coating repels insects which, in the tropics, will eat virtually anything.

There is little but nylon, including human flesh, which fungus spores do not attack, though all pure cellulose acetates, of which nylon is one, resist fungi. Believe it or not, the spores ruin range-finders, gun telescopes, camera lenses and all other optical glass by etching the lens. The deadly enemy of wiring insulation is an Aspergillus species, a cousin of bread mold and so of the magic Penicillin, the spores of which in the tropics germinate in ordinary insulation much as onions do in a well-kept vegetable garden. This mold has the nasty habit of building up immunity to any given fungicide quickly; what kills it one season may be harmless the next.

Though Chrysler made the paraboloid reflector dish out of ordinary steel, it weighed no more than did the aluminum dish of the earliest Radiation Laboratory experimental model. The 6,640 half-inch holes in the dish saved 70 pounds—though weight was a secondary factor. The specifications required that the mount function smoothly in a 60-mile wind, not be overturned by a 100-mile hurricane. No 6-foot expanse of solid metal could oscillate long against such winds without something giving. Chrysler Engineering advanced perforation as the probable answer. The Radiation Laboratory agreed if the holes should be no larger than half an inch, beyond which they might allow some of the radio energy to leak through. Perforation was tested in Langley Field wind tunnels and proven; the holes reduced the air resistance sufficiently.

You take your radio antenna for granted—a few yards of almost any kind of wire will do. An anti-aircraft microwave radar antenna must concentrate its high energy in a narrow beam aimed more accurately than any gun; all the power must follow this beam, none leaking to one side or the other and, unlike any radio, the same antenna sends and receives. The RF lines, as the Army calls the concentric copper radio frequency transmission lines which pass through the whirling spinner motor transmitting and receiving the microwave impulses, had to be centered with extreme precision.

Elevation unit assembly line. The elevation gears swing the searching "dish" up and down the sky.

The front bearing on the spinner motor of one pilot model burnt out while it was under test at Camp Davis. Being outside the calculated microwave path, this motor is lubricated in contrast to the airseal previously described. Other front bearing failures followed. When the motors were torn down the bearings were found to be annealed by heat and the lubricating greases charred.

At first, this was supposed to be a mechanical failure. Dodge men could not believe this. The rear bearings never burned though the mechanical conditions were identical, nor did this failure occur in the front bearings in the roof tests at Dodge where motors were run for thousands of hours. A dozen different explanations were advanced, some blaming vibration.

Others, remembering the eccentricities of high frequency electricity when Chrysler had used a 13-megacycle current to bond brake lining to brake shoes, eliminating rivets, deduced that high frequency radiation leakage was cooking the bearings. This reasoning was supported by the fact that radio frequency current was not used in the roof tests where no bearing had burned, and by the odor of the charred lubricant, electric scorching having a smell all its own. This proved to be the answer. When Engineering phoned its findings to the Radiation Laboratory, the physicists there quickly designed a radio choke or trap which acted as a barrier to radiation leakage at this point, and there were no more bearing failures.

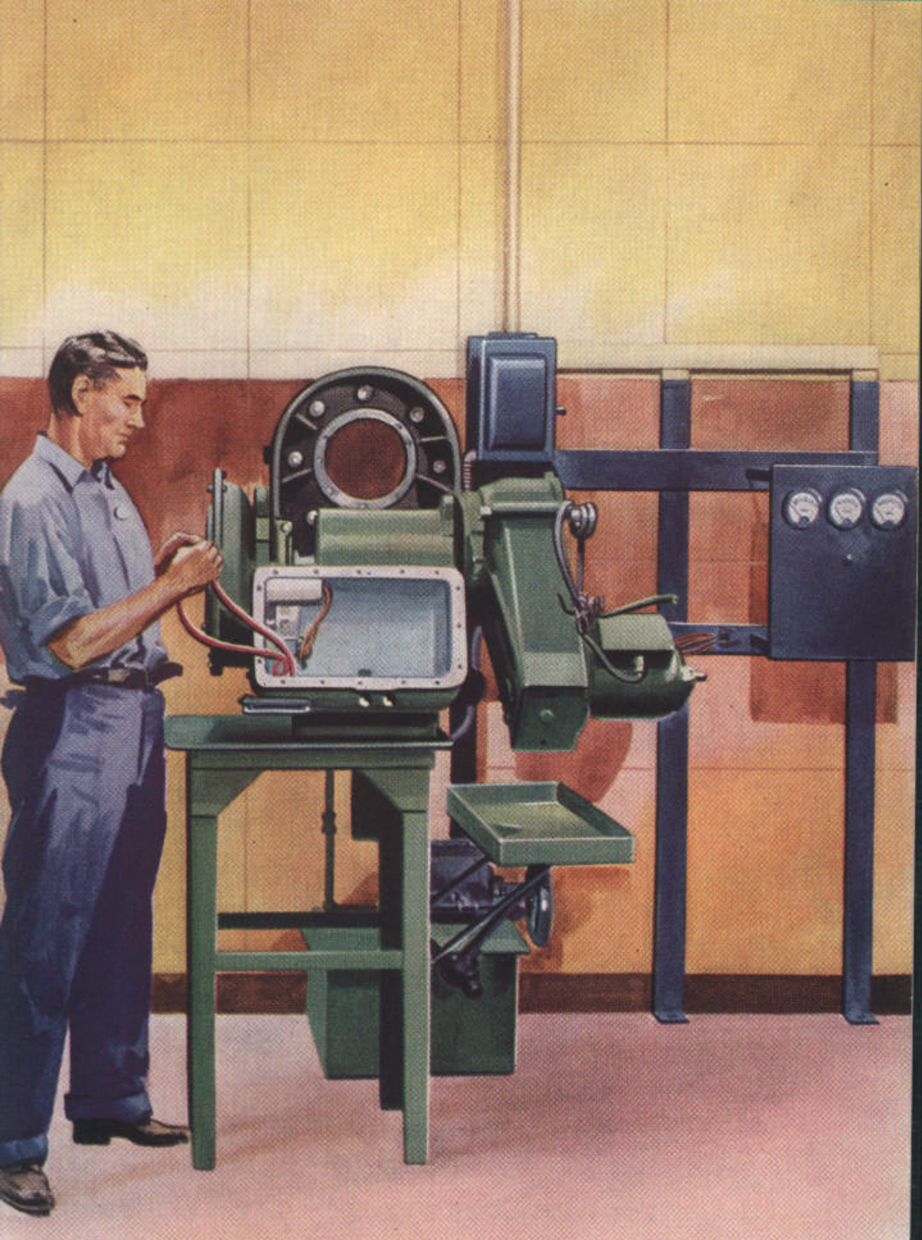
Pedestal support assembly line. The accuracy of the radar-directed guns begins with these heavy steel castings.

Master mechanics can not decide how best to make any part until they know just what that part is to be; they can not know what kinds and numbers of machine tools, fixtures and dies they need until they have settled upon how the parts are to be made. As fast as parts prints came from Engineering, tools were ordered, but design changes were frequent, as was inevitable with what really was a research problem, and changes of design usually changed the tooling.

The production sub-contract with General Electric was concluded September 22, 1942. It called for 2,750 units, the first ten production jobs to be delivered to Baltimore and Syracuse in April, 1943, rising to 50 mounts in May and levelling off at 400 a month in November. At this rate, the contract would have been completed by February of 1944, but further orders were to be expected.

Due to the changing course of the war, however, Dodge's schedule for the year was cut in February, 1943, from 2,500 units to 1,410, with a peak output of 200 monthly set for October and by the time October came the Signal Corps fixed its total requirements at only 1,470 units. To this were subsequently added 147 spare sets, 220 more unassigned SCR-584 units, 240 SP-1M units and 14 experimental A-70's. The latter was a modification of the SCR-584, intended for use with all coast defense guns for the detection of hostile warships, for which Chrysler Engineering had been given a development contract in 1943. The SP-1M was the Marine Corps' version of Navy radar SP.

Inspectors testing for backlash. Absolutely perfect gears would not function, but the error here must be extremely small.



Each elevating mechanism was given a three-hour test in especially equipped testing rooms.

In all, 2,098 SCR-584 radar units were made at a cost to the Government of about $20,000,000.

The first of the six tool room-made models of the antenna mount was delivered by Dodge to the Chrysler Engineering laboratories for life test December 4, 1942, the second shipped to General Electric the day after Christmas. Experimental models of an instrument of the newness and delicacy of microwave radar would, in normal times, be tested for a year, or even two, before fixing upon a production model, but this was war; production could not wait on methodical testing. Before the preliminary trials of the first two Dodge pilot models sent to the Anti-aircraft Board had been completed, Dodge had turned out 50 production mounts.

By the end of August, Dodge had shipped 610 units. About now, however, the General Staff came to a decision which soon resulted in a cancellation of the SCR-584 contract. This decision was that the air defense of continental United States no longer was necessary. The United Nations had won control of the air in all theaters and Axis planes were now too few and too preoccupied with defending their own to attempt even a token bombing of this country.

If the Axis ever had intended an attack in force on the East or West Coasts, or on the Great Lakes region by way of the polar air lanes, it had missed the boat. Radar watched more than the coasts; radar listening posts and anti-aircraft batteries were scattered

Women did most of the assembly of the slip rings and wiring of the main drive shaft.

through the Canadian bush into the Arctic Circle listening always for planes approaching on the Great Circle—planes that never came.

Therefore, on Columbus Day, 1943, the Signal Corps notified General Electric and its sub-contractors that it would no longer need large quantities of the SCR-584 and that the contract to make them would be terminated at the most economical point. This later was fixed at 1,470 sets, plus extras.

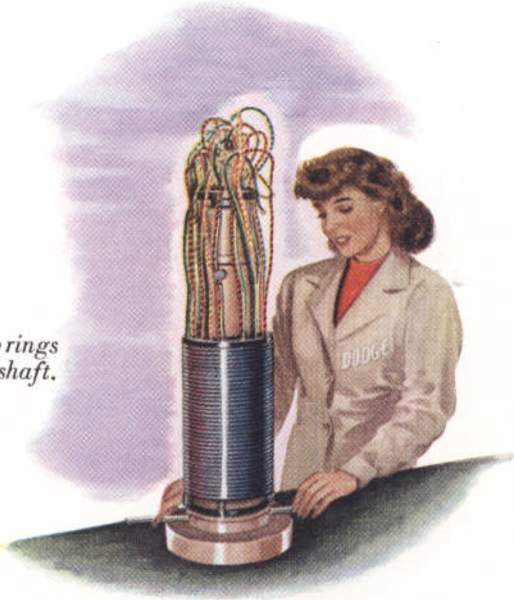
As a result of this changed schedule, Dodge delivered its 1,470th mount January 28, 1944, and between then and April 14th turned out the remainder in the form of spares, coast defense units and Marine Corps sets.

Laid out for a production of 24 mounts a day, the radar shop had been held by the mutations of war to a maximum of 10 daily. The working force began to scatter in January to other war contracts, the last gone by mid-April. Before May, machines and tools were being moved out, a pilot line into storage in a Defense Plant Corporation warehouse in Indiana, most of the rest to other Chrysler war projects. New machinery was coming in for B-29 Superbomber engine pump parts. By July, the sixth floor was making these, and radar was a memory.

At the outset, the Signal Corps had specified that radar being a very secret project, all prints and information must be guarded with extreme caution. It directed that prints must be signed for by one designated person who would be responsible for them and to whom they must be returned before the end of a shift. Later, the Corps ruled that only such prints as related to certain details of the antenna mount must be treated as secret. When Chrysler Engineering designed the semi-trailer, the prints, for secrecy's sake, showed what appeared to be a searchlight reflector protruding from the roof where the paraboloid would function.

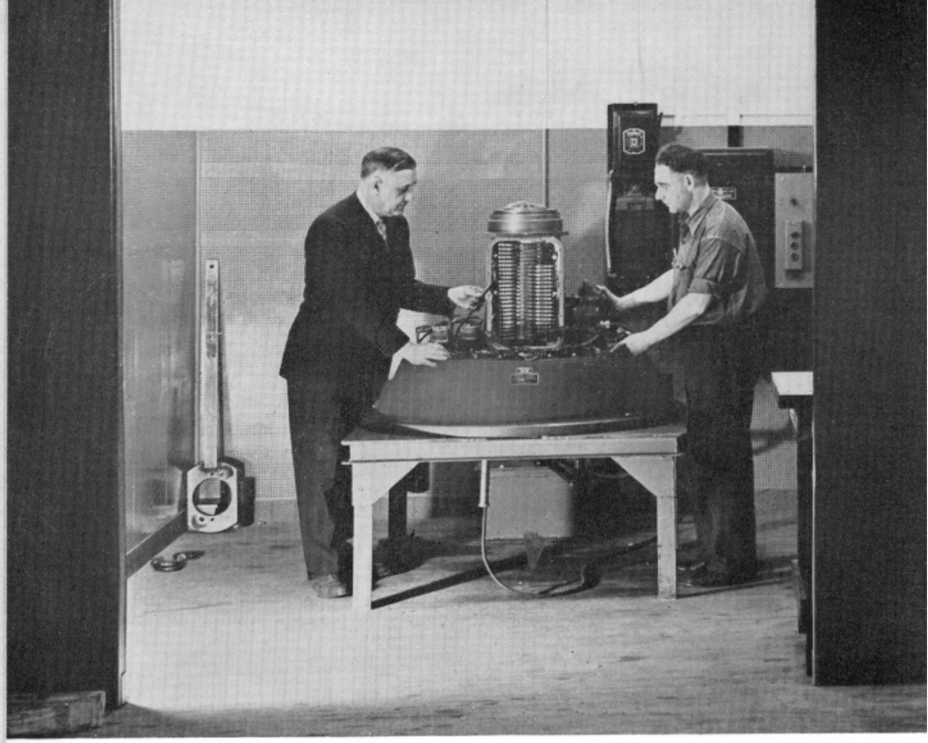
Few of the thousands who worked at Dodge ever passed the doors of the radar shop. Carl Norden's famous bomb sight, guarded as it was, was known by name to every newspaper reader, but the word "radar" was not spoken for a long time. The prudent

Girl assembling the 48 slip rings on the radar's main drive shaft.



did not ask what was going on in the old quarters of the Engineering section at Dodge; the imprudent were told that it was a "Signal Corps job."

It had taken seven trucks to house and carry the 268 radar, pre-war prototype of the SCR-584. So compact is the SCR-584 antenna mount as designed by Chrysler Engineering that it and its accompanying electronic apparatus are housed in a 19½-foot semi-trailer, small enough to clear the hatches of a Victory ship. Chrysler Engineering also designed the trailer, but the Dodge Truck plant, which normally would have made it, was too busy with military vehicle orders and this job was sub-let to Fruehauf, a specialist in this field.



Attaching the co-axial cable to the electrical heart of the SCR-584 radar before the first of many tests.

Moving along the highway to Syracuse or Baltimore it might have passed for a furniture van, except for its olive drab paint and the armed guard which accompanied each, but it had a rigidity and strength far beyond anything expected of a commercial truck.

The paraboloid reflector is raised through a trap door in the roof when put into use. Being a precision measuring device, the least flutter in the trailer body would be as fatal to accuracy in the dish as if a high-powered telescope were mounted on a wobbly base. As the mount also must be exactly level for accuracy, the trailer body may be canted into plumb from any position by a series of built-in jacks.

* * * * *

The discovery of radar appears to date, as nearly as any invention may be pinned down to an exact time, from a September afternoon in 1922 when two research engineers in the Naval Aircraft Laboratory at Anacostia, across the creek from Washington, first noted that radio signals were reflected from steel buildings and other large metal objects.

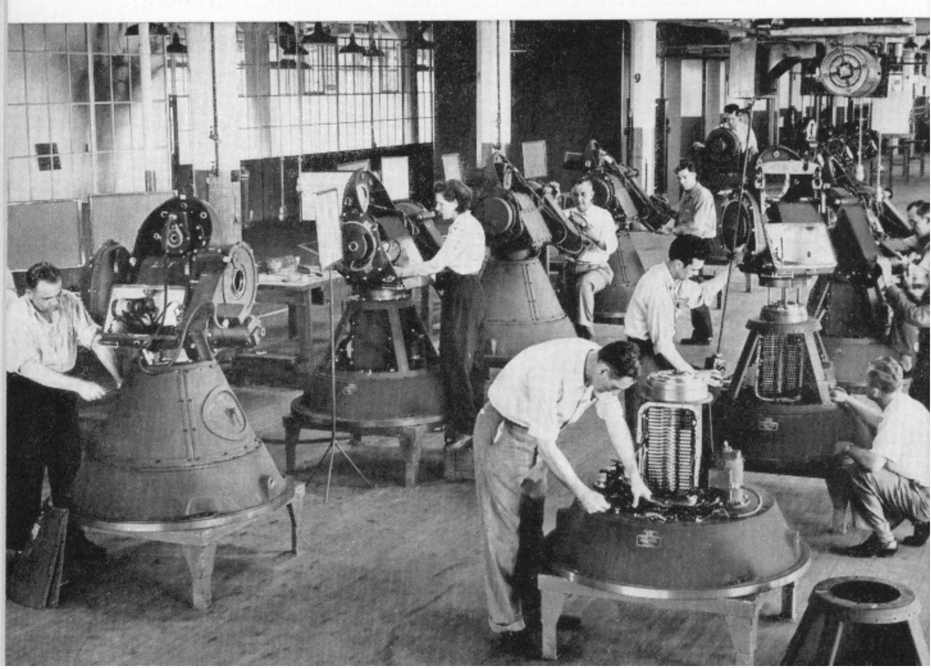
Looking closer into this phenomenon, they found that ships passing up and down the Potomac set up an interference pattern in radio sending and receiving. The two young men were Dr. A. Hoyt Taylor and Leo C. Young, the former now chief consultant and coordinator for electronics of the Naval Research Laboratory, the latter his first assistant.

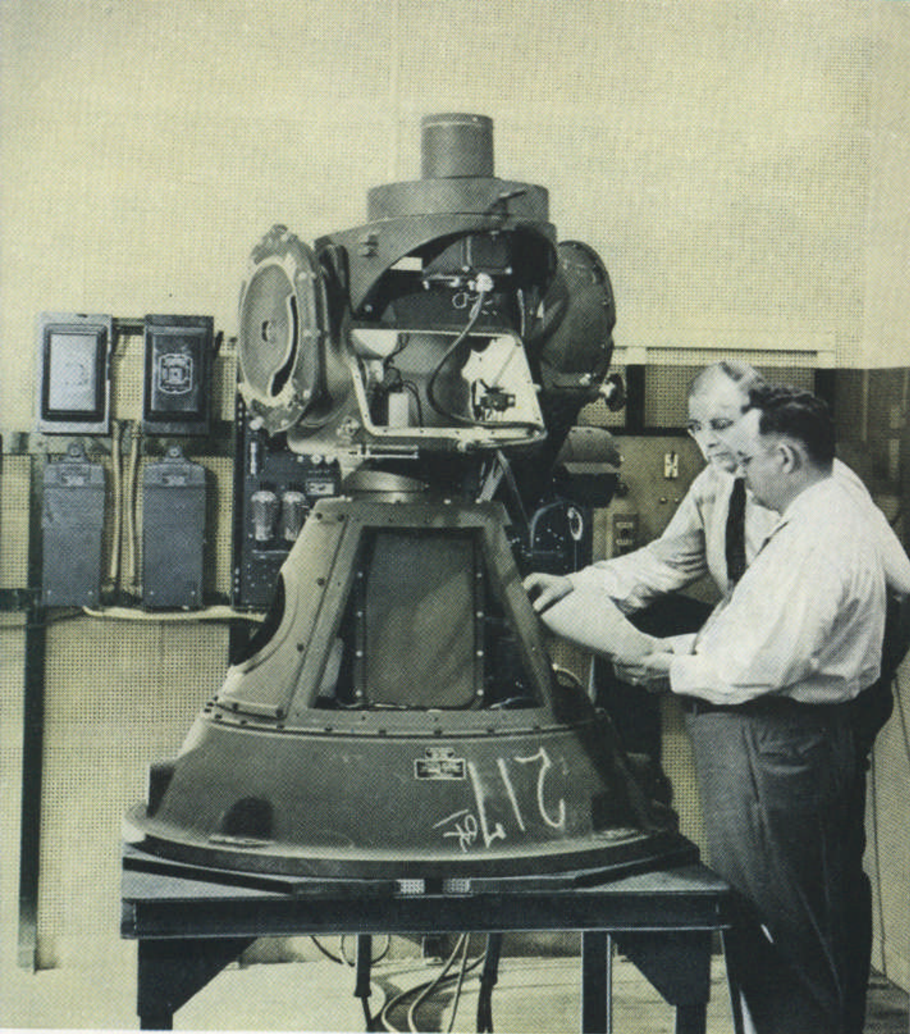
This gave them an idea: maybe this phenomenon could be harnessed in a way to detect the passage of an enemy vessel in darkness, fog or smoke screen between any two destroyers in extended line. They sent a report of their discovery and its possible uses to the Navy's Bureau of Engineering on September 27, 1922, and were encouraged to pursue this idea along with other research problems sent them.

Taylor and Hoyt had not discovered radio reflection; that had been noted as a curiosity as far back as 1887 by Henrich Hertz, the great German physicist and pioneer in electronics, but the subject had not been pursued. In World War I, both sides soon learned how to locate the other's radio stations by triangulation, a principle soon adopted to marine navigation, vessels at sea getting their position by triangulation of their radio signals from two shore stations, a simple geometric equation.

Not so long after this, radio amateurs of the crystal set period began to be aware that on waves as long as 20 meters, often at 10 meters, an airplane passing overhead would deflect their signals; and in the 30's the commercial air lines began to adopt this principle as an altimeter. By measuring the elapsed time between the sending of a beamed signal from a plane and its rebound from the earth, the plane's altitude, not above sea level, but above the immediate ground below, could be determined accurately in the worst of visibility.

The electrical insides of the radar main shaft are visible in this scene on the Dodge assembly line.





Final test booth for the azimuth gearing. Electrical Engineer Sachse and Electrical Inspector Danielson at work.

The British admit that they first discovered the practical military application of radio reflection from reports of our Naval Research Laboratory and of the Carnegie Institution published between 1926 and

1930. It is possible that the Axis discovered radar's war uses from the same source, though both the Germans and the Japanese long had been experimenting with radio reflection.

The Japanese physicist, Hidetsugo Yagi, was so famous in this field that our Navy called its early radar antennae "yagis." Thereafter, each nation worked out the military application independently up to 1940 when, even before our entry into the war, the United States and Great Britain began the free exchange of radar data. Under the stimulus of war, the British were well ahead of us on airborne radar and, no doubt, the Germans were, too.

To return to the 1920's, eight years of experimentation went on before, in November, 1930, Dr. Taylor submitted a report on "radio echo signals from moving objects" which led the Navy's Bureau of Engineering to assign to the research laboratory this specific problem: "Investigate the use of radio to detect the presence of enemy vessels and aircraft; special emphasis is placed upon the confidential nature of this problem."

The following January the Secretary of the Navy wrote the Secretary of War describing these experiments and making this suggestion: "Certain phases of the problem appear to be of more concern to the Army than to the Navy. For example, a system of transmitters and receivers might be set up about a defense area to test their effectiveness in detecting the passage of hostile aircraft into the area."

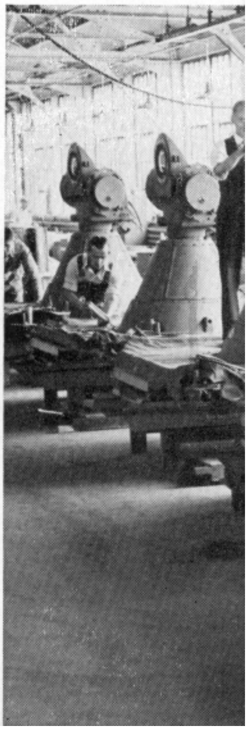
By 1931 planes at a distance of 50 miles had been spotted by radio reflection under favorable circumstances and Dr. Taylor, reporting this fact, added that the laboratory's object now must be to "develop instruments for the collection, automatic recording and correlating of data to show the position, angle and speed of approach of plane or ship." This was the true crossing of the frontier from observed phenomena into practical use, and the real inception of what we now call radar. Hence it is about 15 years old.

So much progress was made in the next four years

The radar pedestal gets a coat of Army olive drab via spray gun in a paint booth.

in developing such automatic instruments that the House Naval Appropriations Committee, excited by what it was told in 1935, voluntarily gave the Naval Research Laboratory a special appropriation of $100,000 with which to pursue this research.

A demonstration in June, 1936, of the steadily improving apparatus made an enthusiastic convert of Admiral Bowen, chief of the Bureau of Engineering, who ordered a set installed experimentally on a battleship as an adjunct to gun fire control. Tested in the Pacific fleet maneuvers that fall, it converted the Navy's line officers. The next two years were given to producing a practical shipboard model installed late in 1939 on the battleship *New York* and exhaustively tested in battle maneuvers in January, February and March, 1940. This was the first permanent American radar installation.



Production manufacture of radar had begun in October, 1939 with the letting of a contract to the Radio Corporation for six sets like that on the *USS New York*. Two of the major electronics laboratories of America, those of Bell Telephone and RCA, by then were working closely with the Naval Research Laboratory. The next August, Admiral Bowen persuaded General Electric to enter the new field. It did so so whole-heartedly that it transferred its large staff of radio research engineers without exception to radar.

General Electric was given a naval contract and a month or so later Westinghouse had been enlisted, so that nearly all of our battleships and heavy cruisers had been equipped before Pearl Harbor and early warning radar sets had been installed on our strategic frontiers.

When the war began our Army was using the 268 mobile radar set for anti-aircraft gun-laying, operating on a wave length of 1½ meters, common to all the warring nations and then thought of as short wave. The 268 had replaced in 1939 a complicated and inaccurate system of sound locators, searchlights, opti-

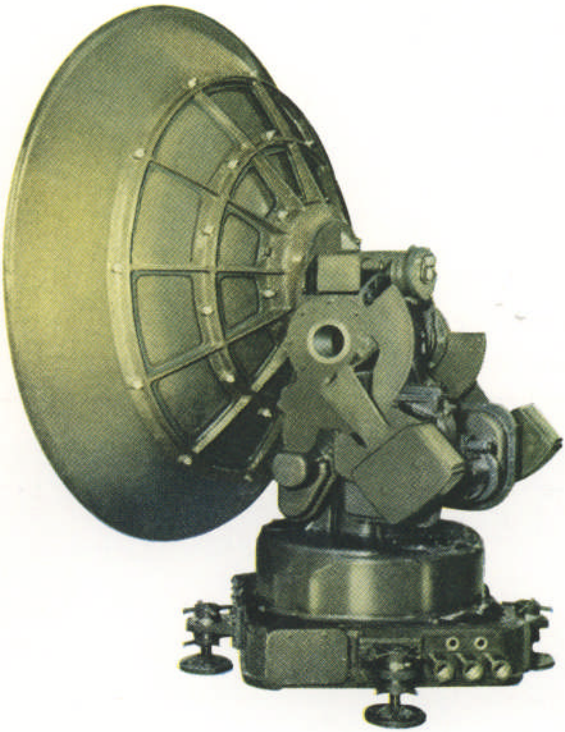
Bolting the radar base to the elevator platform on which the instrument will rest when installed in the trailer.

cal range finders and tracking telescopes. The SCR-584 microwave set which replaced the 268, in turn, and other new type radars, were the creations of the Radiation Laboratory set up in 1940 at the Massachusetts Institute of Technology by the National Research Defense Committee, an independent agency established by executive order that year to "correlate and support scientific research on the mechanisms and devices of warfare."

The Radiation Laboratory, a civilian body operating in close cooperation with the Services, but independently of military authority, its spending supervised only by NDRC, began with a personnel of 48 housed in a few rooms and grew to a force of 3,900 men and women, including probably 20% of the nation's top physicists, using 660,380 square feet of space.

Though 268 doctors of philosophy and one Nobel prize winner served on the staff, the average age of the thousand odd scientists it recruited was 32 years. The Laboratory spent up to July 31, 1945, for nothing but radar research and development, $80,000,000, or nearly twice the endowment of M.I.T. itself. The Army and Navy contracted with private manufacturers for more than two-and-a-half billion dollars of radar equipment based directly upon Radiation Laboratory developments.

The Laboratory had branches in England, Hawaii, Manila and on the Mediterranean, all connected by teletype with Cambridge; sent its scientific personnel



The experimental antenna mount, replaced by the Chrysler design, was too heavy and cumbersome.

into the field, the South Pacific included, under fire to study this equipment in action and to counsel the operating forces. It has been estimated that "RL" in five years advanced radar research by at least 25 normal peacetime years.

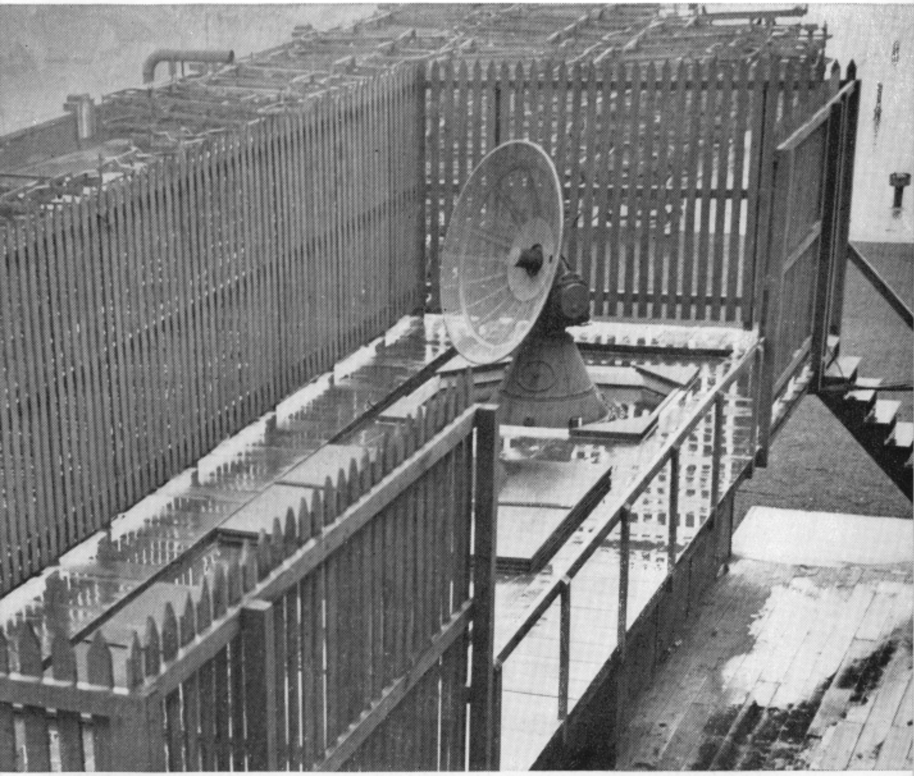
Though no microwave equipment was delivered to Army or Navy in 1941 and very little in 1942, almost all Allied radar equipment by 1944 was based upon microwave technics that had been no more than a speculative possibility three years earlier.

In the midst of the great air blitz of Britain in the summer of 1940 a British mission came to the United States seeking to learn what we were doing in radar. Ordinary vacuum tubes were adequate to the 1½ meter radar which defeated the Luftwaffe that summer. The greater accuracy of microwaves was known, but they demanded, among other technical advances, tubes of a power many hundred times that of anything known in this frequency range.

Dr. Vannevar Bush, then head of NDRC, appointed Dr. Compton to set up a special section of NDRC at M.I.T. to develop detection devices of all kinds. A Microwave Radar Committee appointed by Dr. Compton decided that the problem was so important that it called for a laboratory of its own with wide powers and a large staff. Dr. Lee DuBridge, now President of The California Institute of Technology, was borrowed from the University of Rochester as director of this Radiation Laboratory.

The British Admiralty had put the problem of a greatly more powerful vacuum tube up to a research group at the University of Birmingham who had developed the revolutionary cavity magnetron with a million times more power. The British left samples of the cavity magnetron with the new Radiation Laboratory and suggested that it concentrate upon two problems: (1) a microwave radar for use in and with night fighter planes for the interception of hostile aircraft, and (2) a microwave radar that could follow enemy planes with sufficient accuracy to permit effective blind anti-aircraft fire. As yet unaware that they had won the "Battle of Britain" against the Luftwaffe, the British were concerned with little else.

Even with the great advance gained by the cavity magnetron, many competent men doubted at the



Roof test at Dodge where the instruments were run thousands of hours without use of high frequency current.

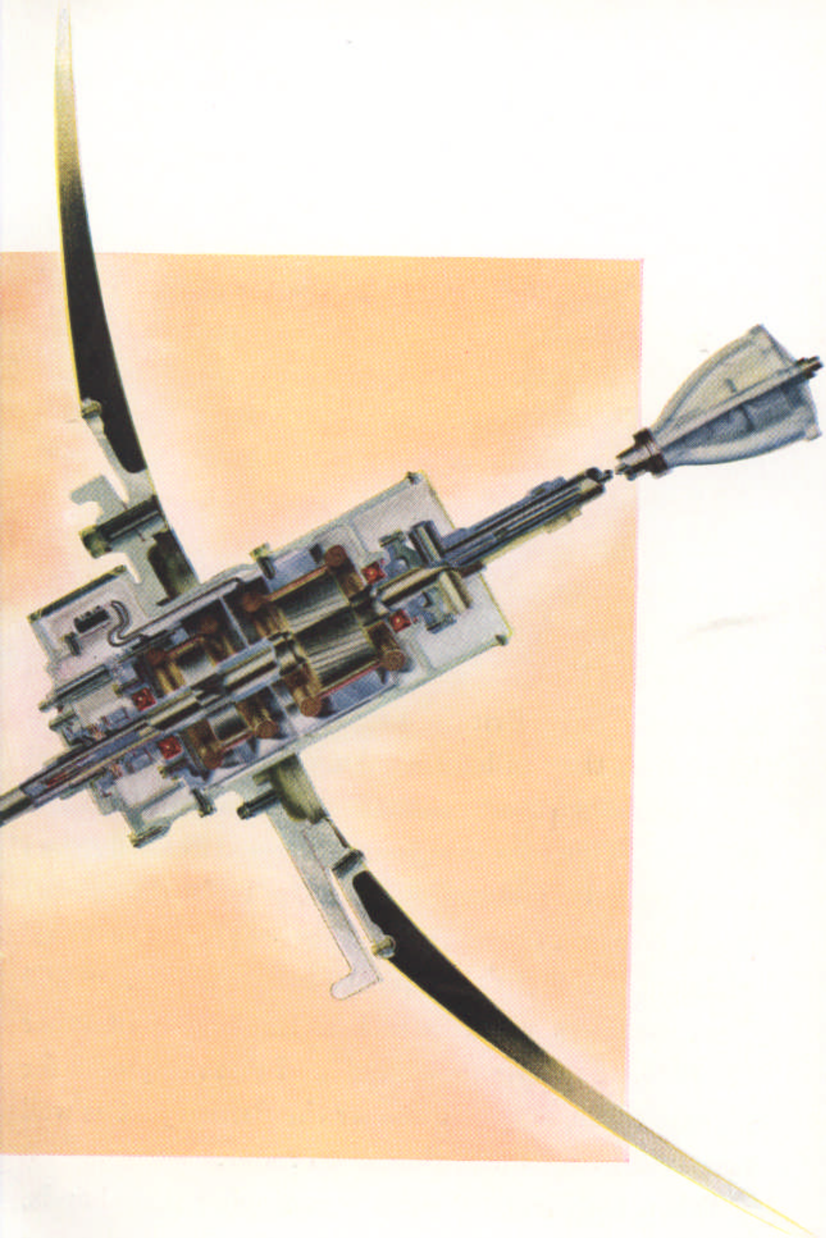
time that microwaves could be adapted to radar. Others thought that it could be done, but not done fast enough to play a part in the war.

The Radiation Laboratory quickly perfected a night fighter microwave radar, however, and early in its testing it was found to have many unsuspected advantages over previously known sets in spotting ships on the surface of the sea. Out of this discovery came the sea-search radar which accounted for more than half the U-boats sunk after mid-1942.

In the early stages of the war most German subs were lost when they surfaced at night to recharge their batteries and were detected by British 1½ meter airborne and naval radar. The Nazis defeated this radar with radar detectors, which warned the surfaced U-boat of a plane's proximity.

In 1942 the Germans were sinking Allied shipping at the rate of 16,000 tons a day. This grave peril was nearly eliminated within a few weeks by microwave radar which drove the Nazis to devise the Schnorkel, a breathing tube through which air was conducted to the engines and foul air exhausted without surfacing.

A further improvement of the sea-search set then achieved a perfection which would spot even the Schnorkel or the thin periscope of a submerged sub. In the latter stages of the war Hitler sent two parties of civilian electronics experts to sea in U-boats with orders to find a way of combatting this newest Allied radar. One of these submarines survived thirteen



Phantom drawing showing the mechanism of the spinner motor and the antenna which it spins at 1750 times a minute.

days, the other nine, and Hitler virtually abandoned the U-boat campaign.

Before turning to this adaptation of the night fighter radar, the Laboratory had begun work on its second assignment out of which came its crowning achievement, the SCR-584 anti-aircraft set. If you recall news reels of anti-aircraft fire you will remember that, as a rule, you have seen the whole sky dotted with black bursts, many of them not remotely on the target, an indication of the relative inaccuracy of long wave radar-controlled guns. In a news reel of SCR-584-directed gun fire you discover the hostile plane by looking for the bursts which march directly in front of or behind or on the target.

A few RAF planes were able to stop the many of the Luftwaffe over Britain because the British radio-locator, as they called their long wave radar, spotted the enemy as they took off from fields across the Channel. This enabled ground-directed RAF fighters to be upstairs and waiting for the Luftwaffe at the right points at the right times. When the RAF smashed 185 of the then record-breaking flight of 500 Nazi bombers which attacked England September 15, 1940, the Germans abandoned mass daylight for night attacks, only to discover the British just as well prepared in the dark, thanks to radar.

When they learned what was tipping their hands, the Germans took to flying over the Channel a few feet above the water. The meter and a half wave was