolutionary idea resulted from the experience gained in the pre-war years and, shortly after war was declared, the Army suddenly placed an order for some two hundred radio-controlled speed boats. It was known that the enemy, in common with our own ideas, was building up an E-boat force, and, therefore, it was most necessary for our gunners to have practice in shooting at them—or something very much like them. And, since it was

impossible to put a crew aboard a target boat, radio had to provide the answer.

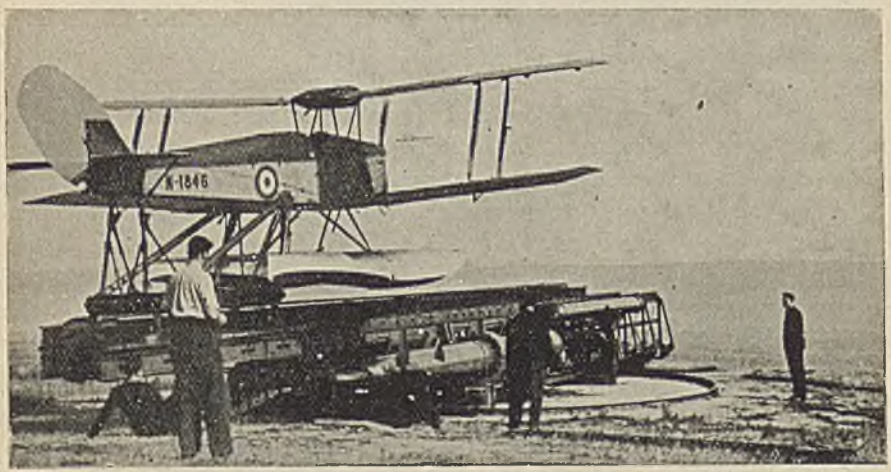
The first boats were called "Queen Ducks," and a second species, hatched soon after by the back-room boys, were christened "Queen Gulls". And, as so often happens, one idea led to another, and a "Queen Gull" was converted into what must have been one of the most marvellous robots of all times.

"Restless"

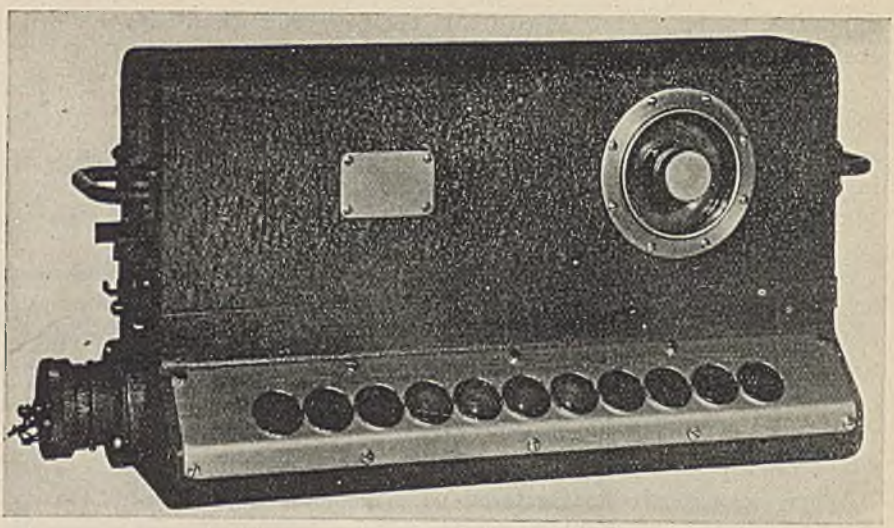
It happened shortly after the two German ships, *Scharnhorst* and *Gneisnau* had slipped out from Brest and escaped through the Channel. The naval authorities were determined that nothing like this should happen again. So, one morning, the telephone rang in the office of a radio-manufacturing company and a voice asked whether Mr. So-and-So knew anything about the working of a "Queen Gull" control apparatus. Mr. So-and-So did. Then could he please come down to the South Coast at once?

When he arrived, he was faced with the following request: "Do you think you can convert this apparatus to give us control over a specially constructed motor-boat which we propose to leave moored and unattended out in the Channel? You see," he went on, "we are planning a robot weapon for use against any large German warship that may attempt to slip through the Channel. We have decided that one possible method of damaging such a vessel is to drive a boat-load of explosive up against it—and we can't very well expect to send a crew on a mission like that! Since time is likely to prove a most vital factor, the only sensible thing to do is to moor the boat as far out from the shore as possible, so that it can be got under way with the very minimum of delay."

"In other words" said the engineer, "you want this apparatus to start



"Queen Bee". Many of the ack-ack gunners who guarded these islands were trained on "live" targets in the years before the war. British scientists have long been pioneers in the art of robot control. This picture shows a pilotless radio-controlled target plane ready for its launch by catapult.



The Piano. A box of buttons which conceals another magnificent engineering job. The buttons light up when pressed; and somewhere at sea a radio-controlled boat answers faithfully to every button.

up the engine by remote control from the shore, to slip the moorings, and to put the boat on its right course—and, presumably, to keep it there?"

"That's about it," replied the official. "A pretty tough proposition, I agree. But that's what we want, none the less!"

It was indeed a tough proposition. Anyone who has tried to start a motor-car engine after it has been standing in a cold road for two or three hours will appreciate the difficulties of starting an icy cold motor-boat engine which has been moored out at sea for half a winter's night—and all this by radio! Nevertheless, it was done. The boat was obtained and prepared for its cargo—a charge of explosive. An amazing piece of machinery was created to work with the radio receiver on board. On the shore, a radio transmitter governed by a set of push buttons could be manned by an operator at any time throughout the twenty-four hours. The scheme was called *Restless*—another example of an amusing code word.

When the shore operator pressed the button marked "Start," an automatic control on board pulled out the choke lever, and pressed the starter button. When—and if—the engine fired, the automatic control held the choke for a given number of seconds, until the motor warmed up. If the starting mechanism failed, the whole process was repeated, without any further button-pressing from the shore, until the engine *did* start, and stay running. Then, still without any more radio signals from the shore, after the engine had been running for sufficient time to ensure its reliability, another automatic device released the moorings which fell into the water. As the mooring rope fell away, yet another automatic device let in the clutch, and at the same time opened the throttle sufficiently to take the

added load and brought into operation the automatic pilot. The boat chugged away in whatever direction it was heading.

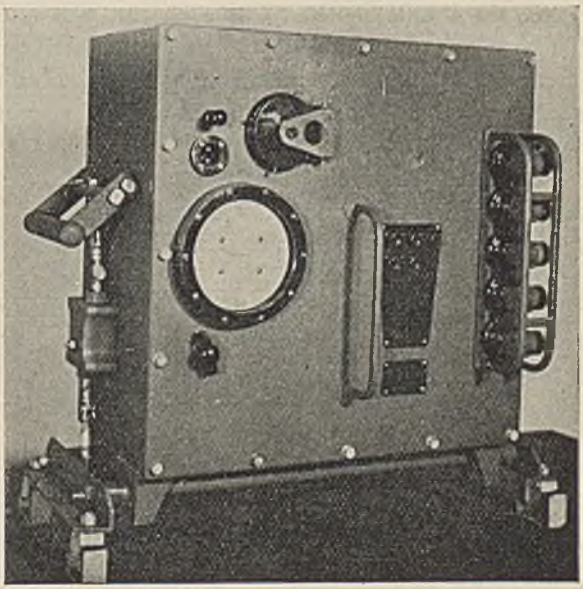
It must be remembered that all this might have to be done, in emergency, at night or in thick fog. There would probably be no opportunity of watching the boat visually as it accelerated and roared away on its errand of destruction. Accordingly, some form of radar reflector device had to be designed to keep a check on its progress. This device, too, was successfully developed and installed; *and it was so accurate that the boat could be steered to within a few yards per mile of any objective.*

Once away under its own power, the operator on shore picked up its course by following it on a radiolocation screen, and pressed more buttons—"Starboard" or "Port"—to head it in the right direction. When it neared its quarry, the pressing of another button automatically cocked the device for firing the charge. Yet another button marked "Uncock" enabled the operator to render the boat harmless if necessary. A final button—to be used in extreme emergency, in case the craft got out of control, or headed for one of our own ships—would automatically flash a signal to the boat and cause it to blow itself up.

"Restless" was never used against the enemy, and has since been dismantled. Nevertheless, the idea was as successful as it was ambitious. On trials, with a crew aboard, it was proved to be so accurate that the crew had to "take over" from the radio control in order to avoid hitting quite a small buoy which had been their target from a distance of twelve miles and more.

"Rascal"

The usefulness of radio-controlled aircraft, and the success of the radio-controlled motor-boat inspired another ingenious idea for use on D-Day. As it turned out, it was not found necessary to use this device but it was ready, none the less, and would undoubtedly have given the enemy a rude shock where he least expected it. This new



The receiving end of the robot radio control for high speed boats. As buttons are pressed in the station ashore, this apparatus receives the orders and puts helm, throttle and clutch into operation.

"Rascal" was designed to breach the much-vaunted Atlantic Wall by high explosive. But the "Wall" fell to other methods of approach. "Rascal" was just another example of radio robot technique.

device was called *Rascal*. It was an amphibious tank, also fitted with a heavy explosive mat on the nose, for use against the Atlantic Wall. "Rascal" was to be taken across the Channel on D-Day in an L.C.T. (Landing Craft Tanks). With its radio robot in charge, it was to have trundled into the water, swum ashore and up on to the beach, and under the guidance of a man behind the buttons in another vessel, it would have rammed itself against the wall and exploded.

"Rascal," *without* its explosive charge, was often tested in the Thames. Those who saw it lumber into the water at Kew Bridge, and paddle upstream to Richmond before emerging and heading for the park, realised that they were watching something rather unusual—but they never knew quite how unusual.

Apart from the radio apparatus, the heart of a robot craft—whether it be aeroplane, boat or land vehicle—is a gyroscope. The same form of controlled gyroscope is used in nearly all large aircraft as the automatic control, or *George* as it is usually called. "George" when set upon a given course, will fly an aircraft in all weathers with an accuracy and ease that would call for the utmost effort on the part of a pilot. "George" has undoubtedly a big future before him in the days of peace; and it is very probable that "George," aided by radio, will produce some big surprises in the field of aviation in the years to come.

Radar Robots

But in addition to the more spectacular robots which flew, swam and moved on wheels, there were many devices designed for special duties in the war which stood, like silent sentinels, year in and year out. A perfect example of these is the radio beacon which flashed out its automatic code message to the "homing" aircraft, telling him faithfully where he was and in what

direction he was flying. When a fighter pilot had been racing all over the sky in chase of raiders, constantly changing course and speed, it was most necessary for him to have a simple yet reliable method of finding his position as rapidly as possible, so that he could return to base in safety.

Radar beacons were installed at various points in the British Isles to provide this aid automatically. By switching on one of his radar sets, the pilot caused a radio beam to flash out ahead of his plane. And whenever the beam pointed towards one of the beacons on the ground, that particular beacon sprang into life, flashing back a specially coded signal which appeared on his cathode-ray tube as a group of spaced lines.

Each ground station flashed a different code group as the pilot's probing beam reached it; and so, by flying around, he could tell instantly towards which aerodrome he was heading, and could pick out the particular aerodrome on which he wanted to land.

The idea behind the radio beacon is by no means new. Just as the rotating beam of a lighthouse enables the sailor to find his way, or the fixed light, visible from only one direction, tells him where he is, so does the radio beam extend these navigation aids, giving a greater range and being unaffected by darkness or fog. Robots of this type—robot beacons employing radar—have a very big future in the age of safer travel that is now beginning.

RADIO FACTORIES

WHAT is an *Industry?* The dictionary says it is a trade; but somehow the word "trade" no longer seems adequate. Carriage building was a trade: motor-car manufacturing is an industry: radio manufacturing is an industry. The difference lies in the fact that no single tradesman can to-day manufacture the average product of the modern mechanical age—no more can any single factory produce economically all the many bits and pieces that are needed to build up an aircraft, a radio or television set. And so the Radio Industry of Britain is a far more complex structure than a mere handful of factories which produced the actual wireless receivers and television sets advertised so popularly in the days before the war. Behind those factories which finally delivered the goods, "as advertised," there was a far bigger chain of other factories which made the many bits and pieces or, as the industry knows them, *components.*

All that the average listener sees of his wireless set is the cabinet, a pair of bakelite knobs, a tuning dial and a length of flex which leads to a plug: the rest he is prepared to take on trust; nevertheless, in order to appreciate the full magnitude of radio's part in the war, it is important to have a clear picture of all that is involved. This may best be obtained from the fact that no fewer than twelve factories are needed in order to supply the components necessary for one radio manufacturer to produce the very simplest form of receiver; and in actual practice many of the wireless sets demanded by the armed forces have been so complex that the products of from thirty-six to fifty different factories were used in their manufacture.

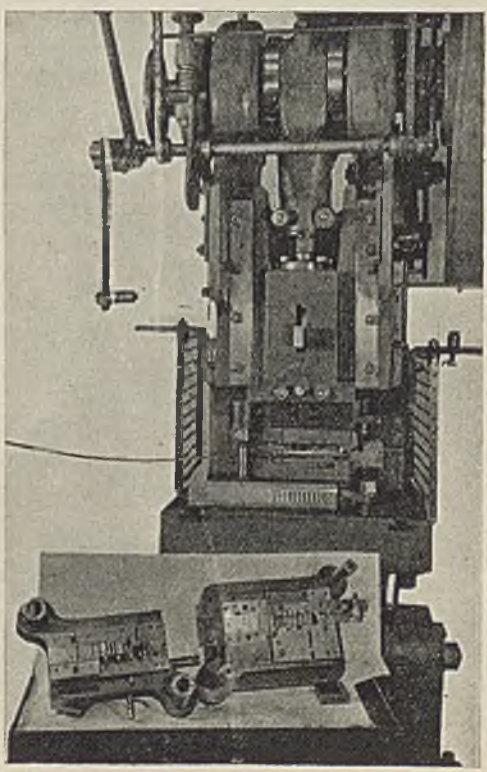
It is the custom to apologise for the inclusion of statistics; and the average practice is to insult the intelligence of the reader by assuming that he or she "will not understand figures anyway—particularly when talking in tens of millions." This, of course, is nonsense: anything can be understood if it is presented in an understandable way. For instance, the bald statement that *one hundred million* wireless valves—or 100,000,000 in figures—were made during the first five years of war, would be meaningless to many people, because that figure is too big to imagine. But imagine, instead, a single

machine turning out one radio valve every minute, without stopping, day and night: *it would have to keep on at that rate for over two hundred and twenty-five years* to produce all those valves—the number which have actually been made in this country by our factory workers, for use by the Navy, Army and Air Force.

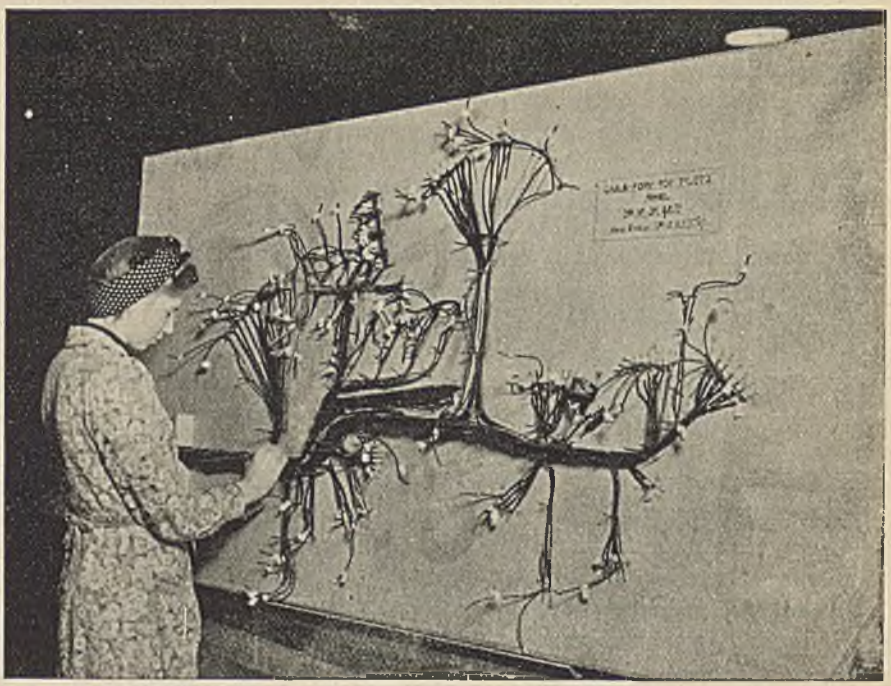
That represents just one component of the range—from twelve to fifty—that a radio set demands. As for wire—mostly copper wire—enough has been made and used to reach to the moon and back.

The answer to the unspoken question that these bewildering figures evoke is: "Yes, the industry has made a lot of wireless sets." The Navy, the Army and the Air Force have asked for, and received, about 7½ million sets of all types, from transmitters that need several lorries to carry them, to small two-way radio telephones that an infantryman carries on his back or wears on his chest. And these sets have been used in submarines and aircraft, in tanks and jeeps, on searchlight sites and in listening posts—all over the world, from London to Penang.

If the mere manufacture of all these sets were the whole story it would surely be big enough, even without taking into account the individual efforts of all the factories that have managed, somehow, to produce all the components, great and small, that were necessary to make them. But there is far more to it than that. Special machinery had often to be designed and built in order to manufacture in quantity the parts to make the sets. Special electrical test equipment had to be planned and produced for checking the accuracy of the products during manufacture. And—particularly in the case of radio sets for use at high altitudes and in the tropics—entirely new manu-



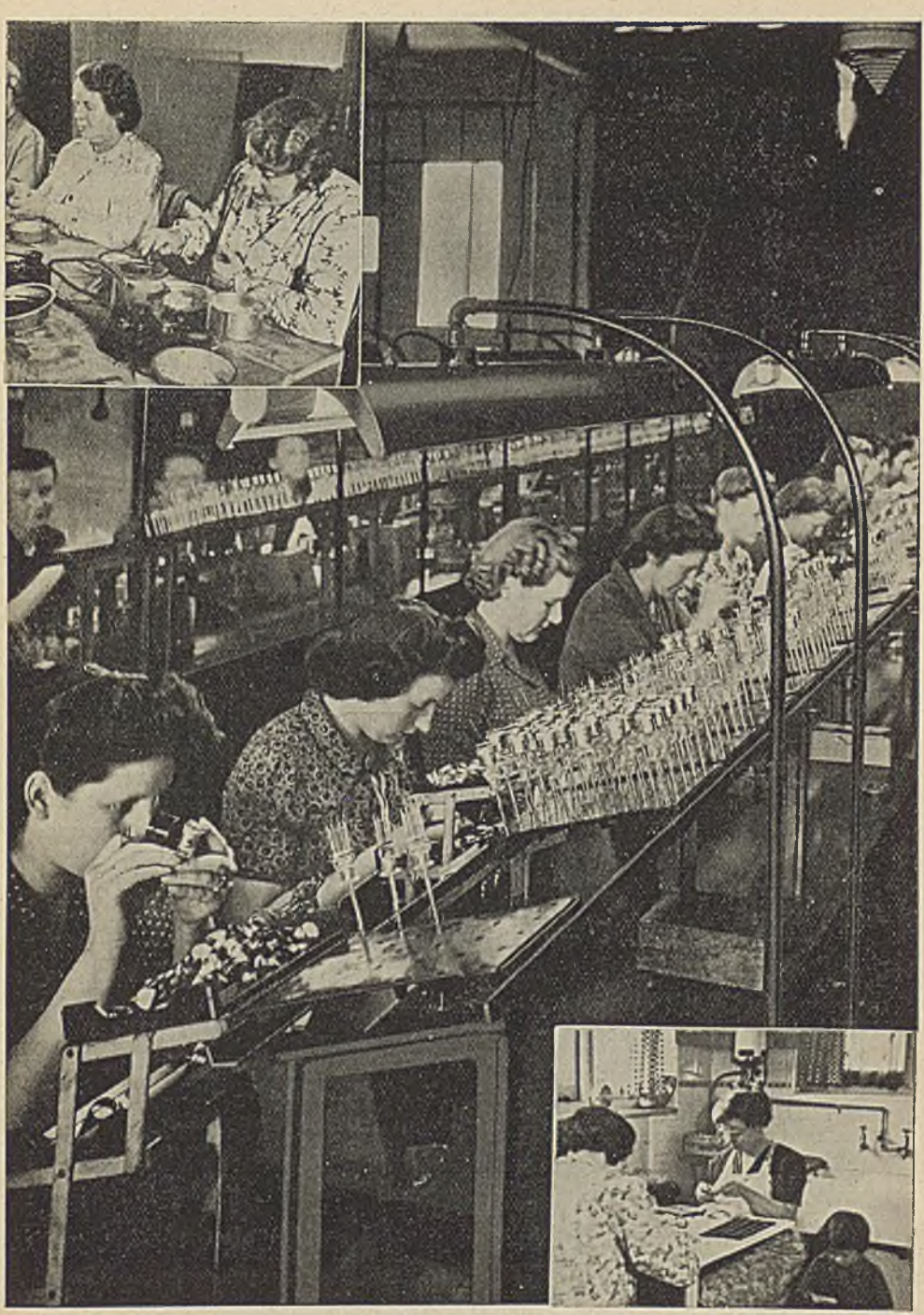
Everyone knows that a lot of valves were needed for the multitude of radio sets manufactured for the war; but, even so, the figure of 120,000,000 is staggering. This machine only made the valve pins. It is a press with a 10-stage progression tool, which fashioned the pins from sheet brass. The estimated output of just one of these machines during the war years is 125,000,000—or, if placed end-to-end, a line of valve pins that would reach from London to Moscow. But several such presses were in constant action, year after year.



There was a time when "wiring" meant running a wire from one point to another. But times have changed. Complicated networks of coded wiring are made up into special cable forms and "installed". This girl is at work on a cable form for a pilot's panel.

facturing techniques had to be evolved. And even then months of specialized research work were often needed before a radio set was considered satisfactory and reliable enough for mass-production; and even then, no matter how thorough the preliminary tests and trials, faults would often show up after the sets had been released for active service—faults that no amount of foresight could have predicted—and the whole cycle of research, modification, test and release would have to be repeated: and this inevitably threw whole production lines out of order until smooth running was once more achieved. And these set-backs were not only experienced by the actual manufacturers of sets: every component manufacturing firm had to contend with them, too.

A typical example of these heart-breaking hold-ups occurred early in 1944, when a special type of radio apparatus was decided upon by the Ministry of Aircraft Production for use in aircraft. This apparatus was so secret that the manufacture of its several units was spread out over the industry, even quite senior members of the various firms being unaware of the purpose for which their products would be used. Working in the dark in this manner must necessarily have its disadvantages, and the whole system of factory inspection and Government inspection has to be more rigid as a result, in order to reduce the margin of error to a minimum. Super-critical inspection has its own brand of effect upon nerves and tempers.



Two methods of manufacture which contributed to radio's war triumph. The main picture shows a production line in a valve factory. The insets show "outworkers" making up components in their homes.

The safest place for a factory during the war was underground. Thousands of pounds worth of vital radio equipment was produced on these sheltered factory benches.

Everyone, from engineer to girl operator, resents the ruthless rejection of work that looks perfect: but inspectors, particularly Government inspectors, work to a book of rules and instructions. And so, in this case, set after set was rejected, sent back along the line for alteration, and often rejected again.

Often when two or more of the finished units from different factories were tested together, fresh faults were discovered; and back went the sets once more, production being completely disorganized as the stoppages occurred. But it was very necessary. The lives of a whole aircraft's crew would depend upon that apparatus being beyond reproach. Paper memoranda flew from office to office, tempers frayed, telephone wires hummed, Ministry Officials dashed about from factory to factory; for, no matter what difficulties arose, that apparatus was still wanted by a definite date.

And at last the job ran smoothly. The finished sets began to pile up in gratifying numbers for despatch, and the first complete sets of apparatus from the many production lines were installed in aircraft. They went into action. And then, suddenly, a pilot returned, cursing and swearing to his aerodrome, smoke trailing out from the charred and blistered "innards" of his radio gear. Something, somewhere, in the complicated apparatus had failed to stand up to the job at high altitude, A day or two later the same thing happened to another pilot.

Back in the factories the air was blue. Hundreds upon hundreds of sets—sets that had been completed and approved—were ruthlessly rejected once more, to be slung down the production lines for alteration. How many times did that happen? More times than any factory manager would like to

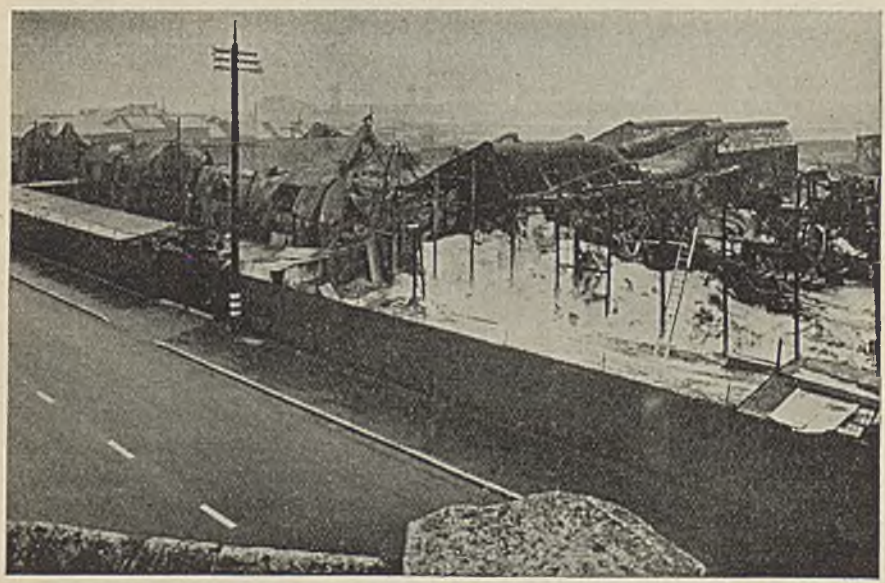
remember. For nearly a thousand different types of radio apparatus have gone into production for the armed forces since war broke out—and very, very few have emerged without at least one "spot of bother."

* * * * *

This chapter began with some notes on the ramifications of the radio industry, and has led up to some of the worries of designers and workers whose job it is to use the products of the industry to make the sets. That may seem to be a big jump, but there is a very close connection between the two ends of the story. It lies in the words, "requirements and design." An explanation of those words will probably give the best possible picture of the magnitude of the job that the radio industry of this country has had to do during the past six years. Take one example.

The Army needs a new type of wireless set. From experience gained in the field, it has been decided that a lightweight radio-telephone set is urgently needed for soldiers to wear, like a haversack. The Ministry of Supply, in charge of the Army's equipment needs, summarizes the requirements of the proposed set.

(1) It must not weigh more than ten lbs.
(2) It must not measure more than a few inches each way.
(3) It must have a range of at least three miles.
(4) It must work off dry batteries.
(5) It must be extremely simple to operate. Its user will not be a wireless operator.
(6) It must withstand a severe knocking about.



As a contrast to the safety of the underground work bench, this picture shows what happened to a vital radio factory during the blitz—just when we needed its output most urgently.

(7) It must be waterproof, for the user may step off a landing craft into six feet of water.

To be sure of getting the best from this tall order, the Ministry of Supply probably invites some three or four manufacturers to produce a pair of sets each—and within a matter of weeks, for the job is urgent.

* * * * *

The first person to get a headache is the designer, who is handed the *requirements* and told to get moving. He starts off by drawing a rough electrical circuit on a piece of paper, his idea being to use as few components as possible, in order to keep down the weight and the size. But he must not be too clever, or else he will cause headaches for other people at a later stage. (He often does, and has to change his ideas.) He decides that a certain type of valve will do the trick, and then learns that he will have to choose another, because a contract he knew nothing about is going to take all the valves of that type that can be made.

But in the end, he produces just what the doctor ordered, the mechanical engineers put his ideas into finished shape, and the two experimental sets are tried out—and work beautifully at the eleventh hour, having been pulled to pieces about half-a-dozen times. They are delivered to the Ministry of Supply to be put through their paces.

Even assuming that the set is accepted, the model which finally goes into production very rarely looks much like the sample that the designer thought "looked so good." That knob will have to be moved: it is in an awkward place. That switch will have to be fitted with a waterproof gland. A special plug and socket must be fitted here. That wire moves about under the vibration test. And so on. But the set goes into production, which means that:

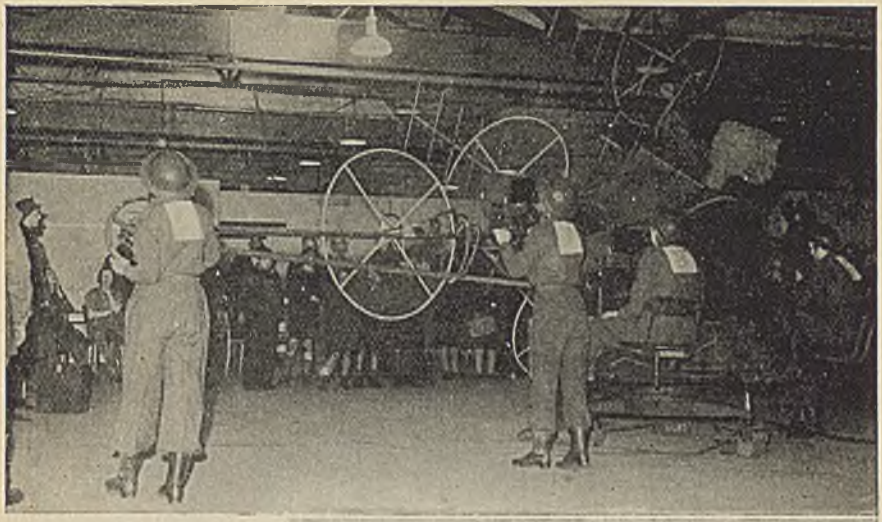
(1) The valve makers have to deliver 10,000 valves of a certain type within three months.

(2) The switch manufacturer has to design and make a new type of switch. (A headache for him.)

(3) The battery makers have to make something that they have not tackled before, and to deliver it in a waterproof packing, in tens of thousands.

(4) The factories which are to make the sets (and there may be half a dozen of them), have to shuffle all their other programmes around, to train all their workers to do an entirely new set of assembly jobs, to chase and worry a dozen and more component makers for supplies on a given date, and to forewarn numerous factory inspectors about the snags they must look for.

And then the *real* fun begins. Just as the first sets start to roll off the production lines, a bomb knocks out one of the component makers' factories. This means, at the best, a re-shuffle of all deliveries to other manufacturers (Ministry of Supply's turn for a headache) of an alternative component;



It was often the case that factory workers did not know what they were making. Such was security. But no chance was missed when it was possible to show them, by films, exhibitions and actual demonstrations, how vital their work was proving to the national effort. Top picture *shows a searchlight crew demonstrating radar control in a factory canteen.* Centre, *a factory lass listens to a colleague's voice through army headphones.* Below, *soldiers demonstrate a transmitter-receiver to the girls who helped to make it.*

at the worst, it may mean re-designing a part of the set, while the arrears pile up. And, then, in spite of all the searching, preliminary tests, the Army reports that water is leaking into the sets through such-and-such a hole. And so on, and so on.

Yet the sets are delivered—in spite of the fact that they have to be modified for use in the desert, and modified again for use in Army trucks, and modified again for use in the tropics.

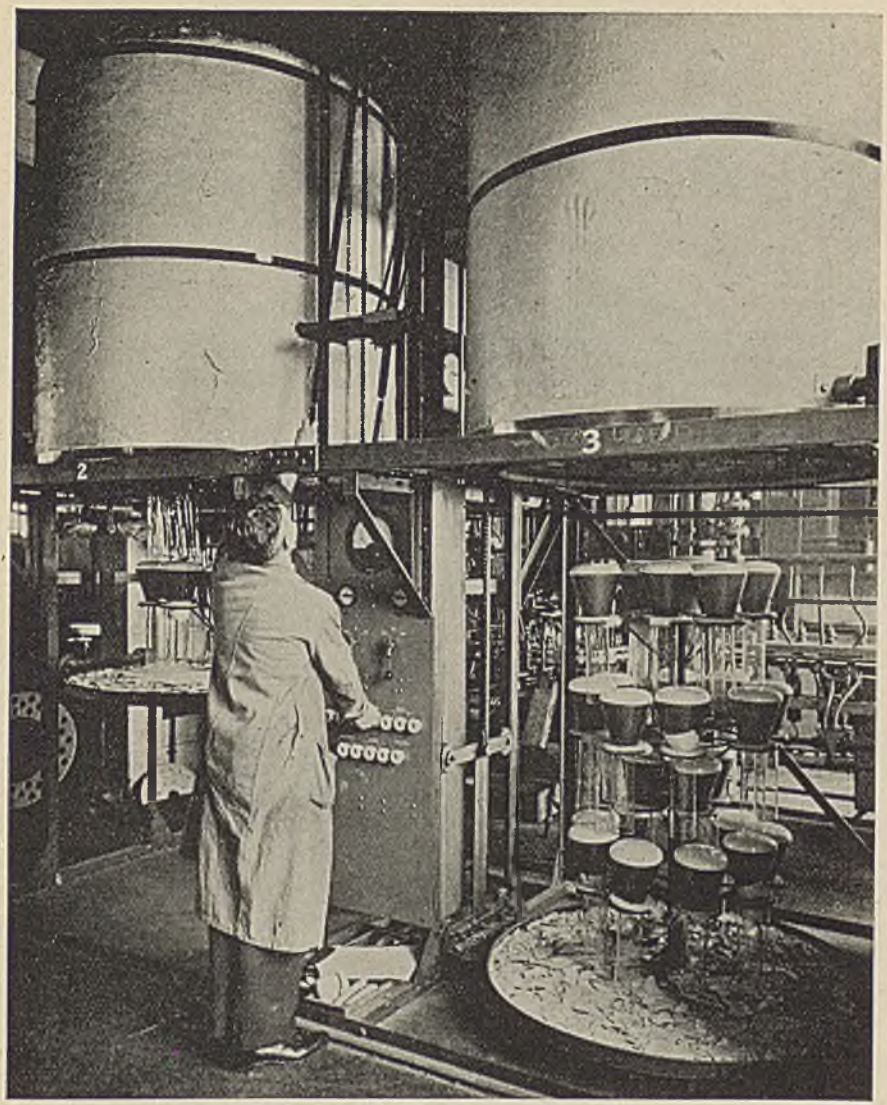
That was one example of co-operative effort by the radio industry to serve the Army. And the Army called for, and received, no fewer than 272 different types of wireless sets and equipment—transmitters and receivers, midgets and giants—delivered in quantities, and with all the spare parts necessary for R.E.M.E. to keep them in tiptop order. And many sets were designed and discarded for every design that finally went into production.

These 272 different *types* of apparatus have represented orders on the radio industry for nearly three million complete equipments. **This one colossal order is equivalent in work and value to some 7,000,000 domestic receivers.**

Then there were the requirements of the Navy which involved a further 200 different types of sets. And the R.A.F. ordered some 500 different types of sets, which totalled about another 3,500,000 for the industry to make.

In all, a grand total of approximately 7,500,000 wireless sets were made and delivered in six years, *plus* special equipment for the B.B.C., *plus* special sets for the police, *plus* a modest 150,000 sets for the civilian listeners, who had to have a look in, somehow.

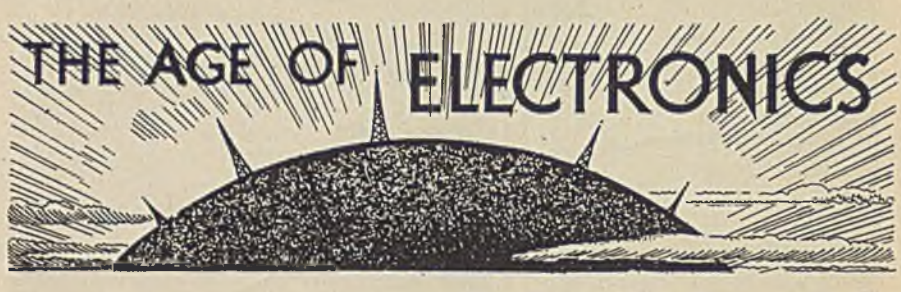
Cathode-ray tube—heart of the radar set. Scores of thousands were made in Britain for equipment of every type. This girl worker is applying a special coating to the inside of a tube.



Another stage in the manufacture of cathode-ray tubes—baking. These ovens have finished their war job, and are already turning out the tubes that will be needed shortly for domestic television receivers.

Think in terms of all the parts required for that grand total, and you have the frightening figure of 750,000,000 components supplied by the various manufacturers involved, *not counting spare parts*, from valves to plugs and sockets.

That, in a nutshell, represents the radio industry's contribution to the war, which would have been lost without it.



As this book goes to press, six years have passed since the events which led up to its opening chapter. When the guns began to rumble over the Polish frontier in 1939, the British Radio Industry was prepared for a new age of wireless entertainment. By to-day, had there been no war, television would probably have been brought into the homes of millions, scarcely a car would have been without its radio. Midget receivers, no larger than a cigar box, would be in the rucksacks of hikers and picnickers. Radiograms in beautiful cabinets would have been developed to a new pitch of perfection. The portable television set might well have been an accomplished fact. But instead of benefiting from the marvels that were planned for him, the civilian listener was soon to consider himself lucky if he could buy a battery for his old portable, or a new valve for his mains receiver. His car radio was "agin the Law", and his television set stood like a white elephant in the corner of the room.

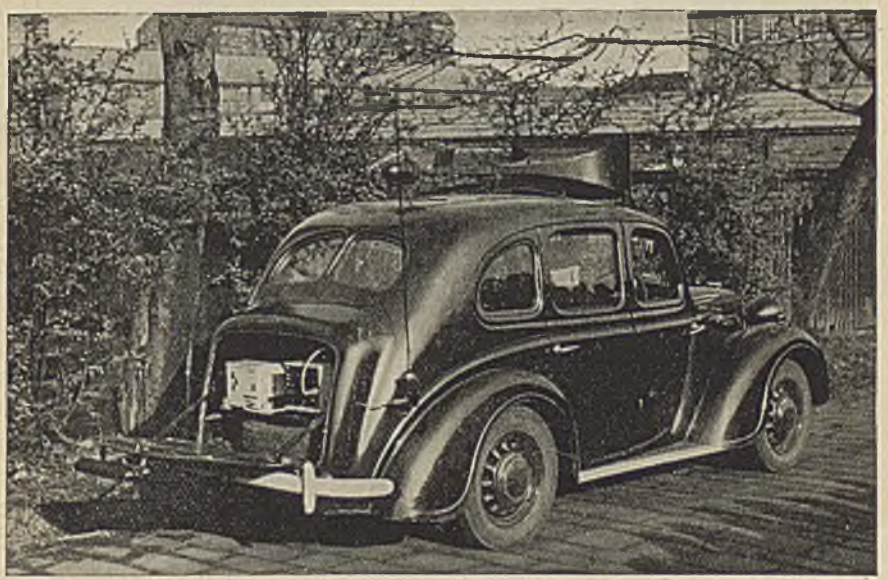
He knows now what superhuman efforts were made by the B.B.C. to provide him with the entertainment and the news which came from his loudspeaker, and he can appreciate the service he obtained from the over-worked, under-staffed radio dealer who, somehow, repaired his set for him when it went wrong, despite the shortage of almost every component. Further, he understands why so few new receivers could be built for him during the six weary years, and why the strictest form of austerity stamped whatever was available. It is to his everlasting credit that he very rarely complained. But to-day, with Peace returned to the world once more, he is beginning to ask: "what now?" And he is well entitled to raise that question; for after reading of the thousand-and-one radio marvels created for war, he must guess that the future holds plenty of good things for more peaceful use.

There is no need to sigh for the things that might have been, for a new radio age has dawned with the final cessation of hostilities. True, the industry cannot begin to produce new, peace-time rabbits from the hat overnight—any more than it was able to deliver the war-time goods in the first twenty-four hours. In 1939 the factories had to pack away their

normal plans and tools: to-day they have to take them out and dust them. *But it is a significant fact that the first new wireless sets for the home and export markets were rolling out of the factories within a few days of the Japanese surrender.*

It is giving away no secrets, now, to say that every manufacturer is already well ahead with his plans for the 1946 models. By the time these are ready for the market, nearly a quarter of a million British homes will already have been supplied with the radios they have needed so desperately for the past six years, and tens of thousands more sets will have been transported overseas to help the re-establishment of Britain's export trade, upon which the future prosperity of the Empire so largely depends.

The overseas listener has a legitimate call upon a part of the initial output of our radio factories. Like us, he has given much, and has had to do without a great deal more. And now, with the return of better times, we are glad to be able to share with him a few of the things that we have all missed for so long. Before many months have passed, television will be on the air again. In a comparatively short time it will spread to the Dominions overseas. Then, it is the earnest hope of the industry here at home, that some of the thousands of our more distant friends will really begin to appreciate and enjoy the full benefits of the finest technique and craftsmanship that the "back-room boys" of British radio have learned and brought to fruition in the years that were spent behind the black-out shutters.



Many motorists carried radio receivers in their cars pre-war and, during the war, radio transmitters and receivers were installed in hundreds of vehicles used for defence purposes. The N.F.S. and Police Forces throughout the country were supplied with large quantities of apparatus similar to that in the above picture. In the new age of electronics which stretches ahead, radio-telephones will be possible in ships, trains, planes and cars—and even, perhaps, in the overcoat pocket or brief case.

The Age of Electronics

This new age is the age of "Electronics" rather than of radio. Or, in more homely terms, it is the age of the radio valve and the cathode-ray tube. Just as "pure radio" was by no means the whole story of war-time wireless development, so do broadcasting and television represent but a section of the peace-time catalogue of radio events to come. The radio-

Another fascinating electronic device is the R.F. (Radio Frequency) heat generator. This device is a form of radio transmitter, the output of which is used for generating heat instead of for radiating wireless signals. During the war it was used for many manufacturing processes—for making steel bolts white hot in a few seconds—for welding together pieces of plastic fabric—for the rapid setting of glue in the aircraft industry. Here, for the amusement of the laboratory staff who made it, heat is being utilised to cook sausages—which it does in a matter of seconds, leaving the porcelain dish quite cold.

location apparatus of 1939-45, which was used for the destruction of an enemy, is even now being re-designed for safety and navigational devices for use at sea, on land and in the air.

Radiolocation enabled British warships to find and pinpoint the Italian Fleet off Matapan in total darkness. Radiolocation will make it possible for every sea-going vessel to see through darkness and fog. The same ingenious radio apparatus that showed the bomb-aimer his target at night will show the air-liner's navigator the nature of the ground below him. The probing beams of radiolocation which helped the night-fighter to approach his quarry will now be used to help the commercial aeroplane pilot avoid collision.

The imaginative mind will foresee many other uses to which the art of

radiolocation can be applied for everyday, peace-time use. For instance, is it such a far step from the invisible radio beam which kept watch for the Army upon the cross-roads used by the enemy at night, to the use of radio beams to *count* the cars approaching every cross-road in the British Isles—to record their approach and to estimate a more positive system of traffic lights for safety and time-saving?—or at least to flash a warning sign, "car ahead?"

Maybe it will sound a far-fetched idea to-day, but the time is surely approaching when everyone will be able to carry about with him a small radio telephone. War-time development of apparatus to work on very short wave-lengths has opened up many new entrancing possibilities. Hundreds of thousands of "radio-telephone channels" can be used over short distances without interference; and the installation of a network of automatic telephone exchanges might well be utilized for handling the calls from a multitude of pedestrian or automobile telephone subscribers, to sort them out and to pass them by line—or radio link—to main exchanges. Certainly it is but a matter of time before the railway traveller is able to pick up the 'phone and dial his office or his home.

These ideas are, at the moment, abstract; yet they indicate just a few lines of thought along which the march of the Electronic Age may pass. In the meantime, there are a host of new developments that are already with us. Within a few months, at the most, plastic fabrics in soft, durable colours will be on the market—in the form of tobacco pouches, rainproofs, children's rompers, beach wear, and so on—"sewn" without stitches by the magic of high frequency radio current.

Electronics for Industry and Health

This same method of "radio welding" was used during the war to "sew up" batteries in airtight waterproof bags, so that they would last almost indefinitely in store, and so that they could withstand the destructive climate of the tropics. And this same technique, which is really a method of creating and localizing a rapid, intense heat, is in use to-day in the manufacture of plywood and plastics. Glues can be hardened and set by it within seconds instead of hours. Metal parts can be raised to a white heat by it in seconds. Sausages and chops can be cooked in half a minute by the pressing of a switch.

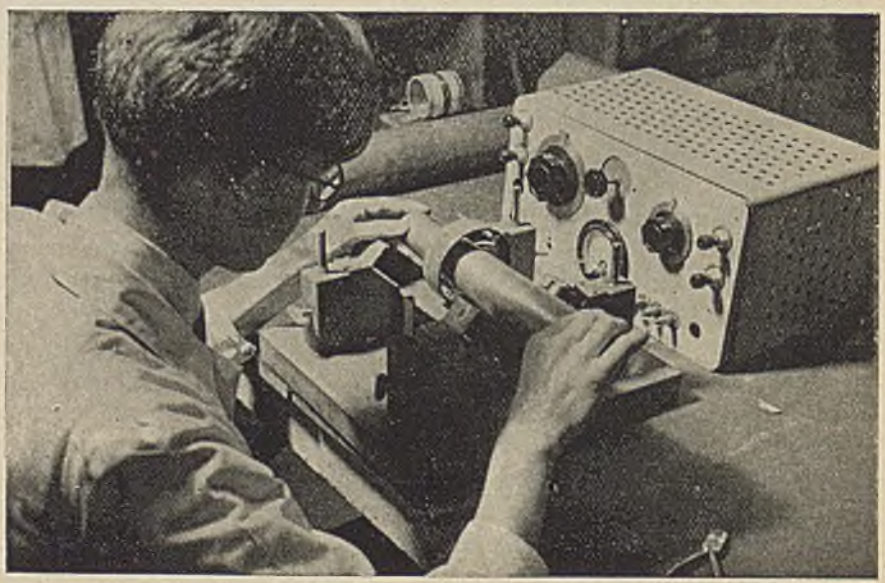
To turn down another road, along which the "Electronics" research workers are progressing, the radio valve and the cathode-ray tube are already harnessed for mediçal and scientific discovery. They are employed for detecting flaws in forgings and castings—to make the machinery of peace more reliable, safer, and less costly.

To return once more to the radio receiver by the fireside, a plan has been produced by the Radio Industry Council for improving the quality of reception for every listener. This plan involves the re-shuffling of all

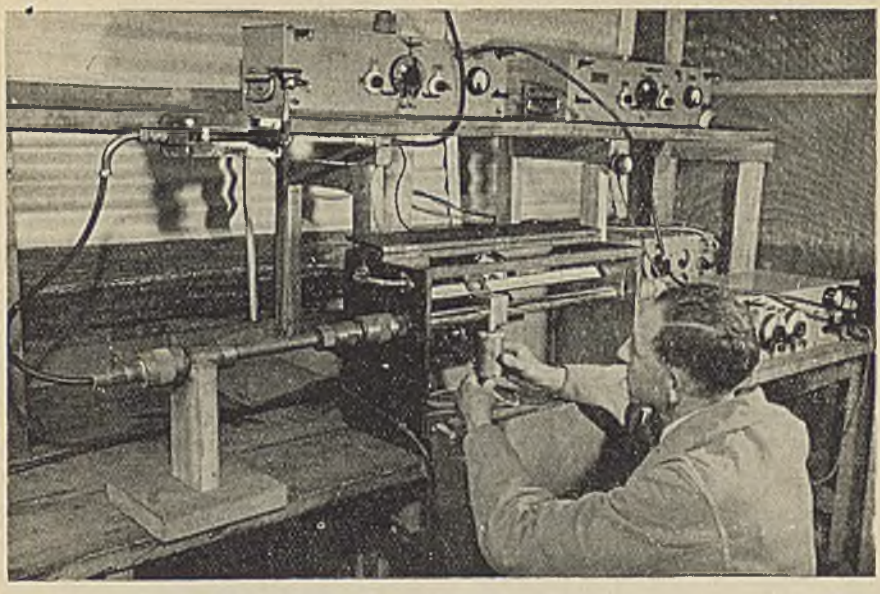
European wave-lengths, and their separation from one another by a wider margin of "silent" ether. Many listeners will recall the difficulties they experienced in the pre-war days, when trying to tune-in one station with another crowding in on top of it. This irritation was caused by an insufficient "spacing" between the wavelengths in use by the various broadcast transmitters. In order to transmit faithfully all the necessary overtones which make rich music, there is a minimum separation which must be observed. An attempt to crowd in too many stations on the medium wave-band means one of two things; either the stations will be so close together that fringes of one programme overlap the fringes of another; or the quality of the transmitted music has to be cut, in order to avoid the overlapping. In many cases, *both* evils were experienced.

Although the Radio Industry plan is not expected to be feasible in its entirety, it is hoped that further work by all the bodies concerned may lead to much improvement in broadcast reception.

In other ways, too—many of them unnoticeable—the radio listener will benefit in the immediate future. The rigorous demands of the Forces in war have resulted in research which has led to far more reliable components of every kind. These components, now available in large quantities for the set manufacturers, will inevitably mean fewer breakdowns, with their attendant repair bills. And, when repairs *are* necessary, the experience gained during the past six years will mean that the radio mechanics have a far easier job on hand—again with a valuable benefit to the listener.



Radio detects cracks and flaws in metal. This piece of apparatus was designed for war work, for the automatic location of cracks in metal assemblies, and for testing shell cases. It will have many uses in the forthcoming industrial age.



Testing high-frequency cable. Another use for radio in the electronic age.

1,000-Line Television

Pre-war, the B.B.C. broadcast a daily programme from one transmitter at Alexandra Palace, using what was known as a 405-line system, and a transmission speed of twenty-five pictures per second. This number of pictures per second is slightly more than the projection speed of the modern cinema film, and obviates flicker. The number of lines per picture determines the definition, or the amount of detail that will reach the receiving set. When the B.B.C. broadcast its first television programmes in September, 1929, the pictures were only split up into 30 lines, and though this was a very remarkable achievement—the first regular television service in history—the detail was naturally poor.

When the Alexandra Palace (London) station was opened in 1936, providing the world's first high-definition television service, the transmitted pictures were split up into 405 lines—a tremendous advance, giving nearly fourteen times the amount of detail of the old system. Indeed, according to the opinion of at least one optical expert, the detail capable of being reproduced at the receiver was virtually equal to that actually experienced in the cinema. The pre-war 405-line transmissions were so good that few of the thousands of "viewers" ever stopped to consider that this new form of entertainment was only two-and-a-half years old when the service was closed down on September 1st, 1939—and that both B.B.C. and set manufacturers were still hard at work, using practical experience to exploit the system to the full.

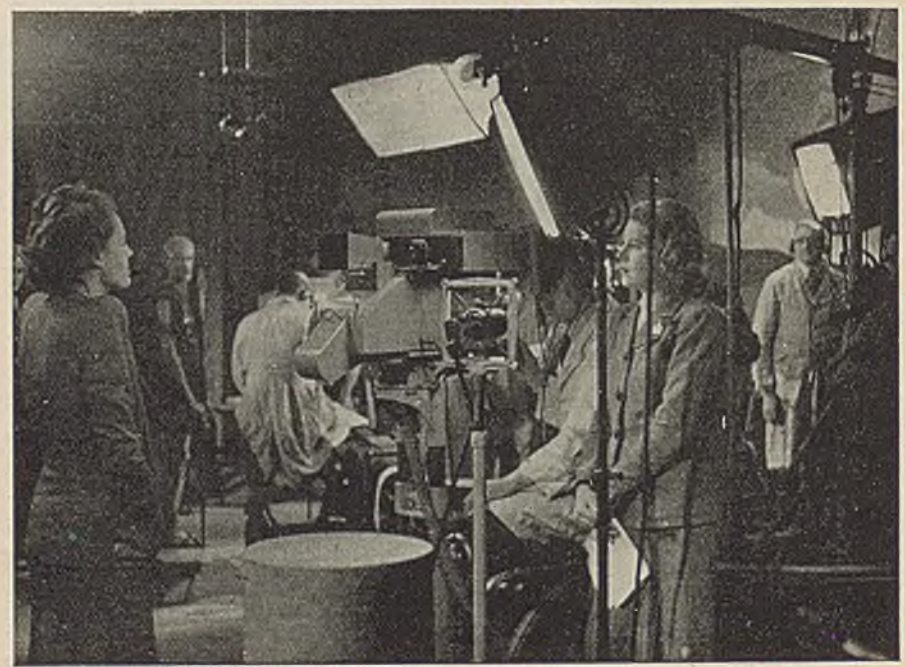
In the six years' gap in television broadcasts, manufacturers have learned

many new secrets while working on radar. During the next five or ten years, 405-line television will be a constantly improving art as more and more innovations are introduced at the transmitting end, and as even better results are obtained from receivers.

And then, even as the 405-line system is explored to its limits, practical work will have been started on a new and more ambitious system employing up to 1,000 lines per picture. This will be a truly amazing development when it comes, for it will provide more than twice the picture detail than the 405-line system at its best.

The New Television Plans

In addition to the introduction of a 1,000-line service, pictures in natural colour and pictures in stereoscopic relief are now in the first experimental stages. But it is most important that everyone contemplating the early purchase of a television receiver shall know exactly what he may expect to receive, and what changes in broadcasting plans are likely to affect the value of his purchase. Much experimental work has to be done before the proposed 1,000-line system can pass from the experimental stage to the reliable, everyday apparatus necessary for adoption by the B.B.C. Such work may occupy from five to ten years.



A pre-war scene, behind the scenes, during a television broadcast. Within five to ten years, scenes acted in television studios may be flashed by radio direct to Britain's cinemas.

In other words, 405-line television still has a long life ahead of it. And this is a good thing, for it means that a proved, reliable system can be put into immediate operation, and spread to the provincial centres, while the infant 1,000-line system is being nursed and nourished and undergoing its teething troubles. But for this fact it might have been considered advisable to hold up all television plans until the new system was perfected, for it would obviously not be fair to expect people to invest money in receivers before reliable transmission could be guaranteed.

Now that the various recommendations of the Television Committee are being adopted, the 405-line system will be developed as the standard form of transmission; and the 1,000-line system will be started up at a later date for those people who want to use it. *There will thus be two transmissions of the same programme, safeguarding the interests of those people who possess 405-line receivers, and making it possible for the 1,000-line system to win its place in the order of things, according to its success.*

Television in the Cinema

This leads up to the most exciting of all television plans. When the 1,000-line system is developed, the picture detail will be so good that it will be useful for direct projection on to the screens of cinemas. Indeed, it is reasonable to expect that television in cinemas will be a fact within a very few years.

The 30-line system would, of course, have been too crude for such a development. One has but to imagine oneself in a front-row seat, looking at a picture made up of only thirty horizontal lines, to understand how unsatisfactory it would have been! With the 405-line system, the picture on the screen was very passable from the centre seats, and was quite good from the back of the hall. With the 1,000-line transmissions of the future, the picture detail, even from the front seats, will be excellent. We live in a marvellous age and radio is one of its greatest marvels.

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★ that a single aircraft of Bomber Command may carry as many as eleven different *radio* sets, weighing half-a-ton and worth about £10,000 ?

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★ that automatic *radio* transmitters saved the lives of countless sailors ?

★ that nearly a quarter of a million of our soldiers carried portable *radio* telephones ?

★ that hundreds of allied "agents" used secret miniature *radio* sets in occupied territory ?

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