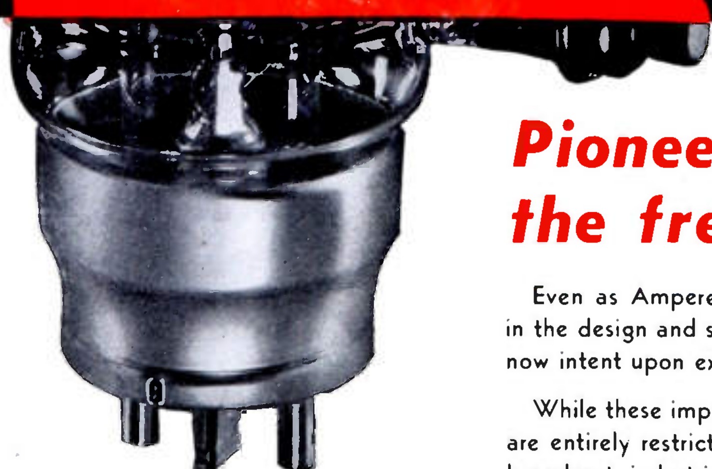
Proceedings of the I·R·E

JULY 1942

VOLUME 30 NUMBER 7

PART I

Institute of Radio Engineers



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Proceedings of the I·R·E

Published Monthly by
The Institute of Radio Engineers, Inc.

VOLUME 30 — *July, 1942* — NUMBER 7

The contents of papers published in the PROCEEDINGS are the responsibilities of the authors and are not binding on the Institute or its members.

Entered as second-class matter October 26, 1927, at the post office at Menasha Wisconsin, under the Act of February 28, 1925, embodied in Paragraph 4, Section 538 of the Postal Laws and Regulations. Publication office, 450 Ahnaip Street, Menasha, Wisconsin. Editorial and advertising offices, 330 West 42nd St., New York, N. Y. Subscription, $10.00 per year; foreign, $11.00.

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INCORPORATED

New York Meeting—September 2, 1942

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This issue of the PROCEEDINGS includes an important group of papers dealing with engineering policy, organization, and procedure and their relation to the national welfare. Current conditions unmistakably show the importance of technology both in war and peace.

The papers here included are stimulating to thought and action having as their aim the better utilization of available technological resources. It should be emphasized that these papers represent the views of their respective authors and that publication of these papers does not imply approval by the Institute of Radio Engineers of the specific proposals contained in them.

Readers of the PROCEEDINGS are invited to submit discussions of these papers or expressions of their viewpoints on such matters to the Institute.

The Editor

The Engineer in Modern Society*

ARTHUR VAN DYCK†, FELLOW, I.R.E.

MUCH has been said and written about engineering, about technology generally, and about their effects upon modern life. Lecturers, statesmen, politicians, businessmen, one and all, have expounded upon and given tribute to the great effects upon life and civilization brought about by the rapid advances in technology during the last half century or so. But it has been oratory and flowery compliments and an acceptance of the fruits without full and correct understanding of them, or appreciation of how they came about, and what they implied for the future.

Under these conditions, technology has come to blossom. But the blossoms are evil—they are poisonous and they destroy. Instead of a more abundant economy and a greater security of life, depression resulted. Instead of a more harmonious, happier world, drawn together by more rapid transportation and communication, we have world war, with waste, destruction and cost which will be felt for half a century to come. How has this happened? Why has technology brought about bigger depressions instead of smaller ones, and why more terrible wars instead of none at all?

A very large part of the answer is that engineers and scientists, busy with all the things they accomplished, failed to do just one thing more. And that oversight was not to have an interest in, and not to keep some control over, the utilization of the things they created. The place of the engineer in society heretofore has been that of a servant creating things for society to use. Having created them, he turned them over to others to use, believing, in his own innocence and habits of truth-seeking and right thinking, that others would appreciate their possibilities for further advance, and would carry them on to right utilization. That was the mistake. Having created complex and more powerful agencies—with power for good and for evil—the engineer did not see to it that they were thoroughly understood by other men, that utilization toward good was encouraged, and application to evil purposes suppressed.

The evidence is all around us. Technology provided a profusion of new articles of commerce and new services of many kinds. But commercial greed was allowed to undermine sound production principles, honest value, and service reliability, and we got the seven-dollar radio receiver and the two-year-life automobile. High-power advertising and high-profit stock manipulation substituted for solid facts and solid business building, and we got the depression. Selfish and short-sighted viewing of the world picture, and failure to knock down on first sight every young bully appearing in the world's back yard and stealing our new ideas became common, and we got grown-up gangsters and world war.

The point is that, as stated recently and well by *Fortune* magazine, "The technological factor has taken on such breadth and precedence, that it is now a decisive element in the rise and fall of civilizations. The world is bursting with technological developments. Technology is no secret weapon. It is simply the application of the sum of man's knowledge of the physical world to the task of getting a job done with maximum results and a minimum of error. It is science in action."

Unfortunately the first people to appreciate this situation, and to apply it, were the wrong kind of men, for the good of the world. Again as *Fortune* says, "The new historical fact is that modern technology has been welded solidly to the iron hand of a demoniac politics to form an integrated weapon of destructive power such as the world has never before seen." If

* Decimal classification: 620. Original manuscript received by the Institute, June 1, 1942. Presented, Cincinnati Section, May 19, 1942; Boston Section, May 22, 1942.

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free civilization is to continue, it can do so only by destroying that demoniac politics. That can be done only by a more efficient use of technology than the demons employ. So far they have been ahead of us in unified, more complete, yes—more intelligent utilization of the technical knowledge and forces available, although for evil purposes.

What has happened is that scientists and engineers have brought forth tools and agencies of tremendous power—and have left them lying around to be picked up by anyone, to use for any purpose. It is as though we made up nice, attractive packages of gunpowder and matches, and scattered them around a kindergarten, and walked away. By not instructing, supervising and protecting the use of its products, science and engineering have failed in one essential part of their job.

Heretofore, the world of science has had little to say about the use to which scientific advances are put. Had it been otherwise, and had scientific methods played their proper parts in home and international affairs, war might have been avoided. A few days ago Viscount Halifax, England's Ambassador to the United States, declared "The present war, different from all others, is one in which the whole apparatus of western civilization is called into play to save or to destroy the essence of that civilization itself. Science, they say, has made all this, and science is now destroying it. Where and how are we ever to break that vicious circle?"

Scientists and engineers must answer the despairing cry of Viscount Halifax. First, free men of free science must destroy those forces which have enslaved science to perverted ends. Then—to prevent that vicious circle ever forming again—free men of science must see to it that their own intellectual integrity, and their own knowledge that honest following of natural laws toward enlightened objectives is the only course which gives true progress and real accomplishment, are made clear and desirable to the rest of mankind. Scientists and engineers know that they cannot get sound results from experiments conducted under false conditions or in violation of natural laws. After years of such training and working, they come to think and act honestly, not deviously; in accord with truth, not evasively. Where they do not know the truth, they seek it out, because they know that until the truth is applied, the result cannot be successful. The bridge continues to stand, the engine meets emergency loads, and the radio maintains its service, only if honesty and truth have gone into their designs. Dr. P. W. Bridgman of Harvard University recently wrote, "A lifetime in the laboratory, struggling to make things work, has shown to the scientist the inexorable need of intellectual integrity. If scientists will make others see their own wider vision, their ultimate influence will far transcend that of any possible technological contribution."

All of this sounds like a desperate situation—and it is that. It is the first time in history that such a desperate condition has existed although there have been wars before this one, and there has been perversion of technology to purposes of war and destruction before this. But now there is a new factor.

Once upon a time, revolutionary inventions came infrequently, and each in itself was not overwhelmingly powerful. It was a long time between the invention of gunpowder and that of the machine gun. It was a long time between the steel ship and the successful submarine. Now, new powerful weapons appear at intervals of a few years, at most, and we know that at any moment we, or an enemy, may find one of conquering force. Both the rate and the power of technological development have increased vastly in just a few years. Aircraft with their range, speed, and offensive power; tanks, with their dominance over infantry; radio with its communication to the ends of the earth and into every home instantly, and the public thought control which that provides; submarines with globe-girdling range; chemical-warfare weapons with their horrors; detection devices, with ability to detect an enemy beyond human vision range; all these and more have come into effective being within one generation.

These modern inventions are becoming more complex, as well as more numerous. One result is that it is more difficult for nontechnical people to understand them and to evaluate their potentialities in advance of wide use. Technical men are trained to look for new things, and having found them to accept and use them wherever they provide improvement. That is possible because they understand the new things thoroughly, in relation to the old. But it is not human nature to accept readily new things not thoroughly understood. It is human nature to resist change from the old, tried, and familiar way. So it comes about that we find men, even in high places, because they have not the technical understanding and judgment, failing to appreciate the significance of air power, underestimating the power of radio broadcasting devoted to corruption of a people, failing even to use facilities provided for their protection.

How serious this condition can be was demonstrated at Pearl Harbor. That attack was successful because it was a surprise. The defenses included devices capable of preventing surprise attacks. Then why was surprise attack possible? Merely because the officers in command did not understand the technical devices provided for them, did not appreciate what they could do, and were not awake to the modern technological tempo. The devices were new—and to old thought that means they cannot be important. How different it would have been if the command had had just a fraction of the technical understanding which invented, manufactured, and installed the devices!

The Pearl Harbor incident is no isolated instance. It was ever thus. In World War I, wireless was new, and ships were lost needlessly because captains would not believe that dependable truthful messages could be obtained through the air beyond an empty horizon. Nor could they be convinced in those days that a big coil of wire in a shack which cluttered up the superstructure of the skip had any real value in finding the bearing of an enemy ship or even a friendly shore beacon.

Statement of these conditions is not criticism—it is merely the remarking of the natural human characteristic which we all have, of placing dependence upon the old way, and of being reluctant to depend upon the new and unfamiliar.

But that human characteristic now results in a dangerous condition. Assuming that we cannot change human nature, we must do something else, now that new things, of great power, are appearing so quickly and so often. That which we must do is to become familiar with the unfamiliar more quickly. Men in places of high decision and command, must be better informed, and more quickly. They must have the open-mindedness of the scientist. They must apply intellectual initiative and imagination and avoid wishful thinking. Above all, they must develop ears more willing to listen to technical advice, in those early stages of new developments when only the technical expert can evaluate correctly the worth and the possibilities of the new thing.

All of this applies not merely to matters of war. It is equally true in the operations of industry at peace, and in the development of society and civilization itself. The technological contribution to industry and to society is made under the same conditions, and with the same human-nature characteristics, as are met in war. The tempo may be faster in war, but the conditions, the laws, and the results, are the same in war and peace.

Up to now, the scientists and engineers have been content to produce their technological contributions, turn them loose in the world, and then to dive back into their laboratories to produce more. So society has had to struggle with the new things, learn about them the hard way, and in many cases hurt them and itself in the process.

There is increasing evidence now that not only scientists and engineers but wise observers in many fields, are awakening to the need for use of the scientific method in all of society's operations. The scientific method is merely that of finding the facts—all of them, not just some of them, putting them together, evaluating them, testing their effects, calculating the result with honesty and without guesswork. It seems that the scientific method has been little used heretofore, except by scientists and engineers. They have been trained in it, and we can reasonably expect that more and more men of other fields will be trained in it as time goes on, and as science and its methods become more universal. Until that time has arrived, it will be the duty of scientists and engineers to step out into society more, and to assist in orderly introduction and utilization of their contributions. Heretofore they have been loath to do it—the laboratory was a much more pleasant, reasonable, and effective place to work. It has taken a world depression, a world war, and a near world collapse to show him that he is needed outside. And he will be needed outside until businessmen and statesmen adopt his training and his methods, of searching out the truth and then applying it. The place of the engineer in modern society is—***in*** it. Until now, he has been *of* it, but not ***in*** it.

The difficulties which will be encountered by scientists and engineers when they attempt to take a more influential part in society, are well described in a recent English[1] book in words which apply to this couutry equally well:

"The tragic events which have led to the dangerous pass in which we now stand have run their course, not so much for lack of will or action, as for lack of thought and foresight, and particularly for lack of *scientific* thought and foresight. Science, it cannot be urged strongly enough, is something which does not stand outside the ordinary ways of acting and thinking. It is simply the most orderly expression of those ways. There is therefore a greater need for science in the present situation than there ever has been in the quiet days of the past.

"An organized scientific approach to the problems of national existence is foreign to the tradition of both the economic and political management of the country. Furthermore, a great number of scientists themselves brought up in this tradition, have neither the desire nor the capacity to see that effective use is being made of their science. These obstacles lie very deep in our social system. In commerce special knowledge is something from which profit may be derived. The idea of a general survey of the needs of the population and of the planning of methods of satisfying them, irrespective of particular interests, meets opposition at every point. The whole tradition tends to prevent things being done. An even more serious objection is that high administrative officers have a classical training and are almost completely ignorant of technical matters. Having little conception of what scientific research is, they fail to see how it can be practically used. The attitude of both business men and civil servants towards scientists is that they must be treated as consultants. They can only be asked particular questions, and their answers must be collated with each other and judged in the light of established custom before they can be used as a basis for the decisions taken by administrators.

[1] *Science in War*, Penguin Books, New York, N. Y.

"On the whole, scientists are excluded from discussions on policy, and even more so from decisions. As a result, even the most authoritative scientific committees often flounder in the dark, and their work, however excellent and to the point, may lie unused for vital months. When it is used, it is not infrequently distorted by the technical ignorance of those who put their recommendations into practice. Part of the blame for all this rests with the scientists themselves. Many scientists have grown to accept the position, and find it difficult to conceive of any other. They are perfectly willing to answer questions if asked, and feel their responsibility begins and ends there. They are not called upon to survey the situation, to make decisions, or to see that they are carried out.

"The scientific societies, which might have integrated the scientific effort of the country, have almost gone into hibernation, and preserve a precarious existence carrying on their pre-war functions and assisting, somewhat ineffectively, in the operation of the National Register. It might be thought that the central position occupied by the advisory scientists would overcome these difficulties. Unfortunately, this is not so. They seem to have been much more concerned with agreeing with Government decisions than with challenging them in the name of science. This attitude can be summed up in the naive Press report of the formation of one such committee 'The Ministry of Poland has appointed a committee of eminent authorities to prove scientifically the validity of the policy that it has adopted.' In the long run the 'yes men' of science are likely to be at least as dangerous as the 'yes men' of politics.

"These difficulties, though serious, are not insuperable, and as conditions worsen they are more and more appreciated by people inside and outside the scientific world. There is great power of individual and co-operative activity in the scientific world, and if it is helped by the pressure of intelligent public opinion, we may obtain, perhaps even in time, the effective utilization of science to save the situation. But the need is very urgent indeed. There is a shortage in applied intelligence in this country, perhaps greater than the shortage of anything else. This shortage will not be met until we make use of the large quantity of available, but at present unemployed, scientific intelligence we have at the moment."

It can be summed up in the recent words of Walter Lippmann, that astute observer of fundamentals. He said: "What we have not had is a finding of facts and recommendations by men who were at once disinterested and expertly qualified. There is a vacuum here and in this vacuum there are generated the controversies which delay action and confuse the public mind. There is generated also the nervous affliction which was described by one witty and highly competent official in Washington as 'galloping frustration.' The vacuum exists because we have not learned sufficiently to call in, before decisions are taken, and at the point where they can be of the greatest use, scholarly and scientific men. Yet in any total effort, scientifically trained men have a part to fill which no one else—no soldier, no statesman, no business man—can fill."

There are things which engineers and scientists must learn before they can serve usefully in these new ways. But these things are easy to learn—far easier than the complex things they have mastered already. And they must free themselves of the inferiority complex which they have developed during these past years. In the recent past, economic organization has depended chiefly upon businessmen and lawyers, the former to develop clever methods of operation, and the latter to prevent or to repair the consequences.

We now have a civilization which is not only highly technical, but subject to rapid change from frequent new technical developments. It is therefore essential that sound and thorough technical knowledge be utilized in the guidance and control of that civilization. Until all men have the scientific viewpoint, the technical men must be depended upon, and the technical men must take on the heretofore avoided task of dealing with human nature and human relations, in addition to the study of Nature herself.

Engineers and scientists have made many contributions to society, of materialistic sort, and will make more. But in the future, if we are to survive happily, those contributions must be accompanied by explanation and guidance, by interpretation of moral intent, and if necessary, by forceful policing against subversive use. There is the difficult job and the sacred duty of science in the society of the future.

A Technological High Command*

How Fast is the U. S. Moving Toward It? Too Slowly, for the Movement is Measured by the Rate at Which Technical Men Move up into Decisive Positions in the Military and War Administration

THIS IS the most technical of all wars in history. The technological factor has taken on such breadth and precedence, as compared to World War I, that it is now a decisive element in the rise and fall of civilizations. It is the dynamo for producing trained manpower. It is the master key to the arsenals of industry. It is the high-precision factor in setting the quality and superiority of the new machines of war. The U. S., therefore, can hardly win total victory unless it bends and coordinates its highest technology to the task everywhere. This is the most difficult and secretive side of the war. It is easier to talk about almost anything else. It is easier to talk economics, or politics, or business, or global strategy, or international hegemony; and the press and radio and commentators do, twenty-four hours a day. But to examine the complex organization of U. S. technology for war is to cut immediately to the bone of not only the problems of total war, but most of the problems of the world.

The world is bursting with technological developments. In fact, the technical explosion can hardly be distinguished from the physical war. Above and below the din of events rages the unmasked struggle for the survival of the technological fittest. Germany, Japan, and, it now strongly appears, Soviet Russia were well prepared with close-knit technological high commands —commands in which technical men were brought to the fore and given their heads over all economic and industrial considerations to create total-war machines of striking power. These are the only commands that thus far have won any success in this war.

Disaster to Disaster

The U. S. is moving further and faster toward a technological high command than the nation realizes. But for both the U. S. and Britain the movement can still be described only as a forced evolution by progression from disaster to disaster. That is, technically obsolete commanders on both the battle and administrative fronts hang themselves right and left in this war, and the real technicians begin to move up and take command from below. In the end the technologist moves into command because he is the only one who can bypass to any extent the inevitable bottlenecks and shortages; and he alone can devise and fight the new machines of war. This is the long way round and by now exceedingly dangerous, wasteful, and bloody. It must be cut short. And the necessity is terribly underlined by a new historical fact set loose in the world.

The new historical fact is that modern technology has been welded solidly to the iron hand of a demoniac politics to form an integrated weapon of destructive power such as the world has never before seen. Before the Nazi and Japanese engine of total war falters, it may well lay waste more of the past and future than the human race can afford to lose. Nothing less than the fitting of this total instrument to the hand of democracy can beat the evil to earth in time. The small craven fear that democracy can be lost by making it an effective instrument at home and against its enemies abroad is the very paralysis of defeat.

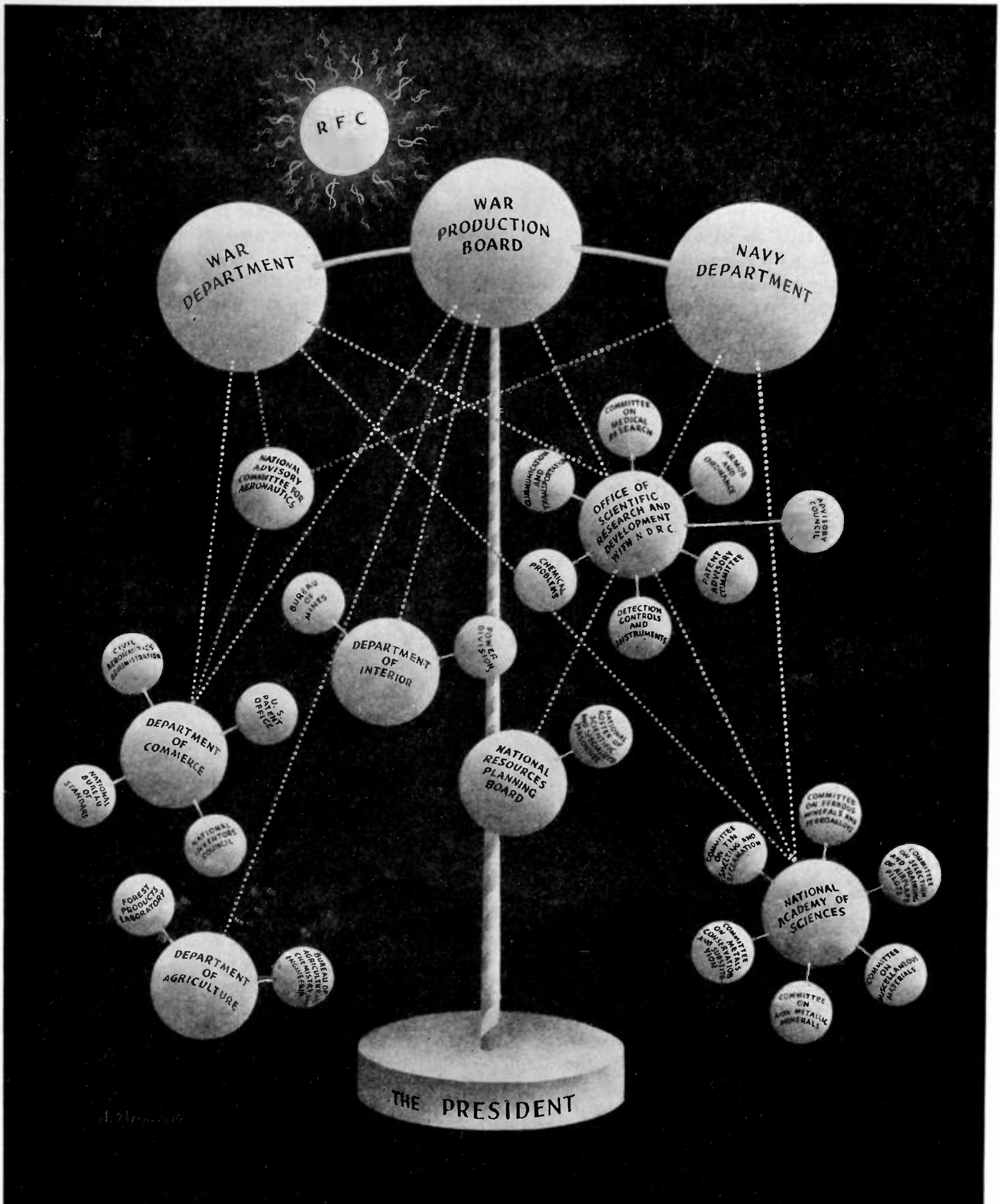
Science in Action

Technology is no secret weapon. It is not a mystic or infallible talisman. It is simply the application of the sum of man's knowledge of the physical world to the task of getting a job done with maximum results and a minimum of error. It is science in action. The periphery of that action, expanding at incredible speed over the last decades now encompasses a leviathan body of knowledge. It may include today a statistician weighing the relationships of scattered economic data, a bull-necked commander of a tank corps with precise knowledge of his ugly monsters of war, as well as a chemist building a new molecular world. Its devices may be a great internal-combustion engine, a new vitamin, an electronic microscope, a new welding technique, or simply a new mathematical formula. If these seem unconnected, put it down as a major failure of education and the press to interpret and link up the vital, working relationships of the technical world in which we live. Before it is even possible to measure U. S. technology as a democratic weapon of total war, it is necessary to understand the order and structure of the technological world.

At the top of the order is pure science—the creative mind exploring for new knowledge to add to man's store. Below this, and the most vital link of all, is development engineering, which takes the germ implanted by the pure scientist and attempts to build it into a functioning, new process, engine, or product. Below this is applied science, working with accepted knowledge for practical, profit-making ends, and its outward visible form is modern industry. Below these are the ranks of skilled technicians, laboratory men, tool- and die-makers, and the like.

The orthodox notion is that these are widely separated interests, working in separate compartments,

* Decimal classification: 620×R560. Reprinted from *Fortune* magazine, vol. 25, pp. 62–67, 191–194, 196; April 1942. Copyright, 1942, Time, Inc. (*Fortune*, April, 1942).



A. Petruccelli

The main dynamics of the U. S. technological mobilization for war. The chains represent direct advisory connections.

with only the remotest connections between them—a notion fostered by the press's spotty reporting of scientific affairs and its disproportionate emphasis on the financial grandeur of industry. In reality the above structure is an organic whole, of which the top two members are the brains, industry the body, and technical labor the skilled hands. It doesn't function properly any longer except as a whole. In the fiery test of modern war, failure to see it whole and in perspective is fatal.

For here is the U. S. technical brain, the equal, if not the best, of any in the world. And here is the U. S. technical plant, the best and most mass-productive of any. The problem again and again is simply the problem of getting brains and plant to work as a coordinated whole. Production is a problem within the larger technological problem. The linkages are everything. A prototype of the wartime technological high command toward which the U. S. is struggling already exists—though merely as a germ—in a few of our highest technological industries, where for the past decade pure science, development engineering, and managerial talent have been merging into a coordinated whole *at the top*. If you follow step by step the growth of U. S. technology into a war technology, the lesson for now and the future is unmistakable.

The Present Structure

To start with, you have all the infinite divisions and scattered power of U. S. technology and research. Pure science dwells largely in the universities. Development engineering sprawls all the way from the universities, through research foundations, to solitary inventors and into industry. Applied science and product research honeycomb the whole structure of modern industry. Add to this an almost unrealized amount of technological research tucked away in all corners of the government. This includes metallurgy in the Bureau of Mines, plastics and chemurgy in the Department of Agriculture, physics, chemistry, and materials in the Bureau of Standards, and a cluster of projects around TVA and the other big power developments. Finally, cutting across the present, there are the technical subdivisions of the army and navy—aviation, ordnance, engineering, medicine, etc.—topped by procurement and the Joint Army and Navy Munitions Board.

The weakness of all government technology at the source, aside from its obvious lack of a coordinated program, is that it has never had the cash or salary standards to develop a really strong technical civil service. The same congressional mind that is now killing every proposed bill for technical planning of the future peace was equally industrious in seeing to it that we were unprepared for the present war.

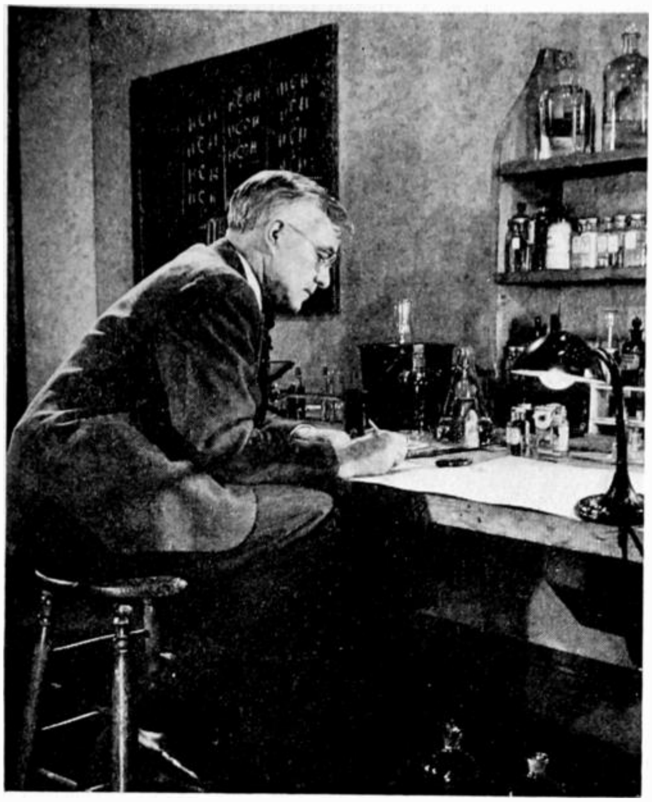
At the outbreak of World War II, integration of this great sprawling body of technological power began like a long, slow, sluggish recoil from an unpleasant fact. The army's technical branches had been starved out for years. The navy was in a better way because it lived in a technological medium that could not be kept afloat without continuous attention to engineering. Flush or broke, however, professional military technology rarely rises above the ultraconservative in applied science: that is, application of proved knowledge to the instruments of war. It has little time and less talent for experimental research and development engineering. That sphere has grown beyond all bounds for the military to keep up with, and, indeed, responsibility in the development field can no longer be considered strictly military. The bulk of the new instruments of war for more than a century have been civilian inventions. To function at all any longer the military must not only tie in closely with civilian industry in a vast and complex organization that is today the War Production Board, but it must also cut deep channels through to the main current of U. S. technology to keep from technical stagnation.

It Began with A. Lincoln

When war broke there was only one integrated technical body then functioning—the National Advisory Committee for Aeronautics (*Fortune*, March, 1941), an ace governmental body created in 1915 to supervise and pursue basic research with government funds in the vital but enormously expensive field of aeronautics. Concerned with the dual military and commercial aspect of aviation, top army and navy staff men sit on the committee with top civilans in the field of aeronautics. Out of its thoroughgoing experimental work at Langley Field grew the outstanding safety and performance of U. S. commercial aviation —and the closely related superiority of present U. S. heavy bombers. There was neither the money nor the incentive before the war for keeping abreast of the rest of the world in the actual development of other types of military aircraft.

Also in existence, but unattached anywhere, was the eminent National Academy of Sciences, whose charter had been signed in the Civil War by Lincoln, who was having his technological troubles, too. The academy was conceived as something of a far-sighted supreme court of top U. S. scientists, academic and industrial, serving without compensation and ready to investigate and report on scientific problems whenever any government body called upon it to do so. The great problem that had begun to appear in the Civil War was the necessity of getting unbiased technical advice from a source as far removed from all economic or political pressures as possible. Under the academy, Wilson added a National Research Council to meet the further technical demands of World War I. Between wars, the academy has served as the nation's top honorary scientific body, somewhat comparable to the Royal Society of Britain.

One of the first big jobs the academy was called upon



Life

Chemist Irving Langmuir of G. E. research laboratories is a great basic researcher and developer of many devices from the gas-filled tungsten lamp to submarine detectors. The scientists shown here represent only a fraction of U.S. technological brain power for war. Their work must remain secret.

to do in this war was to investigate and recommend standards of selection and training for airplane pilots, and in this line it is sponsoring a great program of experimental projects in U. S. universities. Other academy committees rapidly grew up around other technical problems of the army and navy and government. Then OPM, just beginning to run into strategic-metal problems, was assailed by a clamoring flood of new technical processes and proposals to develop low-grade manganese ores in the West and thought of the academy as arbitrator. At OPM's request the academy set up an advisory committee on manganese. The same problem swiftly spread to tin and other metals and materials. And another set of problems began to arise in metal conservation and substitution. Committees multiplied until they finally coalesced into two broad advisory committees to WPB's Materials Division. One is a fifty-eight-man Metals and Minerals Committee, split into four groups, made up of some of the outstanding experts in the field, about three-fourths from industry and industrial-research organizations and one-fourth from government and the universities. The other is a roving committee on miscellaneous materials (chemicals, synthetic rubber, etc.) that changes its make-up according to the problems presented to it.

Meanwhile, technical lines were crossing in all directions. The U. S. Bureau of Mines and Geological Survey, for instance, received sizable appropriations to explore and develop new processes for domestic low-grade-ore deposits. Forest Products Laboratory, under the Department of Agriculture, stepped up a big research project in plastics. A National Inventors Council was created to sift all public proposals for new gadgets of war, attached to the Department of Commerce under G. M.'s Charles Franklin Kettering. These endless extensions form the immemorial U. S. processes of meeting problems one by one, only as they appear.

The technological tide pressed in from all sides in such volume, however, that by the spring of 1940 a group of leading scientists (not the military, be it noted) proposed to the President that he set up a body with funds and power to correlate and initiate research on instruments of war. The National Academy's limitation in this swiftly moving war was that it couldn't do anything until asked. Under the Council of National

Wide World

Aerodynamicist Theodor von Karman (Northrop): fuselage design.

Chemist George O. Curme (Union Carbide): petroleum-gas chemistry.

Wide World

Mathematician George David Birkhoff (Harvard): a world leader in mathematics.

Pix

Physicist Harold Clayton Urey (Columbia): authority on heavy-molecule chemistry.

Defense a new National Defense Research Committee was created in 1940. A year later Roosevelt placed over it, by executive order, the Office of Scientific Research and Development, and another foliation of committees and subdivisions began.

The OSRD is potential kingpin of U. S. war technology. It will spend some $20 million this fiscal year. Its headman and ruler is kinetic Dr. Vannevar Bush, President of Carnegie Institution of Washington. By grant of power OSRD has scope to mobilize and coordinate the whole scientific personnel and resources of the country, all the research of all government agencies, and to coordinate and initiate research on all the "instrumentalities, methods, and materials" of war. In practice OSRD is something less than all this. It does have a top, coordinating Advisory Council (Dr. Bush, National Defense Research Committee Chairman James B. Conant, Committee on Medical Research Chairman A. N. Richards, NACA Chairman J. C. Hunsaker, and two representatives from the army and navy) that meets regularly. But OSRD's main activity has been self-limited to two main areas: medical research and research on direct instrumentalities of warfare, excluding raw materials (spread between many agencies) and excluding aeronautics (which remains NACA's territory).

Within this defined area OSRD, through NDRC, has a network of divisions and sections (Ordnance and Armor, Communications and Transportation, Detection Controls and Instruments, etc.) intricately tied in by fifty to sixty liaison lines with the army and navy. Within it OSRD has mobilized about 3,500 U. S. scientists and technicians, including nearly every available top-ranking physicist in the country, to work on some 600 no-profit-no-loss research contracts farmed out to university and industrial laboratories. This unique contract system halted what might have been a fatal attempt to centralize laboratories in jammed Washington.

Of all Washington agencies, OSRD, with a small administrative staff tucked into one makeshift corner of Carnegie Institution, is the most supersecretive. In a general way it is known that it is working on many

Life

Physicist Ernest Orlando Lawrence (University of California) is a big explorer of atomic structures. He developed the cyclotron atom smasher.

electronic detection and firing devices, magnetic devices, new armor plates, and armor-plate welding, and has a section working on the problem of securing enough of the uranium isotope, U-235, to make atomic power a fantastic reality. But no one knows what new instruments of war may yet come out of OSRD.

This is the mushroom structure thus far of U. S. technology for war. An attempt to diagram its intricate dynamics will be found in the chart on page 310. No organization of the enormously complex field of modern technology can be precisely simple. The various sections of this structure are doing intense and even brilliant work in amassing and integrating the best knowledge to be brought to bear on modern warfare. It is miles ahead of World War I.

The Missing Links

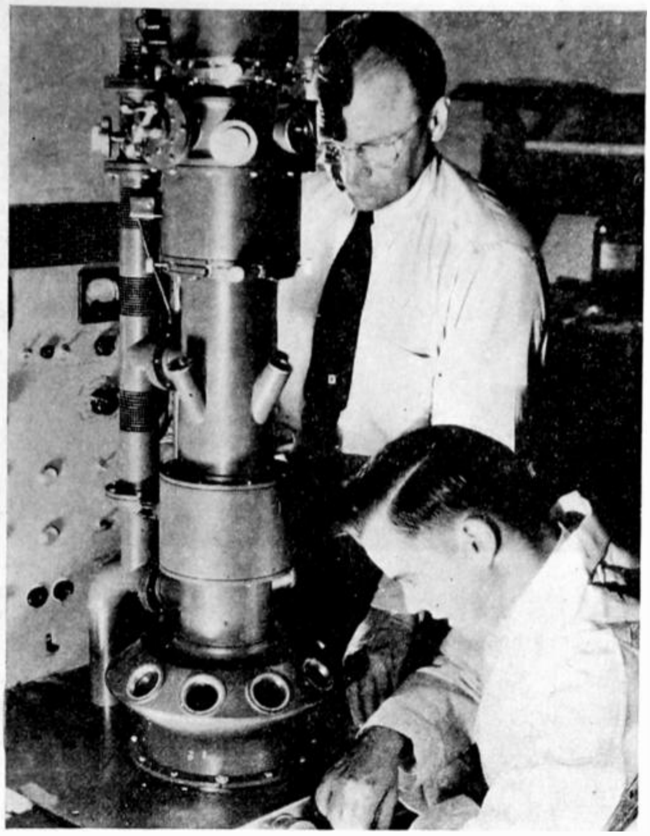
But even while U. S. technical brains—some of the best to be had in the country—were thus mobilized for defense and war, the U. S. military and administrative high command was committing a seemingly endless series of technological blunders.

The list is by now monotonous, and many people are tired of it for various reasons. But blunders form the corpus delicti in warfare, and cannot be examined too often until war is won. There was, first of all, a baffling muddle in aeronautics: a belated heavy, long-range-bomber program; exasperatingly sluggish progress in getting adequate fire power and high-altitude performance into fighter planes; and a continuing failure to provide for any emergency types of long-range fighter planes. On other fronts there was the failure, except for manganese, to put up sufficient stockpiles of strategic raw materials. And the failure to get any considerable or progressive conversion and pooling of the automobile industry and other industries to war production. And the sudden discovery that the U. S. had almost no magnesium production.

Wide World

Photochemist C. E. Kenneth Mees (Eastman Kodak): great man of color photography.

Metallurgist Horace W. Gillett (Battelle Institute) directs wide metallurgical research.



Physicist Vladimir Kosma Zworykin top (R.C.A.) has a long list of electronic-tube developments (television), topped by the electronic miscroscope.

Acme

Radio engineer Edwin H. Armstrong is inventor of the superheterodyne and new FM radio system, now sweeping military communications.

And the long, dragging resistance to expansion of aluminum production. And the failure, once the stockpile failure was recognized, to make all-out provision for other raw material sources—low-grade domestic-ore production in strategic metals and synthetic-rubber plants in rubber. None of these are blunders just discovered by hindsight. Nor is the list exhaustive. In every case ample forewarnings are to be found in technical reports, recommendations, and proposals, and even in lay journals, including *Fortune*, back as far as one, two, and even five years ago.

The key to most of these blunders runs in a word through the whole structure of the U. S. war technology. The word is "advisory"—which means that the technical bodies cannot act until a problem is presented to them, have no responsibility except to make a report, and end by spreading all responsibility so thin that it almost disappears. Not even OSRD, which has the power to initiate research, can do more than present it to the military. The technical brains are almost completely advisory to something else. Between the technical data and the correct technical action something else intervenes. The ultimate decision for action or nonaction in these essentially technological matters rested in the hands of men who were without the capacity or spirit to make the correct technical decisions.

The decisions rested with army and navy general staffs and procurement divisions that have been consistently behind the world's advanced technical thinking in terms of air power. Or the decisions rested with conservative OPM businessmen, who worked harder keeping intact the rigid corporate and competitive compartments of the status quo than building an all-out, flexible production instrument for total war. Or the decisions wound up finally in the Defense Plant Corporation office of Banker Jesse Jones, who, before he could put up the money for the first aluminum-expansion program, had to have explained to him that aluminum is made from bauxite. Except that Mr. Jones is more powerful and therefore more dangerous in his ignorance, he isn't much worse than Senator Mon Wallgren of the Truman Investigating Committee, who asked a witness whether aluminum can be made out of magnesium. The U. S. is now paying a crushing price for the belated technical education of its bankers and public servants.

This is not to imply that the technical men would have been infallible in action, or that the technological structure for war as we have examined it is either complete or as yet well integrated. The NACA is pretty thoroughly dominated by the front office of the U. S. aviation industry—which, be it said, is one of the most alert and technologically advanced of all U. S. industries. The advisory committees on such vital fronts as minerals and metals, too, are overweighted on the side of the biggest U. S. metals producers. But even in the broad areas where business-industrial interests might reasonably be involved, these committees have consistently made recommendations that on the whole were on a higher and swifter level than the action that eventually flowed from their reports.

The reason is that, faced with a definite problem to be solved, the scientific spirit always tends to override the economic status quo to get something done. The repetitious blunders are all blunders of *not* doing something—*not* converting plants, *not* building synthetic-rubber plants, *not* providing for long-range fighter planes. It was the endless battle of corporate research versus corporate finance, of engineer versus the military—and in these large national issues the cautious mind always won. The men and agencies and industries involved have long and even plausible rationalizations as to why things were not done. They were uneconomic, it is explained, or policies weren't clear, or the nation wasn't yet awake. But when a civilization begins to accumulate more reasons for not doing things than for doing them it is in a fair way to stagnation—even on a national income of $94.5 billion a year. Technology as a whole—science, development engineering, industry, and technical labor—is the driving force against the two great inertias that lose wars.

The first is the inertia of the military mind. Charged with the safety of its country in war and the leading of men in battle—responsibilities from which flow its unassailable right to choose its own weapons—the military mind rests heavily on the tried and traditional, and is the least open to innovation of any segment of society. Its technical branches, therefore, are mainly specification and testing adjuncts to the top procurement divisions, which, over the years, have built up close connections with big industrial suppliers and depend heavily on those suppliers' engineering departments.

The second great inertia, closely linked with the first in modern war, is the inertia of industry's heavy investment in plant and equipment. It tends to hold on to old methods, machines, and products and resist any sudden changes or innovations, such as wars demand. This inertia becomes so great in an advanced industrial society, even in peacetime, that some of the most advanced technological corporations, like General Electric and General Motors, spend many millions of dollars a year combating it. They set up development engineering groups—distinct and separate from the corporation's bread-and-butter engineers working on products in production. These development groups have no other purpose in life than to prove that everything the company makes is no good and can be made better. On the broader scale of the country and the war, development engineering is the great missing link in the structure of U. S. technology for war.

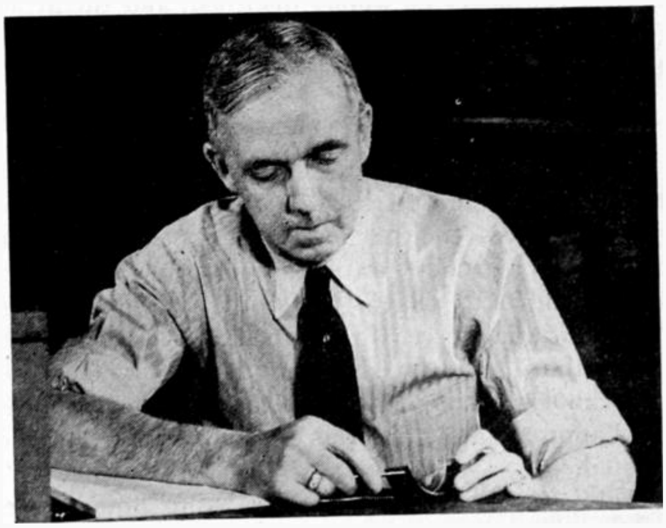
Needed: Engineering

Nowhere in the whole structure can you find development engineering performing its definite function in the whole. OSRD works mainly on long-range scientific problems and parts of problems for effecting improvements in the immediate instruments of war. NACA works on basic problems affecting flight—engine performance and placement, propellers, materials, aerodynamics—but develops no engines or planes on its own. In the life and death matter of aircraft development, the present system works like this: army and navy engineers hand the problem over to the aviation industry in its entirety. There is nothing in itself wrong with this; it is the way to get out production.

Wide World

Engineer Arthur Nutt (Wright): a top in aircraft-engine design.

Engineer A. V. D. Willgoos (Pratt & Whitney): another in aircraft.



Engineer Stanley Sparrow (Studebaker), one of many crack U. S. automotive engineers, developed a light car by adroit weight reduction.

But nowhere is there a body conforming to the cardinal principles of a top development engineering group on a national scale—that is, an entirely separate group of tough, independent, imaginative theoreticians and development engineers, on adequate salary, with no ties to industry, who can call their souls their own and fight radical developments through from idea into metal. Much of their sweat and blood might prove in vain; but there is no other way of prodding inertia. The lack of such a body or bodies between the orbits of the military and industry helps create one of the main bottlenecks of the war: the problem of developing ships and planes and tanks must be turned over *in toto* to big corporations, because only the biggest can afford the needed engineering departments. This leaves the independent engineer or smaller industrial unit, with a new idea or experimental development, baffled and with no place to go. The military ties in closely with the big producers. The military says industry is doing fine; industry says the military is doing fine. It is much too cozy for a war.

The war program is in a stage of violent transition. The ascension of War Production Chief Donald Nelson brought a tightening of war management, sharp action in the conversion of industry, and the moving up around him of young, technical-minded advisers who had been blanketed under the conservatism of the old OPM. Industry is at last beginning to perform some miracles of production. The army has been sweepingly reorganized, and special technical field units are finally being developed to fight this technological war. Even before this appears there may be further drastic shake-ups in personnel, for it is the season when heads are falling. But there is no indication yet that things have changed drastically enough. There is still technical obsolescence high in the army and navy, and deadwood still in WPB and RFC. It is still too much of a financial war and not enough of an engineer's war. Inertia can never be wholly dispelled, and the attack upon it can never cease. A quick look at three broad technological areas will show that all is not yet well.

Three Technical Areas

The points at which technical decisions are made today are the most critical spots in the world. For nothing moves—neither money, nor plants, nor production, nor armies—until the technical decision has been made as to what is to be produced. Technology is the initiating force. If the wrong decision is made, or it is flubbed, or delayed, it may upset a whole series of technological imponderables that can only be measured approximately in terms of time, money, and lives wasted.

Take the case of the Napier Sabre liquid-cooled engine. More than a year ago a British group brought a Napier Sabre to Washington, fresh from successful tests in England, to offer it to the army and OPM. It claimed 2,000 horsepower. It was looked at by OPM production and looked over by OPM's aircraft section. Then from March to August, 1941, the engine rested on blocks at Wright Field, the army testing grounds, waiting to be tested. Army engineers were too busy on the military equivalent of bread-and-butter engineering, or work in production, to get around to it. It never did get around to NACA—for NACA, though it is top body in U. S. aeronautical research, is only advisory and in many cases must wait until a problem or an engine is presented to it. If the army sits on the problem or the engine, nothing happens. So still without a test, the Napier Sabre was turned down by a joint munitions committee of the U. S. and Britain at Washington. Brass-hats pooh-poohed its claims to 2,000 horsepower and doubted whether that power could be supported in a frame—though the Napier Sabre was then flying over England. Not much later, further development of the Sabre in England shot its performance well beyond 2,000 horsepower to a revolutionary new peak in engine output.

This whole lagging episode has various significances. A U. S. development group that had been working months on an experimental engine, shooting at 1,700 horsepower, was finally told to start all over again, aiming at something more astronomical. And meanwhile the U. S. high-altitude P-47 pursuit plane, announced with a great flourish in the newspapers this January as a revolutionary pursuit developing 2,000 horsepower, was hardly revolutionary—though it is a top-rate performer. Nothing is happening on the Napier Sabre in the U. S. The U. S. aviation industry, busy to the hilt on its own developments, and with big plant and equipment investments in them, could hardly be expected, then or now, to be exactly enthusiastic about anything like the Napier. And no one would have the industry miss a stride in its production. But for lack of an independent U. S. engineering group in aviation to catch such developments as the Napier early enough and fight for them, the U. S. continues to miss the bus.

The second great technological area is in shortages and allocations of raw materials. This area is so vast and complicated that no more than a side glance can be given it here. By an intricate series of relationships, the great shortages in metals and materials that develop as the U. S. goes to total war move back upon one another until finally there are shortages in everything except wood, clay, and glass. Unless the highest technological skills in each industry are brought into full play for maximum expansion of production, conservation of materials, substitution of other materials, and allocation of what materials there may be, this can be the most destructive phase of total war for the whole U. S. economy. For at the top of the war economy shortages pinch the big war industries even as they struggle to expand; and in the middle and at the bottom they cripple and wipe out whole areas of smaller industries wholesale. The total result is a further, unhealthy concentration of the economy that may never be reversed. Destruction cannot be escaped in war. Only by making the highest technology of an industry the guiding line—which means free exchange of technical advice and know-how, pooling of patents, and free creation of new competitive plants and processes—can the destruction be limited and shortages attacked at their source.

Except for a few bright spots, mostly in the allocation of hard-pressed strategic metals, this is the darkest side of the war administration's record. The OPM businessmen resisted any big expansion to begin with, and then administered the resulting shortages and necessary allocations generally on the principle that existing corporate hierarchies must be maintained so that all might come out of the war in nearly the same order and positions as they entered it. Nothing is more vain than the belief that life can be picked up at some future date where it left off in 1939, and events are already crumbling the illusion. One of the first fronts upon which it began to crumble was aluminum, where war shattered the notion that production could be expanded without creating permanent competition for the Aluminum Co. of America. But the belief hangs on and still produces delay.

The big and basic shortage implicit in the problem of synthetic rubber is perhaps a classic example. A full-scale U. S. synthetic-rubber plant is an extremely upsetting economic idea, likely in the end to overturn the whole economic structure of a world commodity. The financial mind approaches it with a caution bordering upon reluctance. And rumblings of this mind at work on the U. S. synthetic-rubber program aren't reassuring. A fortnight after Pearl Harbor all basic patents on Buna-type synthetic rubbers were pooled. But an Academy of Sciences technical advisory committee, brought together to review the situation, disbanded shortly after Pearl Harbor with the report that industry was so well ahead on synthetic-rubber research that there was nothing for it to do. And power of action reposed ultimately again in Jesse Jones, who in two months managed to sign contracts for only 30 per cent of the $400 million program. The longer Mr. Jones's mind dwelled on it the more time he wanted, first a year and a half, then two, finally three. With the disposition of an extremely technical program, involving many types of complex raw materials and end products, in such cautious financial hands, it may indeed be years before the American motorist rolls on synthetic rubber.

The third large area of technological action is conversion of industry to war, meaningless without a clear technical plan. Production may roar on at a terrific pace and still produce matériel inferior to or merely equal to the enemy's weapons. For the technology of conversion is again conversion to what. The army, for lack of any independent development engineering, has never had any clear plans for such relatively new weapons as tanks, beyond over-all and general combat specifications. Not until late this February did the tank corps establish its first laboratory to get the basic physical and psychological data for picking tank men and adapting machines to them.

Instead of designing a tank engine—a six months' job for any crack engineering group, and a job that the British did in three months—the U. S. rushed its M-3 tanks into production by pulling a Wright radial airplane engine off the shelf and making it do. It is now generally admitted that the radial engine is unsatisfactory for tanks, and M-3's are being partly discontinued.

In its rush to conversion after Pearl Harbor, and its aversion to pooling its plants as an industry-wide unit, the automobile industry is brewing something of the same, but on a grander scale, for the heavier M-4 tank. It is rushing to develop and get into production on three different versions, or models, of the M-4. One company is planning to make a tank with Diesel power, another is adapting an in-line aviation engine to the job, and a third is improvising a tank with five smaller automobile engines to a unit. There will be a Ford M-4 tank, a G. M. tank, a Chrysler tank (in addition to other M-4 makers), with assorted power units and transmissions. Detroit is going about making tanks as it made automobiles, with all the rigid corporate lines still up, instead of settling for one bang-up standardized model in which each company unit would concentrate all of its engineering skill on developing a part. Instead of working as a cooperative whole, engineering staffs are to all practical intents split into three corporate compartments, each working on a whole tank, and each duplicating part of the work of the others. This might be the best way to go about development, if the army followed up by picking the best tank or best units out of all three tanks and standardizing on them. But the need for tanks is now so pressing that, once the tanks are along toward production, no army supply division will have the opportunity to pick and choose. So the army will use all of them. This will mean a servicing and supply problem in the field of major proportions: spare parts for three different engines and transmissions, in addition to two different kinds of fuel for the gasoline and Diesel power units. Such makeshifts may be the burning order of the day. But they don't represent the highest technology of the world's leader in standardized mass production, and two years have been frittered away for lack of any real technical plan or forethought. It is never too late to make a start.

The World-to-Be

The easiest and most fatal solution to the dilemmas that crowd up in fashioning this technological instrument of total war is to appoint another committee—this time a committee of technical dictators. And the suggestion is often coyly made by various interested parties. But the torn world will hardly be put together by any one group or class or nation of men, but only by a cooperative effort for which we have barely begun to acquire the discipline. The Nazis forced coordination by merely clamping a technical elite, clothed in soulful terms and backed by cannon, over the people and industry alike. America is fighting, if its aims are at all clear, to prove that the rule of such an imposed elite is an unworkable society. But America is now faced with coordinating the workings of its society through the free rising of technical managerial talent to the top and the cooperation and understanding of its people from below.

Democratically this means an unhindered movement of technical skill up and down the line in the military, industry, and war administration. Upward, it means the rise of younger technical men to places of decisive power in the high command. Downward, it means the delegation of responsibility (rather than the continued extension of mere advisory lines) to technical groups representative of the full U. S. technological structure. In such single, major problems as synthetic rubber, for instance, a compact technical committee might be charged with administering the program from beginning to end, with full responsibility for its success or failure. Needless to say, such a technological high command could not be crowded into a single photograph. If there is any key type that might symbolize it, it is the engineer—the doer, the great link between thought and action, the exploratory mind disciplined by the recalcitrant material of the world. Engineering must run as a thread or wire from top to bottom of the U. S. technological structure for war, as the guiding and restraining line upon which everything moves flexibly forward or backward. It must be a wire strong enough to cut any finger that would pull it out of line.

The major fault with the U. S. war effort thus far is that it has not followed even the pattern of its highest technological industries—the chemical and electrical industries. In such great corporate chemical structures as du Pont and Union Carbide & Carbon, which *Fortune* examined in June, July, and September, 1941, it is difficult to see any longer where pure science and development engineering end and practical results begin. This synthesis leads to a flexible structure that accepts as a condition of its existence continual change, continual shifting of processes and equipment into obsolescence over short periods of time. These highly complex industries have come to be conducted by technical committees. Their administrative functions are carried forward by teams made up of various talents, as the capabilities of the men and the character of the problem demand. And at the managerial top a wedding has been achieved between the engineer and man of business. On a vaster scale and to much different ends, this is the general direction in which the country's high command must move if the war is to be wholly won.

The pattern of a du Pont or a Union Carbide cannot be transferred by rote to government, for the ends of government, while they embrace the economic functioning of a du Pont, also go beyond them. In this common task of molding a technological high command the best technical brains of private industry are needed, and their name is legion. Also needed on the highest committees are the best of the independent development engineers, the experimental researchers, and the pure scientists, wherever they may be found: alone, in consulting groups, or in the universities—men like Urey of Columbia, Compton of Chicago, Lawrence of the University of California, the fundamentalists in physics, chemistry, and engineering. Only by the linking of many brains, many men, and many groups do the technological controls reach a workable, democratic equation.

In this war, moreover, the nation is forced to do many "uneconomic" things, such as build synthetic-rubber plants, vastly expand its aluminum plant, and convert industry on a scale never before seen. The practical technical man of industry, long trained to economic ends, inevitably moves in this emergency within a hesitating circle of inhibitions. Without losing the great benefit of his practicality, there is needed as counterfoil the independent scientist and engineer who doesn't pay much attention to economics in his main drive to get something—principle, process, or engine—that works. The compartmentalizing of pure science, and the superstition that it has nothing to do with the practical world until the practical world chooses to notice it, does not build an instrument of total war or a whole society.

This will mean changes, and permanent changes in some of the backward and some of the highest areas of the U. S. economy. Technology, in fact, is bursting the seams of the old politico-economic clothes of the last half century. And the world will cut its political economy to fit the new technology, or a few bitter and brilliant commanders may yet return from this war to tinker with torpedo boats and aircraft in preparation for the next, and, like Lawrence of Arabia, write:

"It felt like morning, and the freshness of the world-to-be intoxicated us. We were wrought up with ideas inexpressible and vaporous, but to be fought for. We lived many lives in those whirling campaigns, never sparing ourselves any good or evil: yet when we achieved and the new world dawned, the old men came out again and took from us our victory, and remade it in the likeness of the former world they knew. Youth could win but had not learned to keep, and was pitiably weak against age. We stammered that we had worked for a new heaven and a new earth, and they thanked us kindly and made their peace."

Wartime Engineering*

ALFRED N. GOLDSMITH†, FELLOW, I.R.E.

Introduction

THE rapid expansion of wartime radio manufacture has created a corresponding need for greatly enlarged engineering staffs. Thus, many engineers working in new fields have been faced with difficult, novel, and urgent problems. Hence, it was thought desirable to assemble in compressed form the guiding principles of engineering ethics, a list of the primary beneficial engineering traits, a study of engineering methods of attacking research and development problems, and a descriptive analysis of design procedure for manufacturing.

The resulting material has been presented before groups composed principally of junior engineers of the RCA Manufacturing Company at its plants at Camden, New Jersey; Indianapolis and Bloomington, Indiana; and Harrison, New Jersey. While the lectures were prepared with the radio-engineering aspects principally in mind, it is believed that the included information is transferable to, and helpful in, other fields of engineering. It is accordingly hoped that it will constitute a conveniently available guide and summary of the art and practice of engineering.

War and the Engineer

While every skilled engineer, to a considerable extent, develops certain methods of his own and successfully applies them, yet there are some general rules which long experience in the engineering field has shown to be safe guides. It is with this thought that I am laying before you in these talks a number of suggestions which, I hope, will prove helpful and constructive. You may not wish to adopt some of them for your own work but, in any case, the suggestions will be before you.

In these trying days, the very essence of success is to work at highest efficiency and to accomplish a maximum of results in the shortest possible time. This is a test period for every engineer, just as it is for our country. I need hardly point out how important it is for us to plunge wholeheartedly into the wartime efforts of the United States. Loyalty to our country, to the organization for which we work, to our fellow engineers, and to ourselves must alike prompt us to make the best possible use of every minute of time and to produce the maximum possible output of high quality.

In normal times a moderate degree of indulgence in certain personal limitations or weaknesses might occasionally be tolerated. I do not mean that such indulgence is ever desirable, but in calm days it can sometimes be pardoned. But in these days of terrific emergency and extreme stress, grim necessity urgently compels the stern repression *by each man within himself* of carelessness, of laziness, of thoughtlessness, and of unco-operativeness.

I hope I shall avoid seeming to "preach" in these talks. I assure you it is not my desire to do anything more than to offer, as one engineer to another, some suggestions that may help each of us and our country. I shall try to give practical advice, frankly expressed, and based on the needs of the present emergency. If occasionally my candor seems somewhat harsh, I know you will understand that these are no times for "pussyfooting" and that my only object is an attempt at genuinely friendly helpfulness.

I shall start with the more general considerations and pass into details as we go along. But in these particular talks I shall not go into intimate technical details of your daily jobs. They are too diverse for adequate discussion in any reasonably available time even were any one man qualified to discuss each of them completely and intelligently. But I am sure you can get help on the questions that arise in your daily work from other sources or from smaller conferences in which you may participate. So I shall here restrict myself to those questions and methods which are of broader use to you and which may help you in tackling the jobs which you face.

Engineering Ethics

As an engineer, each of us is a member of a *profession* and not a trade. That is, we are members of an intellectual fellowship rather than a competitive commercial group. It is important always to remember this in determining our attitude toward our work, our fellows, our company, and our country. As professional men, we have been highly trained over a long period of years. The knowledge of the past has been placed before us in clean-cut form. Carefully written textbooks, painstakingly prepared lectures, the facilities of a university, and all the experience of a great organization have been put at our disposal. Thus you and I owe a great deal to our engineering predecessors, to our families, and to ourselves. And we have the heavy obligation of achieving thorough effectiveness in our work and maintaining unusually high personal standards of conduct and performance. While it would be well if all men were to live up to such standards, yet in our case particularly is it essential that we shall maintain high professional and personal standing.

Under the conditions which we now face, we will find that we have specifically the following loyalties:

First, we owe a great debt to the United States, our

* Decimal classification: 620×R560. Original manuscript received by the Institute, June 1, 1942.

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own country, which is now engaged in a life-and-death struggle with destructive and ruinous forces stemming backward from stark savagery and barbarism. These forces represent a viewpoint which is the antithesis of freedom of thought, integrity and dignity of the individual, and the granting of opportunity to each of us for self-advancement and personal growth. They would represent the stultification and destruction of all that we have been taught to accept as the basis of an ordered, calm, and ambitious life.

The emergency we face is indeed a serious one. Through a combination of incredulity on our part that such violent and unscrupulous aims could exist in our modern world, and through a lack of foresight, "it is much later than we think." Thus time must now be compressed, and extraordinarily much must be accomplished in a brief space. What has been done by our opponents during a decade must be equalled and surpassed by us within a few years. But we have no alternative to accomplishing something which will be almost a miracle. For we shall "hang together or hang separately."

But this does not in the least mean that we must hasten hysterically, fall into a panic, or rush into disorganization. Quite the contrary. It means only that we must face our jobs and the future with steadfast bravery, a cool acceptance of conditions, and a stubborn determination which will overcome all obstacles. Given these qualities, our success and the victory of our country is assured.

While we engineers are conscious that we are members of a profession rather than a trade, we sometimes fail to remember the corresponding distinctions and obligations. A brief consideration of definitions is worthwhile. A trade may be regarded as a business, a special form of handicraft, or a pursuit or activity of a fairly skilled but usual or customary type. There are generally many people capable of following a given trade. Success in a trade does not customarily require outstanding or unusual talents. A profession is an occupation, calling, or activity which necessarily does require exceptional mental attainments and other qualities and involves special discipline, both during the training period and during later professional life. Relatively few persons are provided by nature with the mental and moral equipment to succeed in a profession.

When we examine the differences between a profession and a trade still more closely, we are impressed by the gap between the two—perhaps a wider gap than most of us have realized. The length of time required for training and the scope and demands of the training are both greater for a profession than for a trade. The training of the professional man is indeed long, arduous, and costly. For many years he must acquire knowledge of numerous facts, of methods and procedure, and in many instances must achieve manual dexterity. He must develop habits of thought characterized by exactitude, careful reasoning, and willingness to face the facts, no matter how discouraging or unflattering to himself personally this process may be. A combination of knowledge *and* wisdom is necessary. And these are very different assets, for knowledge, by itself, may be far removed from that skill in its selection, and that judgment as to its timeliness and suitability of application, which are a part of wisdom.

Accordingly the professional man must pass through many years of severe training and must develop a broad viewpoint as to his work and a willingness to serve humanity in the practice of his profession which are less requisite in other paths of life.

The mental qualifications of the competent professional man are numerous and severe. He must be thoughtful, analytic, thorough, honest in his appraisals, and considerably above the average in his mental capabilities.

The character requirements of the true professional man are also numerous. Pre-eminently, he must have high ethical concepts, for it has been found that men who think obliquely and evasively are poor professional material. The professional man is also distinguished by a sense of his commitments to society, to his professional colleagues, and to his own standing. He usually has a feeling of solidarity with his fellows—and this is more on mental, moral, and social bases than from a purely material standpoint. The professional man is self-disciplined. He has a sense of restraint which prevents him from acting precipitately or thoughtlessly or from rushing to hasty conclusions. He has the strength of character to view himself as nearly impersonally as possible and to appraise alike his weaknesses and his elements of strength. At his best, the professional man has a loftiness of attitude which ensures the progress of his field and of himself. He should be more controlled than most men by such ethical concepts as fairness, justice, co-operativeness, and honesty of purpose in his actions.

It may seem to some of us that these ideals are almost unrealizable and perhaps largely theoretical. Yet such is not the case. The viewpoints just expressed have been developed during the long experience of the professions through the centuries and have been found necessary in practice if those professions are to endure and their practitioners are to prosper in high repute.

Professional men are set somewhat aside from the remainder of humanity by their specialized skills, and are accordingly not too well understood. They are also attractive targets for criticism from demogogic politicians, muddled reasoners, and other parasitic or controversy-seeking elements in the community. Against attacks from such groups the professional man has only his own standing and the repute in which he is held in the community as a shield against injury or destruction. It is, therefore, particularly incumbent upon him to practice so far as he can the qualities which have just been outlined. These needs are not mere idle imaginings. These characteristics of the true professional man are rather the results of experience through the ages. They may even be regarded as proven empirically necessary. They have certainly been shown by pragmatic tests to be part of the outlook and code of successful professional men. The pragmatic test is merely finding the answer to the question: "Does it work?" We may be assured that the highest professional standards *do* work—and indeed, their absence is a fatal defect in the case of the would-be engineer. I have not dwelt on the inner satisfaction that the better type of man achieves in living a finer sort of life along the lines of his chosen profession. Yet as the years pass, each one of us finds an inner satisfaction and strength in having pursued, sometimes in the face of discouraging difficulties, a pathway which followed the code of his profession.

I would not have you believe that I am depreciating trades or those who work in them. To the extent that men in commerce or trades elevate their standards, they too can share in the fine standing, worthy accomplishments, and inner pleasure that comes to the true professional man. But those standards, which are perhaps only permissive (though preferable) in the present stage of our civilization when applied to men in general, must be regarded as mandatory for us in the engineering field. To that extent we may be harbingers of a future mankind in a happier world. And we may be proud if we keep the torch of honesty of purpose and pride in constructive accomplishment lit during the occasional darker ages through which humanity may pass.

Toward our own profession, every one of us owes the duty of carrying on a high tradition. Remember that we have inherited the knowledge and experience of the past, accumulated by painful toil, courage in the face of obstacles, and hard and straight thinking over the centuries. It is stimulating to recall that men have endured disbelief, scorn, poverty, intolerance, and even death so that your heritage and mine of knowledge and the capability of mastery over the forces of nature might exist. The least we can now do is to show our appreciation of that priceless heritage. We must forever realize that we are members of a fraternity of intellectual workers.

Toward our own company we owe much the same loyalty as each man on a college team owes to his fellows. Enlightened executives—and there are many of them—have a deep interest in the engineer and abiding faith in his capabilities. These industrial leaders plan the help that can be given to our country through engineering skill. They then promise the Government definite accomplishments based on their faith in what we can do. We owe it to the country and to these men to make good.

As I have said, we are members of a fraternity of professional men. Toward our colleagues we owe frankness, true co-operation, clarity of expression, and unselfish teamwork. The major difference between an army and a mob is in its spirit and direction. Given capable direction and the spirit of unity, an army may confidently look toward victory. Each of you is no less in the front line of defense and offense than the soldier or sailor. We all know well that it takes considerable strength of character and broadness of viewpoint to suppress our little personal weaknesses and petty reactions. Yet it must be done, and this is the very time to resolve that it shall be done. The great engineer is he who does this job of real co-operation the best.

The Engineering Virtues

Every engineer from time to time should try to assess himself frankly and honestly. Self-analysis and self-judgment are stepping stones to greater strength and wider achievement. In wartime or peacetime, the esteem of our fellows and our success in a worldly sense will largely depend on the extent to which we possess and practice certain qualities and methods. There is no use in refusing to analyze ourselves. Our fellow workers and directors will do so in any case, and there is no purpose in trying the ostrich trick of hiding one's head in the sand. Better to determine one's limitations, vigorously try to remove them, and then to walk with our heads high.

The following are some of the major engineering virtues:

Initiative

Life can almost be defined as self-willed motion. When motion stops, life dwindles. Unless a man is ready to "start something" he will get nowhere. Lethargy, uncertainty, indifference, delay, and fear are paralyzing. Enterprise and keen thinking and fast action are the keys to success. Don't be too conservative in trying things out. Remember that a conservative has been humorously defined, with an undertone of indictment, as "man who doesn't believe anything should be tried the first time." The great rewards of history, as well as inner satisfaction, often spring from trying it the first time.

Application

Steady work is an amazing instrument for achieving results. Sweat is the best possible lubricant to keep the wheels rotating. Mere ideas in the abstract lead hardly anywhere. To get results, it is necessary to keep going, and planning, and working even when one is very weary and there is a great temptation to sit back and "take it easy." This last is a fatal fault in an engineer. It is inconsistent with our dignity, our loyalties, and our future success.

There is no good reason for worrying too much about toil. Relatively few people have been ruined by hard work but many have failed through laziness. Lack of application is a costly national or personal luxury. Maybe we have had too much of it in the past; but certainly now is not the time for it.

Originality

Doing the same thing over and over is well enough in its way, but it is not enough during times of stress when unusual results are necessary. Then originality becomes particularly important. Practice imaginative thinking. If you have an idea, carefully cultivate it in detail. Then try to find flaws in it, viewing it with real detachment and in a critical mood. Try to think up numerous alternative ways of accomplishing the same thing. Then compare the various ideas which occur to you as to their respective and comparative merits and faults. Such comparisons lead to a wise and practical decision. Learn to think creatively and in a prolific way. Any man can expand his capabilities in these directions by trying, just as he can develop stronger muscles by exercise. Never be afraid to discard ideas which seem inappropriate or faulty, or accept new ideas, even though radical, if they seem necessary and practical.

Frankness

One of the worst faults that an engineer can have is vagueness, the concealment of facts, or the lack of courage to face facts. Avoid silence where the communication of information is required. And avoid loose or incomplete information where definite statements are needed. We should try to tell the whole story. Science and engineering need the "truth, the whole truth, and nothing but the truth," Substitute candor for double talk, which latter is alike the bane of engineering, politics, and many another field. Engineering does not need "verbal glamour boys"; it demands really creative workers with a genuine output.

Personal Relations

As we all know only too well, it is easy to develop the fault of seeing no good in the ideas or work of the other man. We engineers should keep an open mind. Let us listen very calmly, coolly, and judicially to the other man's ideas. Think how you yourself would react to a scornful, unfriendly, or closed-minded reaction to your own ideas. Try to find something valuable in the other man's proposals, for your own sake as well as his. If you must disagree, after careful consideration, do so courtously and clearly. Explain exactly why you disagree and how far you disagree, and give the other man a full opportunity to convince you with his arguments and reasoning. There is relatively little danger in being open-minded but much hazard in keeping our minds shut.

To get on in life, we must always remember that we are part of a community made up of many diverse elements. Think as well as possible of the other man and of his ideas. And, above all, avoid backbiting. It may be easy to injure the reputation and standing of the other fellow and (with regret and shame be it admitted) there is occasionally a human temptation to play tricks of this kind. But remember that it is probably equally easy for him to hurt your standing. It may be stressed that men generally do not admire the engineer who selfishly depreciates his fellow workers and their accomplishments. This is the easy way to lose friends, standing, and self-respect. Such attacks hurt his fellows, himself, and the general standing of his profession. Our careers depend in part on convincing the executives and others with whom we deal that engineers are broad-minded, capable men who can do things, who are willing to do things, who think well of each other, and who can work together efficiently.

Relations with Your Chief

You may safely take it for granted that those who are directing or supervising your work have been selected because they have had wide experience, have shown an unusual grasp and mastery of their subjects, and have proved that they know how to deal with emergencies and to appreciate good work. Give them your respect and loyal co-operation just as you will wish to receive such help and will need it in the future when you are in charge. Remember that, in the aggregate, they will be sternly judged by what you have accomplished; your company itself will be appraised by the sum total of the efforts of its members; and our country will rise or fall on the integrated efforts and co-operation of all individuals and organizations in the United States.

Engineering Methods in General

In order to reach a certain desired result, as engineers you may apply inductive methods, deductive methods, or both. Let us consider each of these and their most useful applications or scope.

Inductive Method

This is the method where we reason from particular facts or observations to general rules or guiding principles. To carry out such a method it is first necessary to try various experiments. Thus, a number of specific or detailed things are done or methods tried or devices built. Then the results of the experiments or the performance of the devices are carefully studied (preferably with sufficiently exact measurement and test) to see if any underlying rule, law, or more general relationship can be detected.

There are many sorts of relationships from the simplest to the most complex. There are algebraic relationships, exponential or logarithmic relationships, trigonometric relationships, or even unclassified graphic relationships. Sometimes we will find that we must work by the "cut-and-try" method, determining by trial and error whether we have found a simple relationship between two or more quantities or elements in an experiment. It takes a good deal of skill and some experience to separate the essential from the unessential in such work and to discover whether some unforeseen or undesired factor is affecting the results and obscuring an otherwise simple or definite relationship. This is a case where we will find that there is no substitute for patience, thoughtfulness, and experience.

If it is thought finally that such a law or relationship has been found by the inductive method, it is checked again and again (though not necessarily immediately) by trying out experiments which develop from those which we have already completed, endeavoring to predict in advance the anticipated results by application of the supposed law; and then noting whether the facts and the theory still agree. If they do not agree, either the theory is wrong, or it is inapplicable to the particular case for some reason that must generally be determined speedily if further progress is to be made; or else the theory is incomplete. In the last-mentioned case, some important and contributing or controlling factor or factors have been omitted from consideration. These must be discovered if the law is to be expanded into a reliable guide. There is at least one other group of possibilities, namely that the experiment has been incorrectly performed or its results wrongly set down or its meaning misinterpreted.

In other words, if the relation which we have derived does not work out, we must not be content to say that theory and practice seem to disagree—we must try to find out *why* they disagree. A correct and complete theory cannot disagree with practice, although an incorrect or incomplete law will not be a useful guide. Often in finding out why theory and practice do not agree, you and I will learn valuable and helpful facts.

The inductive method is principally used by scientists and engineers in major or minor research projects where the experimenter is working at or near the boundaries of available knowledge and is trying to discover really new physical or chemical facts, methods, or laws.

Deductive Method

In applying this method we reason from the general law to the particular instance. Thus we start with a supposed law, which has been found to be correctly applicable in the past and sufficiently complete and wide in scope to cover the assumed special instance under consideration. We then apply this law and predict a result or effect.

After the experiment is tried, we see whether the desired and predicted results are actually obtained. If so, we have another apparent strengthening of the law, and we have added confidence in its usefulness. If, however, the desired and predicted results are not obtained, we must make every attempt to find out why the law has seemingly failed. Merely abandoning the quest is generally insufficient. Perhaps the law was incorrectly applied. Maybe some other factors vitally affecting the results were omitted from consideration. Possibly the equipment under test was not correctly built or did not operate in the manner assumed by the designer. Or, finally, there may be a flaw or exception or limitation to the supposedly controlling law.

We should try to find out which is the case, as this will enable us to try the experiment the next time with a better chance of success or to determine how the law had best be modified or replaced in order to make it a safe and reliable guide.

Deductive methods, as might be anticipated, apply more usually in development work. Sometimes, when laws are well established as to their validity, scope, and completeness deductive work runs smoothly and to the satisfaction of the experimenter. However, this is usually the case only in long-established and well-covered fields. In general, even clever deductive reasoning requires caution and keen analysis at each stage

Sometimes both inductive and deductive methods are used or mixed in handling the same problem. It generally takes an experienced worker with a wide knowledge of his subject, much experience, keen facilities of observation, and something of what we call (for want of a better term) "intuition" to handle such a problem by the use of the mixed methods. But it can be done and it frequently saves a great deal of time and effort. Intuition seems to be a sort of inner guidance or inspiration, dependent upon accumulated knowledge of a subject, and stimulated by the need for accomplishment and the urgent requirements of a situation.

It is a good idea in determining our methods to study carefully our own capabilities and preferences. As a general rule, the man who is most at home in research work and does it most naturally and best, is not so capable a development man as he likes to think he is. Similarly, the skilled development or design man who by instinct and experience develops equipment and methods readily may be a less effective pure research worker than he believes himself to be. For these reasons, every experimenter or designer should study his own capabilities carefully and impartially, if that is possible, and find out what type of work he does best. He should then endeavor to be assigned to that sort of work.

Further, if a man finds that he does his best work in a given sphere of activity, after he has carried any job to the point where it is about to pass out of that sphere into the next region, he should willingly turn it over to the next man for further work or completion. To speak in a blunt but friendly way, don't try to hog the development road—you may merely block traffic. Many a good research man has stuck to a job long after a development man should have taken it over and turned it into a commercially useful article. Often enough a development man has gone further into detailed design or manufacturing problems than is desirable or, on the other hand, has slipped back into research work where it would have been better to refer the unsolved problem again to a research specialist.

The advice I have just given does not mean that we should be without interest in any type of work other than our own. Quite the contrary, for it is an excellent idea to know something of the type of job which is done by the men who handle a problem before and after it reach us. In that way we can best understand what is meant by the data or model or plan which reach us and we can somewhat shape our own work to give our results or models to the next men in a form which will mean the most to them and will help them to carry on speedily. But avoid contracting that prevalent and contagious disease: "designer's itch." This grave ailment will make us satisfied with nothing that reaches us and will force us to try to change or redesign almost anything that passes before us. A little healthy appreciation of the other man's work and a broad attitude, applied daily to the mind, will be an effective remedy for this disease.

Engineering Methods of Attacking Problems

Let us suppose that a problem has been submitted to us or a job assigned to us. What should be done next? While there are no general rules in the nature of a universal panacea that cures all ills, here are a few hints. In a long experience in such matters, they have proved to be sometimes useful.

In general, it is very helpful to start out by finding out *what is known*. That is, search for and thoroughly study the existing information on the subject. Don't depend too much on your memory for facts, figures, or methods. Even the most experienced engineers can easily enough forget very pertinent facts. I cannot too strongly stress the thought that it is no disgrace to have to seek information. Quite the contrary; for the search for information betokens the open and inquiring mind and the resolution to accomplish the desired results. As a matter of fact, it is sheer folly to insulate ourselves from sources of valuable data. Conversely, when anyone approaches us for information, let us try to help him patiently, remembering that we shall probably be in the same boat, and for the same good reason, before much time has passed.

There are a number of ways of finding out what is known which may prove useful to us. The simplest and most obvious one is first to go to the best available *textbooks*. We may get some general or specific data that way. The more nearly routine the problem, the more likely we are to find help in available texts. It is advisable to make notes at each stage of our study so that, when we have completed our investigation, our notes can be digested, summarized, and used as a guide. Great care and some patience is necessary in making notes. It does little harm to make notes too complete or elaborate, but it does a great deal of damage to have them so incomplete or brief that we have difficulty in interpreting them at a later date.

Let us see if the engineering *handbooks* have any available information on the devices or methods in which we are interested. If so, we shall make notes of them, entering a specific reference with each note so that we can relocate the full information in the handbook or textbook if we so desire. In fact, it is a good idea to give definite information as to where we located *any* data, in the form of a specific reference in our notes.

To get more reference material than is obtainable by the above methods, we should resort to the *published papers* in the major engineering journals. It is sometimes difficult to locate the desired references in an engineering journal. However, the annual or other indexes of these journals will be of some help. The card-index system of an engineering library may also assist us. If we know the names of the engineers who have worked in a given field, we should look them up in the index or file so as to locate their papers which may bear on the subject at hand.

It is usually possible to accumulate a fairly full list of references on a given subject by a process of aggregation. One good reference article may give us a number of other references dealing with the same subject, which latter articles, in turn, will provide additional references. Thus we may soon accumulate a good *bibliography* of the subject and, in the process, a detailed knowledge of the particular field. The *reports* of our own organization's engineering staff are often helpful, and should be liberally consulted. They will usually contain more detailed and practical information than can be found in the average publication. *Standards reports* of the manufacturing associations (for example, the Radio Manufacturers Association or the National Electrical Manufacturers Association) or of engineering bodies (for example, the Institute of Radio Engineers, the American Institute of Electrical Engineers, and the American Standards Association) may prove helpful. Now and then issued *patents or* accessible patent *applications* will also be instructive. But we should keep in mind that patents and patent applications are not necessarily completely scientific presentations in some cases nor will they always furnish the most useful forms of technical data. They should, therefore, be taken as interesting and suggestive but not necessarily final in every instance.

Speaking of reports, the technical reports prepared by you should be carefully written and in such detail as will enable others to understand fully what you have found and described. Technical-report writing is a real art, and it is well to read and assimilate good books on the subject for your guidance.

It has been found that home study in the evenings, or even during part of the day, is sometimes not a bad idea at this stage of a new project. Frequently the change in surroundings or the quiet of the home may prove helpful in accomplishing a good deal in the assembly of data and in getting new ideas. It is usually a helpful plan to have loose-leaf notebooks for the data we shall accumulate or even to use a card index for particular subjects or fields in which we steadily work. These are useful tools for the engineer.

Continuing our process of finding out what is known, we must not hesitate to call on our *fellow engineers* (but try to avoid interrupting them at a particularly busy moment). There is no odium or loss of standing involved in asking questions. Nobody knows everything about a subject. Then too, we may be able to help the other fellow a little later on and he should be willing to give us what assistance he can at each stage.

In trying to get a definitely new idea, "hunch," or inspiration, don't force the issue too hard. Overstraining in an attempt to get a new idea may have the opposite effect. One can become stale or overtired in that way. There are no rules governing the arrival of an inspiration. Some men get their best ideas in the early morning working hours, others in the late afternoon, and still others say they tend to get their new ideas during their normal hours of sleep, perhaps waking up with the answer to the problem which has been bothering them. It is not a bad idea to study your own reactions and to see into which of these classes you may fall. You can then try to arrange some of your work so that you can sit back and think intensely and take notes of your ideas at those times when experience shows you are mostly likely to "find the answer." It is thoroughly in order to make a great number of sketches and to jot down a considerable group of alternative ideas on any subject without analyzing each of these too thoroughly. Thus you will have a number of alternative plans in your notes, secured when you were in an "original mood." You can always analyze each of these later for its advantages and defects thus choosing at last the one that seems most hopeful and likely to work out in practice.

Occasionally it is a good plan (if conditions permit) to lay aside work on a particular problem for awhile, and instead work for a spell on some other job. A return to the original problem in due course will sometimes show that considerable progress toward its solution has somehow been made in the intervening period.

And now, suppose that we have found what looks like a plausible or probable solution, method, or design. We shall then be ready to start putting our ideas into equipment, such as an experimental, functional, or "breadboard" model, or even what we hope will be the final manufacturing form. If we wish to make only a functional and experimental model we need consider only the requirement that it shall produce the desired result regardless of its adaptability to manufacture. But, if we are tackling the even more difficult job of making a manufacturing design—and this, it must be stressed, is an entirely different matter—we shall have to consider many additional problems of design as well as factory methods and limitations and economic controls. But in either case, this is the time to plan the model, of whatever type, very carefully. Consider in detail just what the model must accomplish. How can it be made most simply, and from the least possible number of parts? What parts are already available? Be sure to utilize these as a matter of economy of time and money. Even in building a purely experimental model, let us try to imagine as far as we can what the final and manufactured form will be like ultimately and then make our model as much like that as possible (unless we are in so early a stage of a development that it is not practical to visualize the final commercial form of the device). Keep our setup as simple, complete, and reliable as possible; but let us not waste time on unimportant details. Cultivated good judgment along these lines is an important asset to the development and design engineers.

In making tests and observations on our setup, we must watch not only for the desired results but also for any odd, or unexpected, or undesirable effects or performances. Very close observation is important at this stage. A great many new things can be learned in that way and many future "headaches," or "bugs" in the apparatus, can be avoided. Your general slogan should be "watch closely and think hard." Avoid distractions and try not to hear or see what is going on around you unless it directly concerns your work. Develop, if you can, "earlids"—they are as useful in shutting out undesired sounds as are eyelids in keeping out intrusive scenes. Stop, look, and think!

There is another thought which may be particularly important to us in wartime development and design. It may sometimes seem to the engineer that the requirements of the Army, Navy, or Air Force are unnecessarily stringent or detailed. But it is well to remember that, while the customer may not be invariably right, it is an excellent idea to give him every benefit of the doubt. This is particularly the case in connection with military divisions of the government in wartime. They are closest to the actual use of the equipment under the stringent and grueling field conditions. They have had experience in the difficulties which arise in its use; they must live with it; and they generally will have a more complete and clear conception of service conditions which must be met than designers who have not been active in the field for a long time. Accordingly it is wise to keep an open mind on specifications even if they look too stiff. However, it is in order to ask questions as to the reasons for them. And if we have unusual difficulty in meeting them, perhaps the specifying group may be able to suggest a solution or even to provide for us a model of something fairly similar to what we are supposed to produce and thus help us to "make the grade." Don't hesitate to ask for help in such directions, particularly under the present emergency conditions. It is readily possible to be too "dignified" in such matters. You will often find that the customer can be a helpful friend.

Engineering Factors Guiding Design

All products logically start with a clear concept of their purpose, general construction, and mode of use. It is a difficult task then to translate them from the mental field into the world of physical things. This process involves the element of skilled design.

Design itself may be regarded as a means to a certain end. Its procedure is controlled by the function or use to which the product is to be put, the availability and suitability of the materials which go into the product, and the methods of construction and test which are at hand.

The use to which a product is to be put necessarily determines its functional design. That is, unless the design from the very beginning is such that the device will produce the desired practical result, no progress is possible.

Nevertheless, a merely functional design, however interesting and encouraging, is usually not in itself of major practical importance. It must be possible to manufacture the desired article readily, at a reasonable cost, and within acceptable limits of time. The availability of suitable materials, and of methods of handling such materials, determine whether the proposed design is manufacturable and economic. There may be many methods of translating a functional design into a manufacturing design, but some of these will be too complicated, too costly, or too slow to meet the requirements.

There is no substitute for good judgment and careful analysis. Accordingly designers should avoid plunging hastily in a direction which, for the moment, seems attractive. Rather, they should carefully analyze a number of possible methods of passing from a functional design to a manufacturing design. They should then select that particular method which best fits the current conditions.

One of the worst mistakes an engineer can make is to start design work without carefully considering the numerous guiding factors governing the nature and use of the desired product and then translating these factors, perhaps in tabular fashion, into corresponding physical embodiments. This should be followed by a thoughtful comparison of the various possibilities and the selection of that one which, on the whole, offers the maximum advantages and the minimum disadvantages. Rarely, if ever, will any decision be free from disadvantages—but good judgment and the relative appraisal of advantages and disadvantages will go far toward contributing to the success of the engineer. It is natural enough to be impatient with delay and to desire to get started on a job immediately. But yielding to these natural desires is frequently costly in time and money, for the later rectification of early mistakes is a sorry and trying job. "A thought in time saves nine."

There are a great number of factors which markedly control or influence the design of a given piece of equipment. Some of the most important factors are the following.

Nature of Specifications

Specifications are a sort of bible to the designing and planning engineer. Many an engineer has invited—and encountered—serious trouble by not reading the specifications sufficiently closely and then checking on reliable methods of meeting each and every feature of the "specs." Take the specifications very seriously. If you don't expect to be able to meet them, it is better to say so in advance and try to have them modified or else secure such help as will enable you to meet them.

It is important to be sure that every element in the specs can be met before the job is started. Once the design is well advanced, it often becomes an appalling task to change even one element without scrambling many of the others. Delays and changes in the later stages of the work are extremely costly and time-consuming. And it must be remembered that now, more than in any other period in our history, time is of the essence. Peacetime standards may not be adequate for wartime needs. To repeat, let us take the specifications seriously, plan meeting them in advance, be sure that each element can be met before we start, if that is at all possible, and make every effort to avoid changes in the latter part of the development or design.

Conditions of Use

Obviously it makes a great difference under what conditions equipment is to be used since these conditions will vitally affect its design and required performance. Such questions as the following arise. Will the device be subjected to marked temperate changes? And with what effects on the materials and operation of the device? Or to wide changes in barometric pressure (with possible consequent high-voltage insulation problems)? Or to high humidity? Or to heavy jars and violent vibrations? Or to sudden accelerations? Will it be used continuously or only intermittently? Must it stand up under frequent and even prolonged overload? Must it be handled in the dark, and how? How noisy are the likely locations of its use? Must the operating personnel wear heavy gloves? Is it fixed, portable, or transportable equipment? Is it required to work in any position? Will many assemblies of the device be made, or only a limited number? Must it fit into a given space, or pass through openings of a limited size? From which side or sides must it be operated? How shall it be installed or removed? How is it associated with adjacent or near-by equipment? Is it a well-standardized type or is it likely to be changed shortly? Are weight considerations of prime importance? How skilled are the personnel who are likely to use the equipment? What service problems must be met in advance?

We should try to accumulate as complete a list as we can of such working conditions, and then to give them major consideration in design and construction, as well as subsequent test. These requirements are of interest even in experimental models but are of course vital in the manufacturing model and design.

Servicing

Every piece of equipment may develop some trouble sooner or later, and often enough at an entirely inopportune or dangerous time. Hence it is generally necessary that servicing problems shall be reduced to a minimum. Breakdown might occur at a tragically wrong time and place. Accordingly parts should be as far as possible conveniently accessible, easily removed, and readily replaceable (if there is any likelihood of their failure). Appearance is generally less important in wartime equipment than great convenience of use and reliability. The training and methods of the personnel who will probably do this servicing must be considered in each instance. Let us not hesitate to ask questions in these regards if we do not have the facts. A question is less embarrassing than an apparatus breakdown.

Cost

It is obviously necessary that the designer of equipment which is to be manufactured from his plans must be thoroughly acquainted not only with the design processes but their capabilities, limitations, and costs. It takes years of experience to become a master in this field but everyone should make a good start. As apparently simple a factor as the permissible tolerance set by the designer for a given dimension, or the reference point or plane of such a tolerance, may make a device either practical or impractical from the viewpoint of the factory expert. Further, it may make the product economic, or, on the other hand, unsalable. The same comment holds for specification of materials, finishes, and fittings. Thus there must be very close co-operation between the designer and the factory men if there is to be speedy, uninterrupted, and economic production.

Drawings

Most large plants have specifications for standard drafting practice. Such practice may differ from plant to plant, and it is necessary to be thoroughly acquainted with the practice in our own company and systematically to adhere to it. Not only the designer but also those engaged in development work should become thoroughly acquainted with this material since it dictates a line of thought and procedure which is useful to all and which may short-circuit otherwise costly and unnecessary misunderstandings or errors. It is extremely wasteful and dangerous to make "off-standard" drawings.

Interchangeability and Economy

Most modern manufacturing, particularly on a mass-production basis, depends on some form of interchangeability. Interchangeability, in its most complete form, enables the assembly of a complete device from component parts selected at random from lots of each of such component parts. That is, an operative device will result from the assembly of any available components. The advantages of such a possibility, both at the plant and under servicing and replacement conditions, are obvious.

In some forms of interchangeability only the subassemblies can be assembled at random to form an operative whole. These subassemblies form normal groups or combinations of parts. Sometimes the same subassemblies can be used as parts of a whole group of devices, which again increases economy in manufacture.

Selective interchangeability is another type in which all component parts are classified or graded into groups. A selected group of one component will then combine with a correlated selected group of another component, and so on. The advantage of selective interchangeability is mainly the broader tolerance in manufacturing each component which then becomes acceptable. On the other hand, the components must be classified or graded, and complete interchangeability in servicing may no longer be possible (that is, a certain amount of modification or machine work may be required from the servicemen).

Economy and speed in manufacture are largely associated with a wise and corresponding degree of interchangeability. Very careful design of the manufacturing model is involved in interchangeability. As previously indicated, the manufacturing model will generally differ markedly from a merely experimental or functional model. The functional model need only carry out a purpose or requirement and perform a certain job. However, it may be in a form inappropriate for manufacture or normal use in practice. Needless to say, manufacturing models should be designed with the help of the factory men. The construction of such models, their assembly, and their performance should be checked systematically in the factory throughout the manufacturing process. Any errors in the manufacturing design or in the process specifications can thus be corrected, the records made complete and instructive, and the lessons thus learned can be embodied as improvements, or in the avoidance of errors in later designs.

In the modern plant, fixtures, specialized machine tools, and cleverly contrived gauges, all play their part in economical production and in the obtaining of that precision which is required for the desired type of interchangeability.

Materials, Processes, Finishes

In his selection of these factors, the development man and the designer can prove himself to be either a skilled and valuable man or the opposite. The designer should ask himself many and searching questions as to the available choices in each case, the advantages and disadvantages of each of them from the manufacturing and customer viewpoint, the relation between each of them and the corresponding saving of time in production (with particular reference to the needs of war production), and the cost and labor requirements of each. Minimizing the demand for highly skilled and experienced labor is important at this time.

Unusual materials, processes, or finishes are strenuously to be avoided because of the delays, chances of error, and high costs they introduce. Only where they can be proved to be absolutely indispensable should they be considered.

There are usually available in any large factory assembled data on standard shop practice. Here again we have material which is of great value to the practical development or design engineer and which should be thoroughly understood and applied by him.

Over-all Reliability

One of the characteristics of most adequate designs is that they are "balanced." That is, every part of the device is designed from a given viewpoint as to cost, performance, and reliability—and the criteria apply alike to each part of the design (except perhaps a few parts which, for some special reason, require unusual precision or particular care or better materials than the rest). Designing for an over-all equalized reliability permits the user to judge more accurately what will be the probable life of the device in actual use. It contributes to economy in manufacture. Further, it prevents some one weakness from unfavorably controlling or limiting the useful life of the device. It requires considerable experience and good judgment, however, to design equipment so that it will run something like the "one-horse shay."

In closing, I would like to suggest that we all go through a mental overhaul, so to speak, every few months. It is astonishingly easy to get into a rut, or to drift behind the times. Let us review the thoughts which have been laid before us, and the experience we have gained. We shall decide whether we have used both of these to the full. We should keep notes of our own on the experiences we have had and draw conclusions from them which will serve as further guiding ideas for our own use in the future.

And, if you have any suggestions which you think might be useful to others (and I am sure you will have), I hope that you will convey them to your directors (or even send them to me) so that they may be made more generally available. We have a tough job ahead of us, so let's all pull together and get it done promptly.

And we should always remember that our work is being increasingly appreciated and judged to be of paramount national importance. In its leading editorial on December 26, 1941, *The New York Times* said:

"As this war developes we can be increasingly thankful that we need no 'propaganda' to convince ourselves of the necessity and justice of what we are doing. All argument was silenced at Pearl Harbor. More and more this nation will value the gifts of certainty and of unity which our enemies bestowed upon us by their very act of aggression. Few causes and few wars are as simple as this one has become. The defeat of the Axis Powers has become as well-defined and essential an objective as was, a generation ago, the completion of the Panama Canal.

"We suspect that it arouses a not wholly dissimilar emotion. We have grown up since 1898, when we looked for 'glory' in our brief and one-sided war with Spain; and even since 1917, when an exalted and Utopian mood seemed necessary. *Today's war requires the industrial and engineering type of heroism and fortitude. It requires planning, patience and exactness.*

"We know that war itself is not glorious, though there is glory in some of the qualities which it reveals and utilizes. We shall give praise to every American, soldier, sailor or civilian, who forgets risk and hardship and does his duty, or more than his duty. But principally the mood of this nation at this moment, if we may judge by what is said, written and done, is reflected in a desire *to get on with the job, and get done with it*. One may well believe that this is a frame of mind more dangerous to our enemies than the fanaticism of Berlin, Rome or Tokyo is dangerous to us. For, after all, the fanatical phase passes and is always limited to a minority in any nation, whereas the sober determination to finish what has been begun will engage a majority to the end.

"We think there prevails in this country a grim resentment at the necessity of devoting wealth, ingenuity, labor, courage and precious human lives to the ugly task of sanitation which the Axis has, by its existence, created. We have been interrupted at our work. We want no more such interruptions, and, God helping us, we will have no more."

Fellow engineers, we are in the first line of defense and offense. Let us then *think straight, plan well and work hard* to bring for all of us a brighter tomorrow.

Navy to Commission Radio Engineers*

JAY L. KERLEY†, NONMEMBER, I.R.E.

THE United States Navy is now offering commissions to men experienced in the field of radio engineering, with rank commensurate to their professional standing. Men interested in entering this branch of the service may obtain full information from the offices of Naval Officer Procurement which are being set up in all large cities.

The uses of radio on ships, planes, and submarines are so widespread—both in direct communication and for special purposes such as direction finding—that the Navy needs a large number of people with experience in the design, development, and test of modern television and radio apparatus. A college education normally is required, but it will be waived in cases with unusually good experience. A reasonable state of physical fitness is necessary, but the prime requirement is technical ability—engineering and service ability.

The commissions, which are granted in the Naval Reserve and run up to the rank of lieutenant commander, are similar in all respects to those in the regular Navy—the reserve officer carries the same responsibilities and is eligible for the same privileges as the regular officer. He receives the same pay and allowances, he wears the uniform at all times, and he is subject to orders to anywhere in the world at any time. The pay and allowances vary from $143.00 to $440.00 per month, depending upon the rank and duty station. Uniforms are at the officer's expense, but may be obtained ready-made in the larger cities, and only the necessary number are required at present. When the reserve officer has obtained the required clothing list, he becomes eligible for a uniform gratuity of $250.00.

After his preliminary interview with a Procurement officer, the candidate will receive a formal application to be filled out in triplicate. This includes a certified birth record or sworn statement of citizenship, a transcript of college education, three letters of recommendation, and names of three sponsors. After the application is received the applicant is called in for physical examination and formal interview, all sponsors are contacted, and others asked regarding the applicant's fitness for a commission, all of which takes about six weeks. The date of submission of the formal application is important, in that if a commission is granted it serves to cancel any conflicting orders—such as a call by the local draft board—received in the meantime.

With his commission the candidate will receive his "acceptance and oath of office," and he is no way bound until he signs the acceptance and takes the oath, "to defend the Constitution of the United States against all enemies foreign and domestic and to well and faithfully discharge the duties of the office . . . . ." With his commission he may receive his orders to active duty, most of which give him four days plus necessary travel time to get to his duty station, and which become effective on the day he accepts his commission.

Most newly commissioned officers are being sent to a specialist school for five months before reporting to their active-duty station. The reservist is given full pay during his schooling and receives transportation from home to school and from school to his duty station. He can collect transportation for his wife from home to the active-duty station, provided it is within the United States.

The new officer may be assigned active duty in the Bureau, designing new equipment; at a Navy Yard or air field, installing and servicing equipment on the ships; on a repair vessel, servicing equipment; or on a combat vessel servicing the equipment and directing the enlisted personnel in its operation. Nominally he directs others, but there will be many times when he must handle a soldering iron and a pair of pliers. He is apt to live in work uniform—there is plenty of hard work and little glory.

Obviously, no one can foresee the conditions at the end of the war. The reserve officer can, however, plan on being released to civilian life sometime within a year after cessation of hostilities, when he will not sever connections with the service (unless he so chooses), but will retain his commission and an inactive duty status. (This is the difference between a reserve and a regular commission.) The advantage in holding his commission is that in case of another war or a national emergency, he would be recalled with his full rank. When in an inactive status the reservist is not required to drill, or take training duty, although he may do so if he wishes and if facilities are available. Since he was originally commissioned for his professional ability he is merely required to maintain his standing in his profession, and a reasonable standard of physical fitness.

The special-service commission offers an outstanding advantage to professional men, for it practically is the only way that he may serve in the armed forces without losing years of professional experience. As his duty is the pursuit of his own profession, his years in the Navy may be listed as practical experience when he returns to civilian employment. Further, certain

* Decimal classification: R565. Original manuscript received by the Institute, April 8, 1942.

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radio applications that presently are secret will undoubtedly find commercial uses in peacetime, offering to the reserve officer a unique opportunity to be an experienced man in a new field.

A preliminary interview may easily be arranged at any of the Naval Officer Procurement offices, at which time questions will be answered and professional fitness for the service determined. Those who are not near an office may write in, giving a detailed description of their education and training.

A New Frequency-Modulation Broadcasting Transmitter*

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Summary—*A new frequency-modulation transmitter is described which uses a novel amplifier circuit permitting an unusually simple mechanical design and an economical vacuum-tube complement.*

The choice and design of circuit components, governed by both mechanical and electrical considerations, are discussed in detail.

THE DESIGN of a commercial broadcasting transmitter for the frequency-modulation field requires the engineer to adopt some unique viewpoints. Even more than in circuit-development work at standard broadcasting frequencies, the goal of the designer now is the utmost simplification of the circuit and circuit elements. Each additional coil, condenser, or other piece of equipment introduced to improve performance brings with it additional complications in the form of stray capacitances to ground and reactances of connecting leads. Frequently, these stray elements are in such a location or of such magnitude as to preclude the entirely satisfactory operation of an otherwise desirable design. Much of the engineer's efforts are centered on the determination of the physical location of the circuit components which will minimize the deleterious effect of stray reactances, always with the hope that this minimum may be sufficiently small to permit satisfactory performance of the transmitter under everyday commercial conditions. Frequently it is discovered that with all his care the designer is faced with an irreducible minimum of strays that, while small, has an astounding ability to irritate and annoy.

In the face of such a situation, it may be possible to modify the circuit so that the undesirable reactances become harmless. This paper describes just such a solution to difficulties encountered in the development of a 10-kilowatt transmitter for frequency-modulation service.

Since a successful commercial transmitter of 1-kilowatt capacity[1,2] was available and was suitable for use as a driver, this account will be confined to the problems involved in the design of a 10-kilowatt amplifier, together with the associated power and control equipment.

One of the commercial objectives was the use of air cooling for the amplifier stage of the transmitter. The large physical dimensions of the plate-cooling structure on air-cooled tubes capable of delivering the necessary power at once focused attention on the stray capacitance that would exist from the plate of the tube to ground. Preliminary calculations indicated that this capacitance would be of the order to 30 to 40 micromicrofarads per tube, a reactance of some 80 to 100 ohms in the frequency-modulation band.

Fig. 1—Western Electric 389AA vacuum tube.

A new air-cooled vacuum tube recently made available (Fig. 1) offered the first help, since performance data indicated that a single tube would be adequate to deliver the required output power. A calculation of a single stage using this tube showed the rather large loss of some 800 watts in the plate tuning coil, even with a coil having a Q of 400. Of even greater concern was the sharpness of the circuit (high ratio of reactive volt-amperes to watts) which would considerably

* Decimal classification: R414. Original manuscript received by the Institute, December 4, 1941. Presented, Summer Convention, Detroit, Michigan, June 23, 1941.

† Bell Telephone Laboratories, Inc., New York, N. Y., and Whippany, N. J.

[1] J. F. Morrison, "A new broadcast transmitter circuit design for frequency modulation," Proc. I.R.E., vol. 28, pp. 444–449; October, 1940.

[2] W. H. Doherty, "Synchronized FM," *Pick-Ups*, pp. 3–5; August, 1940.

increase the difficulty of securing satisfactorily low distortion over the audio-frequency modulating range of 30 to 15,000 cycles at the full swing of 75 kilocycles.

W. H. Doherty of the Laboratories suggested the use of a novel circuit which offered distinct advantages for use in high-frequency amplifiers. A schematic diagram of a conventional triode amplifier is shown on Fig. 2 and the corresponding diagram of this new circuit on Fig. 3. It will be noted that the new circuit differs essentially from the conventional one in moving the radio-frequency ground connection from the filament of the tube to the plate, the plate being grounded through the by-pass and blocking condenser C_1. Since the capacitance of C_1 should be large (have low reactance) the stray plate-to-ground capacitance in parallel with it becomes of no further importance, and is replaced in the circuit by the much smaller filament-plate capacitance. In this "grounded-plate" amplifier the tube filament is, of course, at high radio-frequency potential above ground, and the problem of supplying the filament current is most easily solved by constructing the plate-tuning inductance of hollow tubing and threading the filament leads through it as shown. This places the transformer end of the filament leads at radio-frequency ground potential and avoids the hazard of operating filament transformers above ground. The radio-frequency driving voltage is applied between the filament and grid by a coaxial transmission line wound in parallel with the coiled tube which encloses the filament leads.

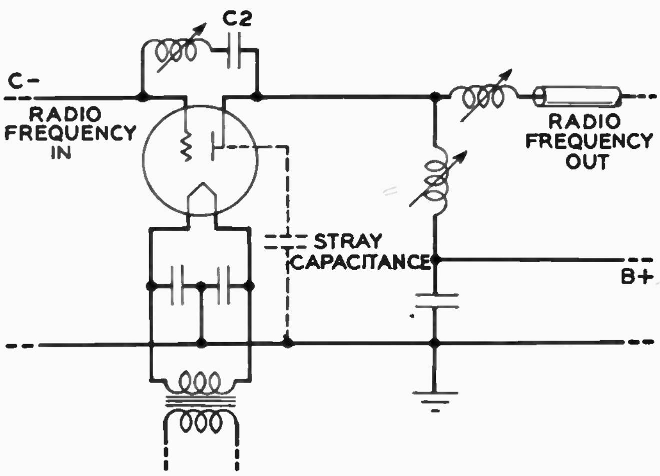

Fig. 2—Schematic diagram of conventional amplifier.

The design of a stable, efficient, and compact amplifier now appeared much more promising. It will be noted that the grounded plate circuit lends itself admirably to the mechanical design of the stage. Past experience had shown that inductive (coil) neutralization and tuning permitted the "broadest" circuit possible and hence the lowest distortion. In this circuit inductive neutralization requires only the connection of an inductance between the grid of the tube and ground. This same neutralizing coil also conducts the negative bias potential to the grid of the tube, with condenser C_2 blocking the direct-current bias to ground.

The plate by-pass condenser C_1 must be insulated for operation at the direct plate voltage employed and carry the radio-frequency plate current. The plate-cooling fins of the tube must be enclosed by a sleeve or duct to confine the air stream to its proper path. In the design of this amplifier the functions of plate by-pass condenser and air duct are combined by the use of a dielectric tube of the proper diameter to slip over the cooling fins. The inner and outer surfaces of this tube are silver-plated to form the two plates of condenser C_1. The outer coating or plate is grounded and the inner coating makes contact with the plate structure of the vacuum tube. Such a condenser structure favors a uniform distribution of current over the conducting plates and has a form that presents no assembly difficulties in attaining a satisfactory product.

However, the neutralizing inductance previously mentioned presents several problems. First and foremost, the inductive reactance should be smoothly variable under power to facilitate the adjustment of the circuit. This coil must be designed to carry currents of the order of 30 amperes, which necessitates a conductor of ample proportions, and precludes the use of a small compact unit. Proper neutralizing requires adequate shielding of the neutralizing coil, and the large dimensions and current-carrying capacity involved increase the difficulty of such shielding without excessive length of connecting leads. The problem of a sliding contact or other means of varying the effective inductance introduces further difficulties in coils carrying high currents. Arcing and burning of contacts are all too familiar occurrences. A coaxial transmission line shorter than a quarter wavelength, short-circuited at the receiving end, offers an almost ideal inductance for

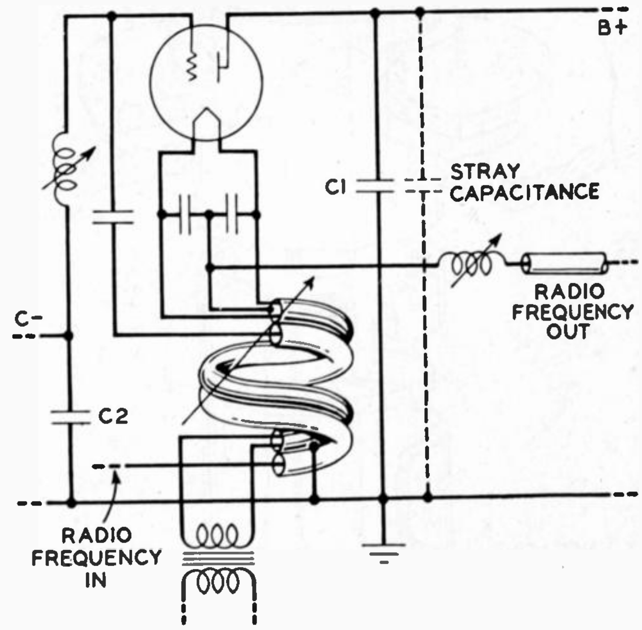

Fig. 3—Schematic diagram of grounded plate amplifier.

this circuit element. A movable bridging contact is used to vary the inductance of the line by changing its effective electrical length, and the large space available for contacts makes possible the design of a positive bridging contact of ample current-carrying capacity. It would be difficult to imagine a structure more adequately shielded. The question of the blocking condenser C_2 is solved by supporting this neutralizing line from the ground plane by means of a flange insulated from the ground by a sheet of mica. This construction is shown on Fig. 4. In this illustration, *A* is the inner and *B* the outer conductor of the transmission line short-circuited by the adjustable contact *E*. This entire structure is mounted from the ground plane *D* by means of the flange *C*, insulated from ground by the dielectric *F*. Thus, a variable neutralizing inductance of high current capacity and thorough shielding is incorporated with a blocking condenser in a single unit of simple and straightforward design.

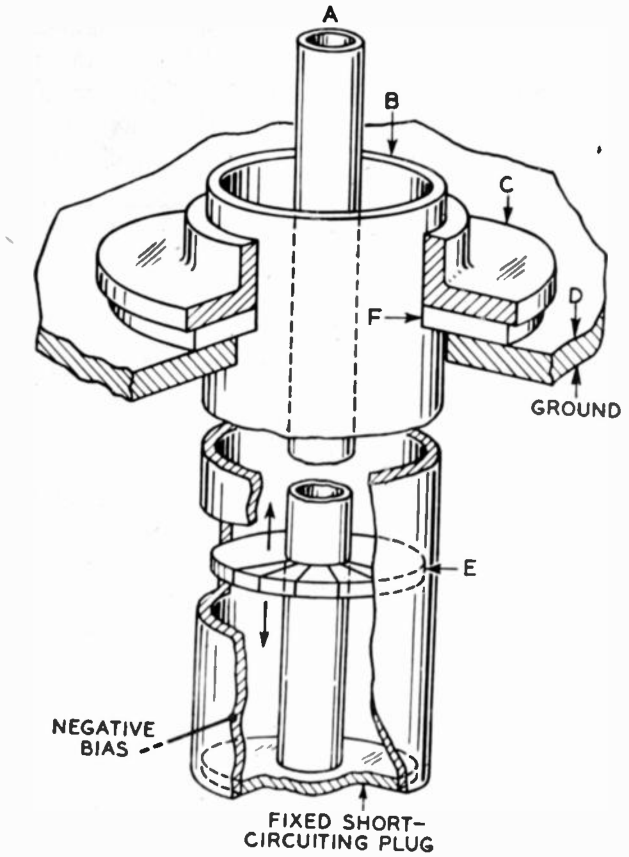

Fig. 4—Neutralizing line.

The use of a tuning line for neutralizing suggests that a similar device may prove advantageous for the plate-tuning inductance. It will be recalled that this coil must also serve to carry the filament leads and a coaxial transmission line supplying the radio-frequency excitation to the grid-filament terminals of the tube. Fig. 5 indicates the general construction finally adopted. *A* is the inner concentric transmission line which supplies the radio-frequency driving voltage. The inner conductor of this line *A* is connected to the tube grid through a conventional grid-bias blocking condenser. The outer conductor is connected to the filaments through mica by-pass condensers. Surrounding this line *A* is a tube *B* which, at each end, is con-

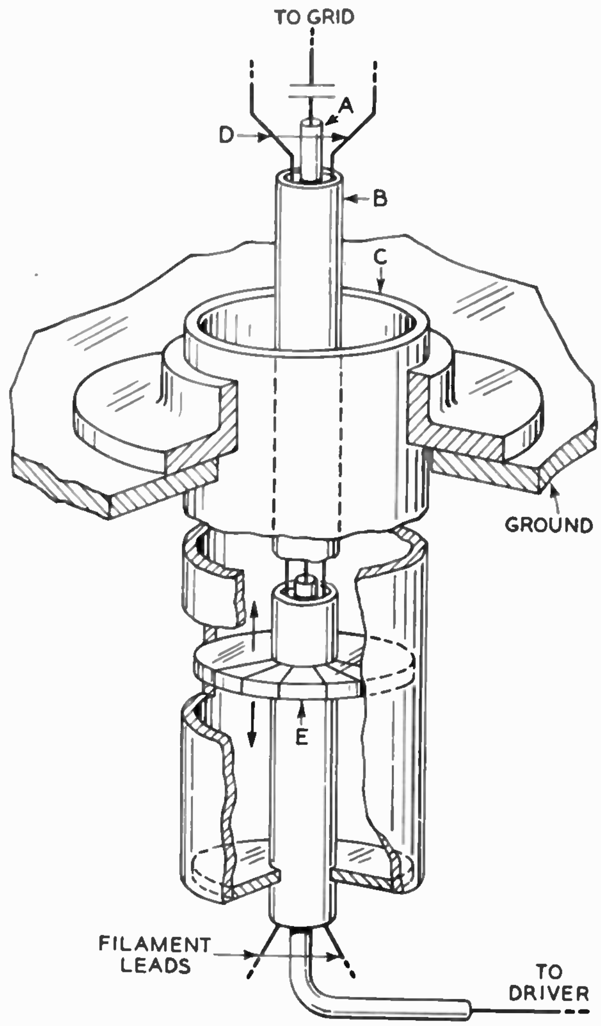

Fig. 5—Plate-tuning line.

nected electrically and mechanically to the outer conductor of line *A* and thus is at the same electrical potential. The annular space thus formed constitutes a duct through which the filament leads *D* are carried. The tube *C* forms with tube *B* a variable-length coaxial line short-circuited at the lower end by the bridging contact *E* as in the case of the neutralizing line. The position of this contact *E* may be adjusted under power to change the effective electrical length of the line, and hence its reactance, for plate-tuning purposes. Since the outer conductor of this line is at ground potential, it is mounted directly on the ground plane as shown.

The output of the amplifier is connected from the filament of the tube (through the by-pass condensers) to the transmission line through a series variable inductance which serves to adjust the output circuit impedance. Since both ends of this coil are at high radio-frequency potential above ground, a short-circuited transmission line is not the most convenient device to use. A coil with an adjustable copper "slug" to vary the reactance has been found to be most satisfactory.

The complete amplifier as finally assembled is shown on Fig. 6. It will be seen that the horizontal shelf or

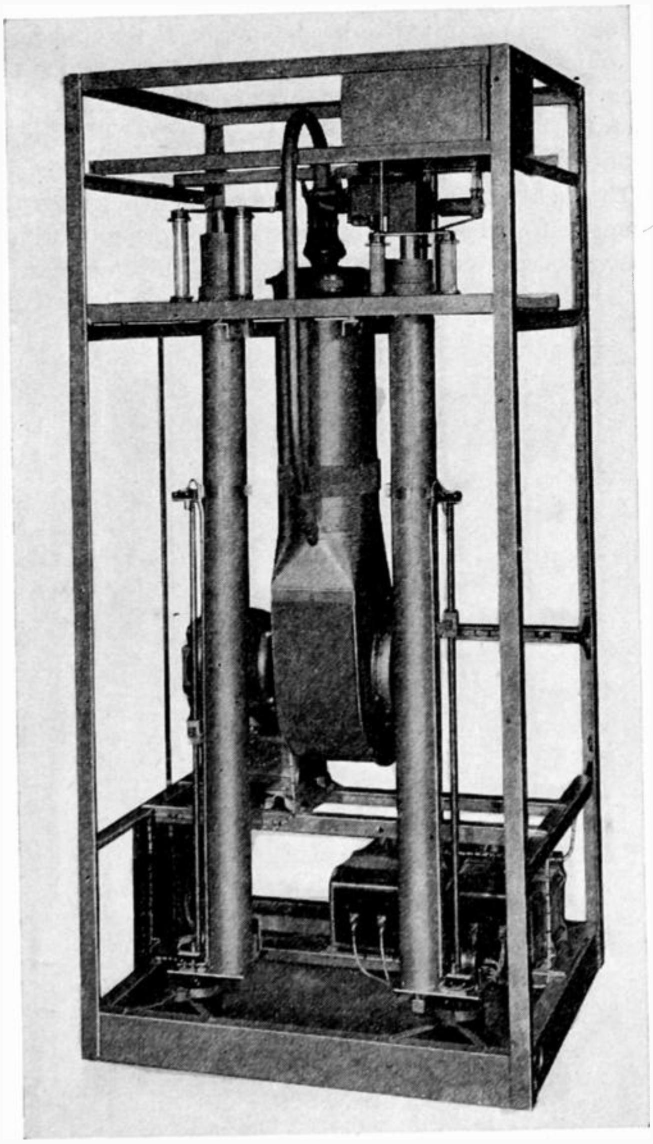

Fig. 6—Power amplifier.

panel mounting the vacuum tube constitutes a ground plane of restricted area, and all radio-frequency ground returns are connected directly to it with the almost complete absence of additional connectors. In this manner undesirable mutual impedances are kept to a minimum, and with the effective shielding of the neutralizing and plate-tuning lines, a most stable and satisfactory stage results. The blower seen below the tube gets its air supply through air filters in the lower rear portion of the unit, and the heated exhaust air escapes from the top. Special attention has been given in the design of the air-cooling system to provide adequate cooling for the grid and filament terminals and also the plate seal. This has been done by the use of a deflecting ring which diverts a portion of the air stream directly against the plate seal, and a tubular by-pass which conducts a portion of the air blast above the tube and allows it to blow directly down on the grid and filament terminals. The absence of intricate circuit parts and connections and the clean mechanical assembly finally attained are particularly noticeable, and are largely made possible by the use of the grounded plate circuit.

A 3-phase full-wave rectifier supplies approximately 17 kilowatts at 7250 volts for the amplifier. By using three single-phase transformers, emergency operation on open delta at somewhat reduced power is possible. The use of air-cooled, fully enclosed transformers and retardation coils throughout allows the assembly of the rectifiers in a single self-contained unit (Figs. 7 and 8)

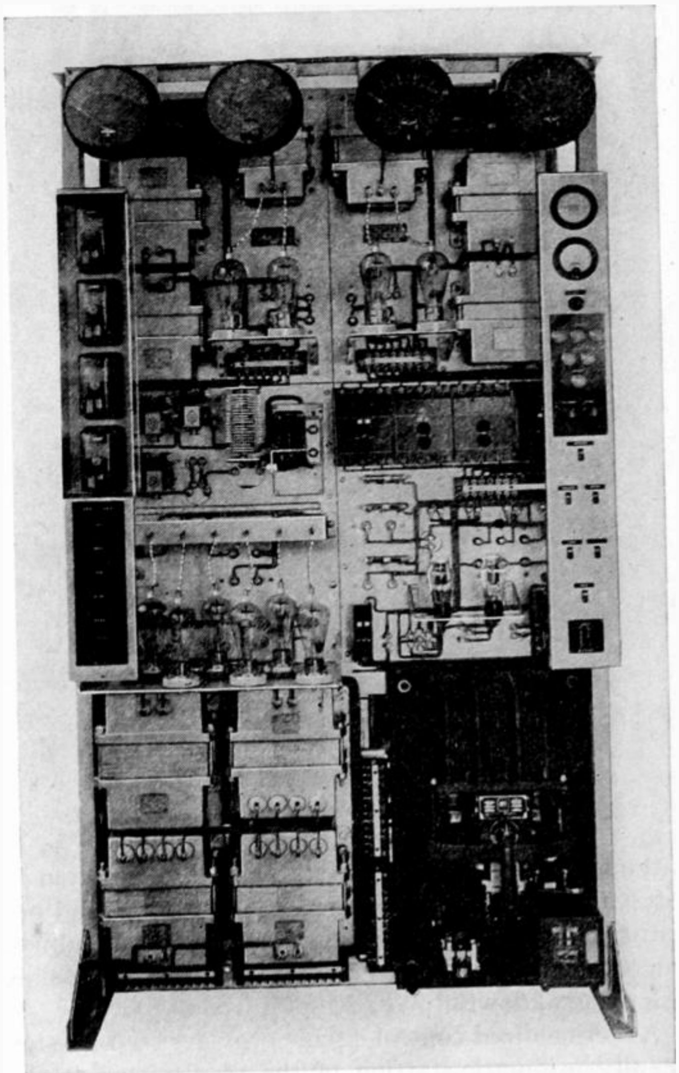

Fig. 7—Front view of power unit.

with no external high-voltage cable or busses. This segregation of the power equipment, which permits the elimination of mechanical vibration and stray magnetic fields from the radio-frequency units is an appreciable factor in securing the low noise levels obtained in this equipment. In order to insure quiet operation, all contactors and relays are operated on direct current supplied by a selenium rectifier.

All radio-frequency amplifier stages are operated with fixed bias. This permits a two-fold advantage: an optimum bias may be obtained and the filaments may be kept at direct-current ground potential. The bias is obtained independently of drive conditions and without the necessity of a compromise in the value of cathode resistor to limit the static plate dissipation to safe values. By operating the filaments at ground potential a flash arc occurring in a tube does not subject the cathode apparatus to high voltage with a possible risk of breakdown.

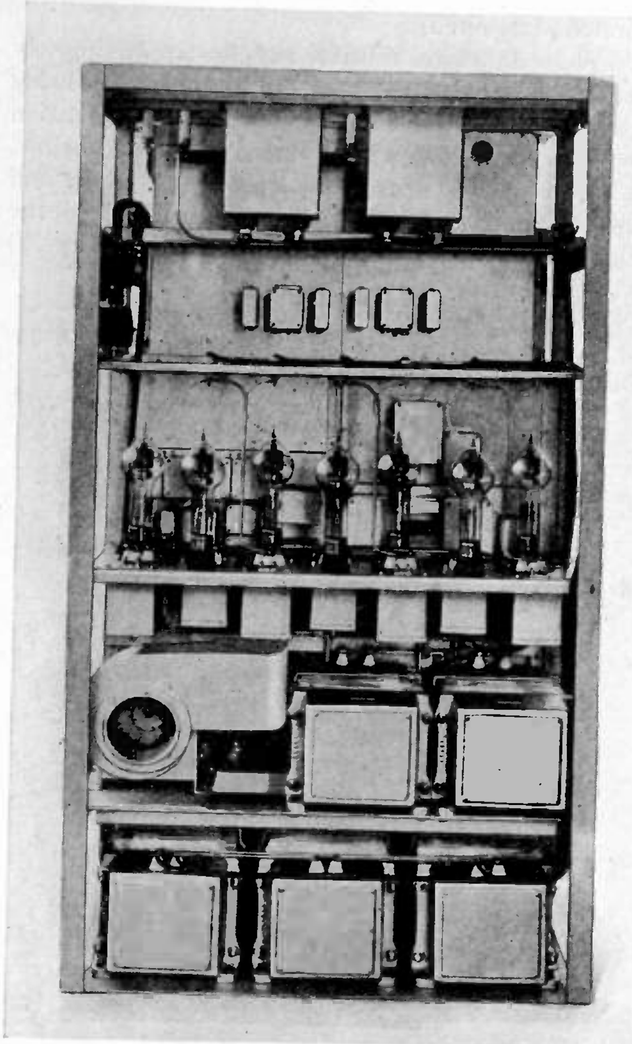

Fig. 8—Rear view of power unit.

A sectionalized control circuit provides step-by-step or fully automatic starting of the transmitter at the option of the operator. Regardless of the method used for initial starting, the transmitter is fully automatic in starting up after power interruptions. The high-voltage rectifiers are controlled by a circuit breaker equipped with automatic overload reclosing.

A time-delay relay prevents application of high voltage to any mercury-vapor rectifier tube until the filament has reached operating temperature. Laboratory tests have demonstrated that the usual heating time can be greatly reduced without adversely affecting tube life by applying approximately 150 per cent normal voltage to the filaments until normal temperature is reached. The delay relay serves the dual function of preventing the application of power until the tubes are up to operating temperature and of reducing the filament voltage to normal when this temperature is reached. As this relay is designed to have a delay which is proportional to its de-energized time, there is no danger of damaging the tubes by applying the overvoltage when the filaments are already near their operating temperature. The overvoltage starting is applied only to the tubes in the high-power rectifier as the heating time for these tubes then becomes the same as for the smaller tubes in the other rectifiers under normal voltage starting. This development is of particular value to the station operator since the reduced restarting time may permit the restoration of service, following an interruption, in time to prevent the loss of program revenue.

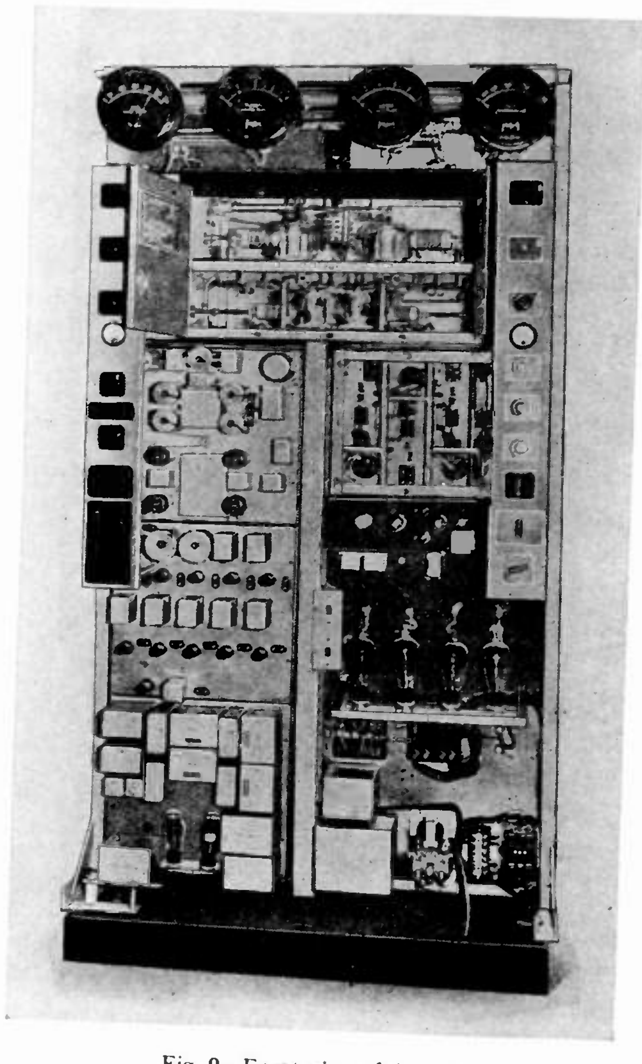

Fig. 9—Front view of driver.

The adjustment of tuning lines and all other amplifier controls is accomplished by the use of small motors operated by push buttons on the control panels. This type of control has the distinct advantage of permitting the location of the particular tuning elements in the most advantageous location from a circuit standpoint without introducing involved mechanical connections to the front of the unit.

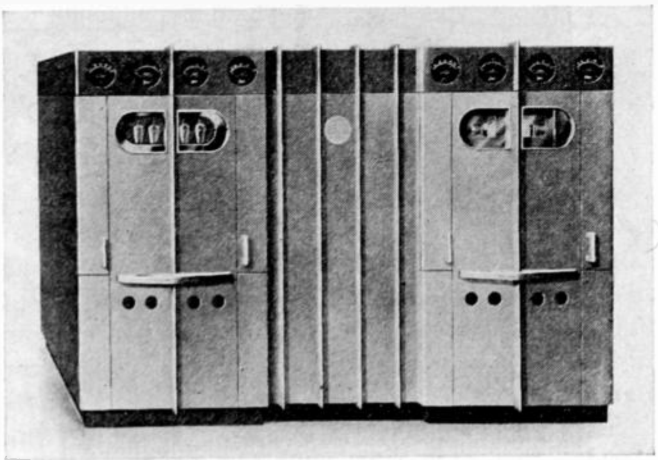

Fig. 10—Front view of transmitter.

A front view of the driver is shown on Fig. 9. In assembling the transmitter, the power unit, the amplifier, and driver are arranged in that order from left to right. This assembly of units (Fig. 10) is enclosed within a cabinet which furnishes complete protection to both the operating personnel and the equipment. Instant access to the transmitter is afforded by large doors, both front and rear, which are fully protected by safety devices. In the design of these safety devices the basic principle has been to prevent access to any compartment of the transmitter until the high-voltage supply for that compartment has been de-energized and grounded.

The consolidation of the transmitter into a single compact assembly with all equipment self-contained results in a minimum of necessary floor space. This is important in the frequency-modulation field since, in many cases, these transmitters will be installed in the upper floors of office buildings where available space may be at a premium.

Acknowledgment

The authors take this opportunity to acknowledge the generous help of their associates in the Bell Telephone Laboratories who have by their assistance and advice made this development possible.

The Self-Impedance of a Symmetrical Antenna*

RONOLD KING†, ASSOCIATE, I.R.E., AND F. G. BLAKE, JR.†, ASSOCIATE, I.R.E.

Summary—The rigorous formula for the input impedance of a symmetrical, cylindrical antenna as derived by Hallén is used to obtain complete tables and curves for the input resistance, reactance, impedance-magnitude, and phase angle as functions of the variables h/λ and a/λ. Here h is the half length and a the radius of the center-fed antenna. Expressions are derived for the maximum input resistance and for the resonant and antiresonant lengths. Curves are shown for the input resistance of resonant and antiresonant antennas as functions of a/λ.

Introduction

BRILLIANTLY conceived and boldly formulated, classical electromagnetism is one of the outstanding achievements of physical science. Unfortunately for physicist and engineer alike, it is usually studied piecemeal according to a plan (which is followed in preference to any other by most texts and treatises), in which electrostatics, magnetism, steady and quasi-steady currents, and electromagnetic waves are presented as more or less vaguely related subjects instead of as special cases of the same amazingly general theory. An unhappy consequence of this and of an emphasis on historical generalization from restricted experiments rather than on deduction from general equations is apparent in the conventional treatment of antennas as elements in electric circuits. Bluntly expressed, this seeks to investigate a problem in general electromagnetism in terms of a special case, the conditions for which are not fulfilled. Thus, to analyze even the simplest antenna (consisting merely of an isolated straight conductor of small but nonvanishing radius) in terms of an "equivalent" circuit of lumped capacitance, inductance, and resistance, or in terms of an "equivalent" section of a transmission line is fundamentally incorrect and pedagogically most undesirable. No such equivalence exists in any general sense of the word. This has, of course, been recognized by numerous investigators who have attacked the problem in more fundamental ways.

Probably the most familiar direct method of analysis is one which proceeds from the definition of electromagnetic-energy functions. In its more elementary form it involves specifically the integration of the Poynting vector over a great sphere enclosing the antenna in order to determine a fictitious resistance, called the radiation resistance (referred to maximum current amplitude), which is used to supplement the inadequate "equivalent" circuit consisting of a coil and a condenser or of a section of a transmission line. In a more general approach the energy method proceeds by integrating the complex Poynting vector over the surface of the antenna itself in order to determine both the input resistance and reactance, and so eliminate the need of "equivalent" circuits. Although

* Decimal classification: R120. Original manuscript received by the Institute, September 24, 1941.

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fundamentally correct, this latter method demands as a prerequisite a knowledge of the distribution of current in the antenna. That is almost equivalent to presupposing a solution of the very problem to be solved, for if the distribution of current is accurately known as a function of the applied voltage, the input current is also available, and with it the input impedance. This difficulty has been side-stepped in the literature by postulating a distribution of current which is sinusoidal[1,2] or which is an exponentially damped sinusoid by analogy with transmission-line theory.[3] The solutions obtained are, then, correct only for an antenna with the assumed distribution of current if such a one exists. Actually they are only rough approximations for the distribution obtaining in a cylindrical antenna of nonvanishing radius.

Methods of attack which do not depend upon a postulated approximate distribution of current, but which proceed directly to determine this distribution from the boundary conditions, may be considered in two groups. In the first group the subject of investigation is a conducting ellipsoid of revolution for which solutions have been obtained in rather intricate series form.[4,5] For antennas which are ellipsoidal in shape these solutions are exact and appropriate. On the other hand, if the antenna is cylindrical, one is faced with the problem of selecting an ellipsoid which is actually equivalent to the cylinder as an antenna. In the second group a cylindrical antenna of relatively small radius compared with its length is analyzed directly by methods leading to integral equations in the electric field[6] or in the distribution of current itself.[7,8] These integral equations are then solved by methods of successive approximation in which the quantity $1/\Omega$ with

$$\Omega = 2 \log (2h/a), \tag{1}$$

is assumed to be small compared with unity. Here h is the half length of a center-fed symmetrical antenna, or the full length of a base-fed antenna over a perfectly conducting plane; a is the radius. Since Ω lies between 10 and 30 in most practical antennas, this is a reasonable assumption which is well satisfied in a very large number of important applications. The parameter Ω is plotted as a function of the ratio h/a in Fig. 1.*

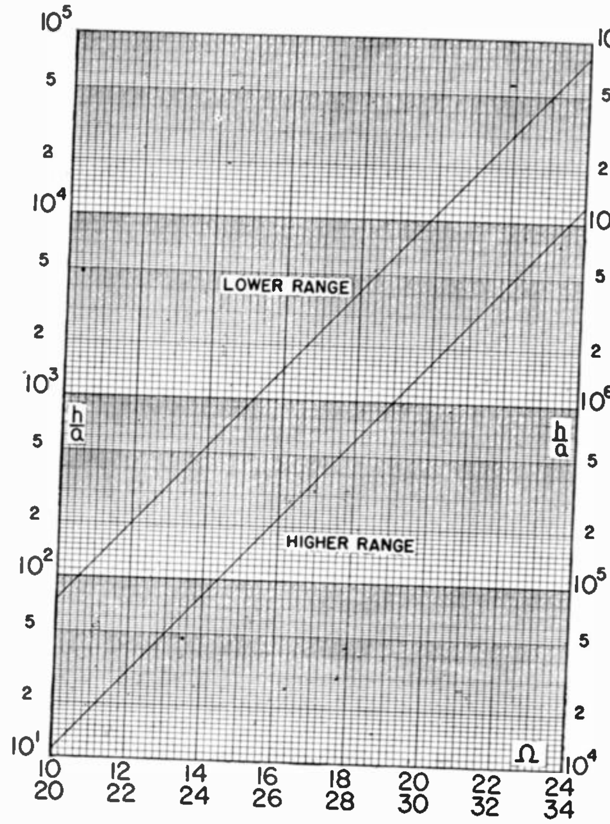


Fig. 1—The parameter $\Omega = 2 \log (2h/a)$ expressed in terms of h/a.

The purpose of the present paper is to extend Hallén's analysis in the following ways. First, to make use of Hallén's formula for the input self-impedance of a symmetrical antenna to determine the input resistance, reactance, impedance-magnitude, and phase angle for a useful range of values of the ratios h/λ and a/λ. Second, to derive an expression for the maximum input resistance. Third, to obtain expressions for the resonant and antiresonant lengths. In all of these calculations and derivations it will be assumed that Ω is sufficiently large so that all terms in $1/\Omega^2$ may be neglected as compared with unity.

Calculation of the Input Impedance

Hallén's expression for the input self-impedance of a symmetrical, center-driven antenna of half length h and radius a is given below. It defines specifically the impedance across the terminals of a dimensionless and impedanceless generator connected at the center of the antenna. It gives the impedance across the ends of a transmission line (Fig. 2) to a high degree of approximation if the separation of the two conductors of the line is a very small fraction of a wavelength. This is the case in most practical arrangements using parallel or

[1] P. S. Carter, "Circuit relation in radiating systems and applications to antenna problems," Proc. I.R.E., vol. 20, pp. 1004–1051; June, 1932.

[2] J. Labus, "Rechnerische Ermittlung der Impedanz von Antennen," *Zeit. für Hochfrequenz.*, vol. 41, pp. 17–23; January, 1933.

[3] E. Siegel and J. Labus, "Scheinwiderstand von Antennen," *Zeit. für Hochfrequenz.*, vol. 43, p. 166 and p. 172; May, June, 1934.

[4] L. Page and N. I. Adams, Jr., "Electrical oscillations of a prolate spheroid," *Phys. Rev.*, vol. 53, pp. 819–831; May, 1938.

[5] J. A. Stratton and L. J. Chu, "Steady state solutions of electromagnetic field problems," *Jour. Appl. Phys.*, vol. 12, pp. 230–248; March, 1941.

[6] L. V. King, "On the radiation field of a perfectly conducting base insulated cylindrical antenna over a perfectly conducting plane earth, and the calculation of radiation resistance and reactance," *Trans. Roy. Soc.* (London), vol. 236, pp. 381–422; November, 1937.

[7] E. Hallén, "Theoretical investigations into the transmitting and receiving qualities of antennas," *Nova Acta*, (Uppsala), ser. IV, vol. 11, no. 4, pp. 1–44; November, 1938.

[8] Both methods may be adapted to antennas of varying cross section.

* Note added in proof: An entirely different method which is based on a study of transmission modes and which lends itself to a study of antennas of various shapes has been given by S. A. Schelkunoff in "Theory of antennas of arbitrary size and shape," Proc. I.R.E., vol. 29, pp. 493–521; September, 1941.

concentric lines. The small gap may then be considered to be filled by equal and opposite currents of which one belongs to the antenna, the other to the line. The line

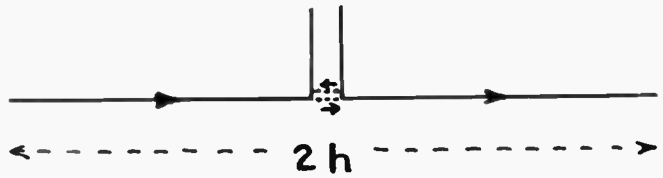


Fig. 2—Circuit of the antenna and line.

is thus effectively terminated by a short piece of conductor of the same radius as the antenna at the center of which is concentrated the impedance Z_{00} of the antenna. This does not take into account mutual impedances between the line and the antenna. Usually these will be very small compared with the self-impedance of the antenna, especially if a parallel line of close spacing is used. The expression gives double the input self-impedance of an antenna of length h erected vertically over a semi-infinite plane and perfectly conducting half space. The formula is

$$Z_{00} = -j60\Omega\left\{\frac{\cos H + \alpha_1/\Omega + \alpha_2/\Omega^2 + \cdots}{\sin H + \beta_1/\Omega + \beta_2/\Omega^2 + \cdots}\right\}. \quad (2a)$$

Here,

$$H = 2\pi h/\lambda. \quad (2b)$$

The functions α_1 and β_1 are conveniently written as follows. The coefficients of higher powers of $1/\Omega$ cannot be expressed in terms of known functions, although they may be evaluated in special cases by numerical methods.

$$\alpha_1 = \alpha_1^{I} + j\alpha_1^{II} + jhr_\alpha(r^i + jx^i)/30 = A_1^{I} + jA_1^{II} \quad (3a)$$

$$\beta_1 = \beta_1^{I} + j\beta_1^{II} + jhr_\beta(r^i + jx^i)/30 = B_1^{I} + jB_1^{II}. \quad (3b)$$

The real functions α_1^{I}, α_1^{II}, β_1^{I}, β_1^{II}, r_α, and r_β are defined below.

$$\alpha_1^{I} = (1/2)[\cos H(\overline{\mathrm{Ci}}\ 4H - 2\ \overline{\mathrm{Ci}}\ 2H) - \sin H\ \mathrm{Si}\ 4H] \quad (4a)$$

$$\alpha_1^{II} = (1/2)[\cos H(\mathrm{Si}\ 4H - 2\ \mathrm{Si}\ 2H) + \sin H\ \overline{\mathrm{Ci}}\ 4H] \quad (4b)$$

$$\beta_1^{I} = (1/2)[\cos H(4\ \mathrm{Si}\ 2H - \mathrm{Si}\ 4H) + \sin H(2\ \overline{\mathrm{Ci}}\ 2H - \overline{\mathrm{Ci}}\ 4H + 4 \log_e 2)] \quad (4c)$$

$$\beta_1^{II} = (1/2)[\cos H(\overline{\mathrm{Ci}}\ 4H - 4\ \overline{\mathrm{Ci}}\ 2H) + \sin H(2\ \mathrm{Si}\ 2H - \mathrm{Si}\ 4H)] \quad (4d)$$

$$r_\alpha = (1/2)\sin H - \cos H(1 - \cos H)/H \quad (4e)$$

$$r_\beta = (\sin 2H - \sin H)/2H - (1/2)\cos H. \quad (4f)$$

Here,

$$\mathrm{Si}\ x = \int_0^x \sin u/u\, du; \quad \mathrm{Ci}\ x = \int_0^x \cos u/u\, du \quad (5)$$

$$\overline{\mathrm{Ci}}\ x = \int_0^x (1 - \cos u)/u\, du = 0.5772 \cdots + \log x - \mathrm{Ci}\ x. \quad (6)$$

The even integral function $\overline{\mathrm{Ci}}\ x$ as defined by (6) is more convenient than the integral cosine function Ci x defined in (5). Although Hallén states that he computed all of the function in (4) with great accuracy, his paper contains only a small-scale set of curves which are not adequate for the calculation of Z_{00}. Accordingly, these functions have all been recalculated after a complete and careful check of the entire analysis had been made. They are reproduced for values of H from 0 to 7 in Fig. 3 and also in Table I. The internal

TABLE I

α, β, AND r FUNCTIONS

H	α_1^{I}	α_1^{II}	β_1^{I}	β_1^{II}	r_α	r_β
0.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.1	−0.0100	+0.0006	+0.3374	0.0000	+0.0001	−0.0030
0.2	−0.0393	+0.0053	+0.6667	+0.0006	+0.0019	−0.0133
0.3	−0.0864	+0.0175	+0.9802	+0.0028	+0.0055	−0.0292
0.4	−0.1490	+0.0407	+1.2710	+0.0083	+0.0130	−0.0506
0.5	−0.2234	+0.0773	+1.5326	+0.0197	+0.0249	−0.0767
0.6	−0.3061	+0.1293	+1.7594	+0.0397	+0.0420	−0.1065
0.7	−0.3925	+0.1974	+1.9475	+0.0713	+0.0651	−0.1387
0.8	−0.4781	+0.2816	+2.0938	+0.1176	+0.0946	−0.1720
0.9	−0.5583	+0.3812	+2.1960	+0.1811	+0.1304	−0.2050
1.0	−0.6291	+0.4935	+2.2540	+0.2641	+0.1724	−0.2363
1.1	−0.6866	+0.6157	+2.2682	+0.3681	+0.2203	−0.2644
1.2	−0.7278	+0.7450	+2.2403	+0.4941	+0.2734	−0.2881
1.3	−0.7504	+0.8778	+2.1725	+0.6423	+0.3311	−0.3061
1.4	−0.7527	+1.0090	+2.0681	+0.8112	+0.3920	−0.3173
1.5	−0.7345	+1.1351	+1.9308	+0.9996	+0.4550	−0.3208
1.6	−0.6957	+1.2517	+1.7644	+1.2042	+0.5186	−0.3161
1.7	−0.6377	+1.3550	+1.5731	+1.4216	+0.5814	−0.3024
1.8	−0.5619	+1.4419	+1.3601	+1.6477	+0.6418	−0.2798
1.9	−0.4708	+1.5097	+1.1301	+1.8781	+0.6983	−0.2484
2.0	−0.3673	+1.5562	+0.8864	+2.1071	+0.7493	−0.2085
2.1	−0.2541	+1.5805	+0.6317	+2.3304	+0.7933	−0.1607
2.2	−0.1343	+1.5819	+0.3691	+2.5431	+0.8291	−0.1058
2.3	−0.0108	+1.5605	+0.1011	+2.7393	+0.8555	−0.0450
2.4	+0.1134	+1.5170	−0.1701	+2.9154	+0.8715	+0.0205
2.5	+0.2360	+1.4528	−0.4425	+3.0676	+0.8764	+0.0891
2.6	+0.3552	+1.3695	−0.7142	+3.1931	+0.8697	+0.1594
2.7	+0.4687	+1.2691	−0.9833	+3.2883	+0.8513	+0.2298
2.8	+0.5756	+1.1534	−1.2479	+3.3520	+0.8211	+0.2986
2.9	+0.6750	+1.0247	−1.5065	+3.3828	+0.7795	+0.3642
3.0	+0.7662	+0.8851	−1.7560	+3.3799	+0.7272	+0.4249
3.1	+0.8487	+0.7362	−1.9946	+3.3422	+0.6651	+0.4795
3.2	+0.9225	+0.5800	−2.2200	+3.2732	+0.5942	+0.5265
3.3	+0.9876	+0.4181	−2.4292	+3.1705	+0.5158	+0.5649
3.4	+1.0435	+0.2515	−2.6196	+3.0361	+0.4315	+0.5937
3.5	+1.0905	+0.0816	−2.7884	+2.8713	+0.3427	+0.6122
3.6	+1.1280	−0.0903	−2.9325	+2.6772	+0.2512	+0.6201
3.7	+1.1556	−0.2634	−3.0495	+2.4552	+0.1587	+0.6171
3.8	+1.1731	−0.4364	−3.1375	+2.2070	+0.0669	+0.6034
3.9	+1.1795	−0.6082	−3.1945	+1.9344	−0.0226	+0.5792
4.0	+1.1743	−0.7772	−3.2188	+1.6393	−0.1082	+0.5451
4.1	+1.1569	−0.9422	−3.2096	+1.3235	−0.1884	+0.5019
4.2	+1.1265	−1.1017	−3.1662	+0.9889	−0.2619	+0.4506
4.3	+1.0829	−1.2535	−3.0891	+0.6383	−0.3276	+0.3924
4.4	+1.0253	−1.3960	−2.9790	+0.2743	−0.3845	+0.3283
4.5	+0.9541	−1.5271	−2.8369	−0.1003	−0.4321	+0.2598
4.6	+0.8695	−1.6448	−2.6647	−0.4823	−0.4698	+0.1883
4.7	+0.7719	−1.7467	−2.4645	−0.8681	−0.4973	+0.1152
4.8	+0.6625	−1.8316	−2.2390	−1.2535	−0.5147	+0.0419
4.9	+0.5424	−1.8974	−1.9903	−1.6345	−0.5222	−0.0304
5.0	+0.4129	−1.9426	−1.7214	−2.0072	−0.5201	−0.1004
5.1	+0.2763	−1.9665	−1.4356	−2.3666	−0.5090	−0.1669
5.2	+0.1345	−1.9683	−1.1361	−2.7086	−0.4897	−0.2289
5.3	−0.0108	−1.9475	−0.8252	−3.0290	−0.4628	−0.2858
5.4	−0.1572	−1.9044	−0.5062	−3.3234	−0.4293	−0.3366
5.5	−0.3026	−1.8394	−0.1824	−3.5880	−0.3903	−0.3811
5.6	−0.4448	−1.7536	+0.1437	−3.8194	−0.3468	−0.4189
5.7	−0.5822	−1.6480	+0.4696	−4.0142	−0.2996	−0.4497
5.8	−0.7131	−1.5241	+0.7922	−4.1701	−0.2498	−0.4737
5.9	−0.8359	−1.3873	+1.1087	−4.2854	−0.1984	−0.4909
6.0	−0.9496	−1.2287	+1.4166	−4.3583	−0.1461	−0.5016
6.1	−1.0528	−1.0608	+1.7134	−4.3874	−0.0938	−0.5061
6.2	−1.1450	−0.8821	+1.9963	−4.3725	−0.0421	−0.5049
6.3	−1.2256	−0.6946	+2.2623	−4.3145	+0.0084	−0.4986
6.4	−1.2940	−0.5002	+2.5087	−4.2133	+0.0572	−0.4876
6.5	−1.3497	−0.3005	+2.7331	−4.0697	+0.1041	−0.4725
6.6	−1.3926	−0.0976	+2.9325	−3.8852	+0.1486	−0.4539
6.7	−1.4224	+0.1067	+3.1054	−3.6621	+0.1907	−0.4322
6.8	−1.4387	+0.3111	+3.2485	−3.4022	+0.2303	−0.4079
6.9	−1.4412	+0.5135	+3.3602	−3.1072	+0.2674	−0.3814
7.0	−1.4301	+0.7123	+3.4392	−2.7801	+0.3020	−0.3531
$\pi/2$	−0.70908	+1.21883	+1.81571	+1.14279	+0.50000	−0.31831
π	+0.88048	+0.67199	−2.09014	+3.31813	+0.63662	+0.50000
$3\pi/2$	+0.75905	−1.75824	−2.43800	−0.91571	−0.50000	+0.10610
2π	−1.21287	−0.72676	+2.21909	−4.32722	0.00000	−0.50000

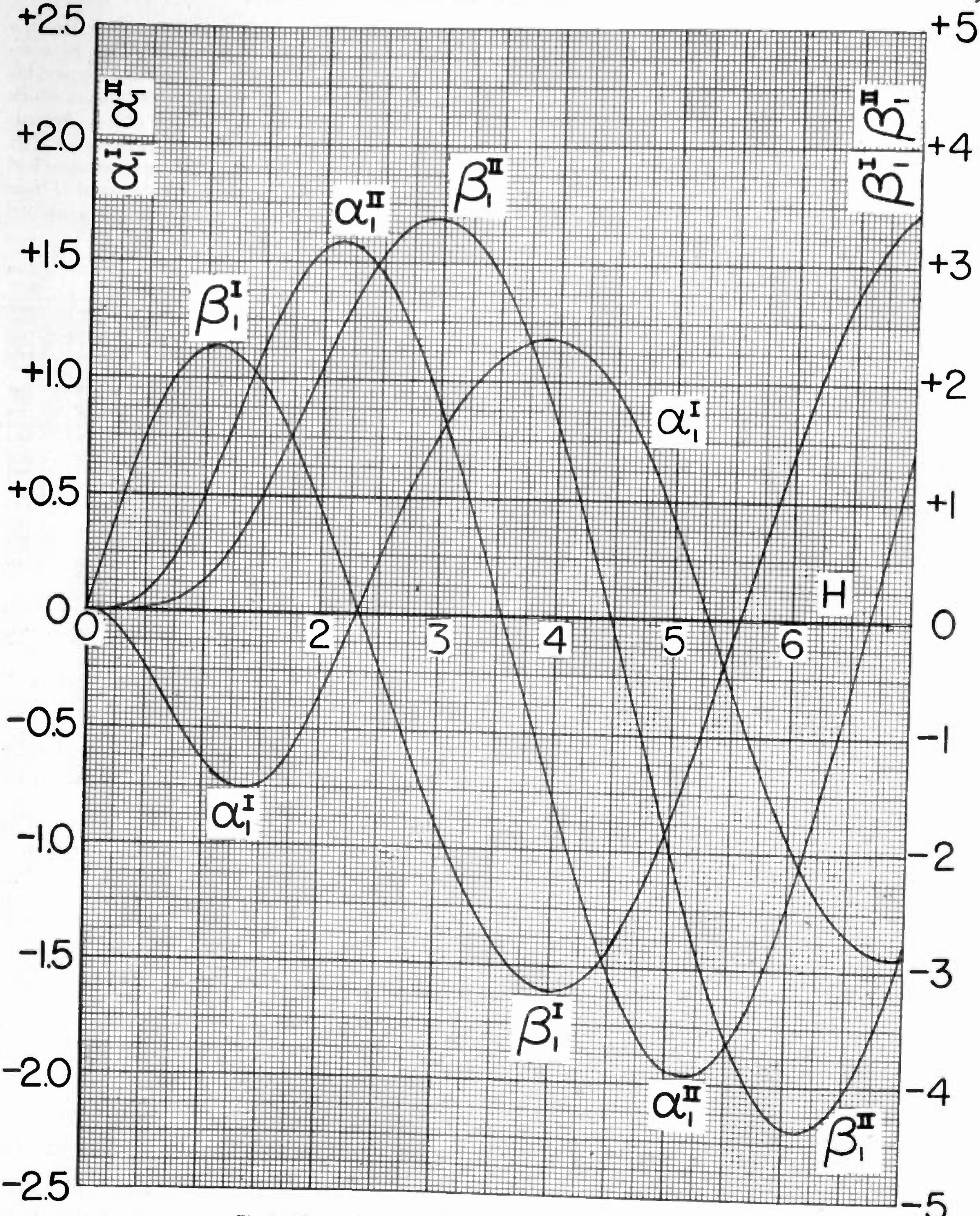


Fig. 3—The functions α_1^I, α_1^{II}, β_1^I, β_1^{II} as functions of $H = 2\pi h/\lambda$.

impedance per unit length of a cylindrical conductor has been expanded in (3) into its real part, r^i (internal or ohmic resistance) and imaginary part, x^i (internal reactance). These are defined by well-known formulas for the effective alternating-current resistance and reactance of round wires.[9]

[9] See, for example, N. W. McLachlan, "Bessel Functions for Engineers," Oxford University Press, Oxford, England, 1934, p. 140, equations (22) and (23).

Subject to the following inequalities, which are to be looked upon as conditions on the small quantity $1/\Omega$,

$$|\cos H + \alpha_1/\Omega| \gg |\alpha_2/\Omega^2| \quad (9a)$$

$$|\sin H + \beta_1/\Omega| \gg |\beta_2/\Omega^2|, \quad (9b)$$

a good approximation for (2a) is given by

$$Z_{00} = R_{00} + jX_{00} = -j60\Omega\left\{\frac{\cos H + \alpha_1/\Omega}{\sin H + \beta_1/\Omega}\right\}. \quad (10)$$

Upon separating the real from the imaginary part and using the notation of (3), one has

$$R_{00} = 60\Omega\left\{\frac{A_1^{II}(\Omega \sin H + B_1^{I}) - B_1^{II}(\Omega\cos H + A_1^{I})}{(\Omega \sin H + B_1^{I})^2 + (B_1^{II})^2}\right\} \quad (11a)$$

$$X_{00} = -60\Omega\left\{\frac{(\Omega\cos H + A_1^{I})(\Omega \sin H + B_1^{I}) + A_1^{II}B_1^{II}}{(\Omega \sin H + B_1^{I})^2 + (B_1^{II})^2}\right\}. \quad (11b)$$

These are the most accurate formulas for the input self-resistance and the input self-reactance of a symmetrical antenna which can be obtained from Hallén's analysis in terms of known functions. It is readily shown that they are a better approximation than those derived on the assumption of a sinusoidal distribution of current. Thus, if the following much more highly restricting inequalities,

$$|\Omega \sin H| \gg |\beta_1|, \quad (12a)$$

$$|\Omega \sin H| \gg |\alpha_1|, \quad (12b)$$

are imposed in addition to (9), (10) becomes

$$Z_{00} = -j60\Omega[\Omega \cot H + \alpha_1/\sin H - \beta_1 \cot H/\sin H]. \quad (13)$$

The real and imaginary parts are

$$R_{00} = 60\left\{\frac{A_1^{II} - B_1^{II}\cot H}{\sin H}\right\} \quad (14a)$$

$$X_{00} = -60\{\Omega \cot H + A_1^{I}/\sin H - B_1^{I}\cot H/\sin H\}. \quad (14b)$$

Using (3) and (4) and the relation,

$$2\log(2h/a) = 2\log 2 + 2\log(h/a), \quad (15)$$

these expressions can be transformed exactly into

$$R_{00} = R_{00}^{e} + R_{00}^{i}, \quad (16a)$$

and

$$X_{00} = X_{00}^{e} + X_{00}^{i}, \quad (16b)$$

with the external or radiation input self-resistance R_{00}^{e}, the internal or ohmic input resistance R_{00}^{i}, the external input self-reactance X_{00}^{e}, and the internal input reactance X_{00}^{i} defined as follows:

$$R_{00}^{e} = 30[(1 - \cot^2 H)\overline{\mathrm{Ci}}\, 4H + 4\cot^2 H\, \overline{\mathrm{Ci}}\, 2H + 2\cot H(\mathrm{Si}\, 4H - 2\,\mathrm{Si}\, 2H)] \quad (17a)$$

$$X_{00}^{e} = 30[(1 - \cot^2 H)\,\mathrm{Si}\, 4H + 4\cot^2 H\,\mathrm{Si}\, 2H + 2\cot H\{2\,\overline{\mathrm{Ci}}\, 2H - \overline{\mathrm{Ci}}\, 4H - 2\log(h/a)\}] \quad (17b)$$

$$R_{00}^{i} = (r^{i}\lambda/2\pi)(H\csc^2 H - \cot H) \quad (17c)$$

$$X_{00}^{i} = (x^{i}\lambda/2\pi)(H\csc^2 H - \cot H). \quad (17d)$$

These formulas for R_{00}^{e} and X_{00}^{e} are the same as those obtained by Labus,[2] and with $H=\pi/2$ they are the same as those derived by Carter.[1] It is clear from (12) that for all finite values of Ω, (13) and (17) are not valid over a considerable range of H. On the other hand, for $1/\Omega$ reasonably small, (10) and (11) are good approximations for all values of H. Accordingly, (10) is a better formula for the input impedance than is (13). It is to be noted, moreover, that (10) includes a higher-order correction for the effect of the radius of the conductor on both R_{00}^{e} and X_{00}^{e}. According to (17a), R_{00}^{e} is quite independent of the radius, a condition which actually obtains approximately only over the limited range not excluded by (12). It will be seen that the radius of the conductor actually plays a very significant part in determining R_{00}^{e} as calculated from (11a).

Curves for R_{00} and X_{00} as functions of $H=2\pi h/\lambda$, and with a/λ as parameter, are reproduced in Figs. 4 and 5. Actually these are curves for R_{00}^{e} and X_{00}^{e} except for antennas made of copper or other highly conducting material. In the case of copper the contribution to R_{00} and X_{00} by R_{00}^{i} and X_{00}^{i} is sufficiently small to be negligible for most practical purposes. This was verified by direct calculation for the extreme cases shown by curves A and E in the figures (see Table II). Curves showing $|Z_{00}|$ and $\theta=\tan^{-1}(X_{00}/R_{00})$ are given in Fig. 6. Especially important low ranges for R_{00} and X_{00} are shown to a much-enlarged scale in Figs. 7 and 8, respectively. The curves of Figs. 9 to 11 contain the same data as Figs. 4 and 5 but plotted with H as parameter and with a/λ as variable. Tables II and III give calculated values of R_{00} and X_{00}.

Maximum Values of the Input Resistance

The half lengths of the antenna for which the input resistance assumes its maximum values may be obtained by differentiating the general expression (11a) with respect to H and equating the derivative to zero. Since this leads to an excessively intricate equation, a simpler method is to be preferred. This depends upon maximizing the leading terms in (11a) first. These are given by (14a), and this obviously has a maximum value of infinity at $H=n\pi/2$ with n any even integer. Accordingly one may assume that the true maxima of (11a) will occur at

$$H_m = \frac{n\pi}{2} - \epsilon \qquad |\epsilon| < 1. \quad (18)$$

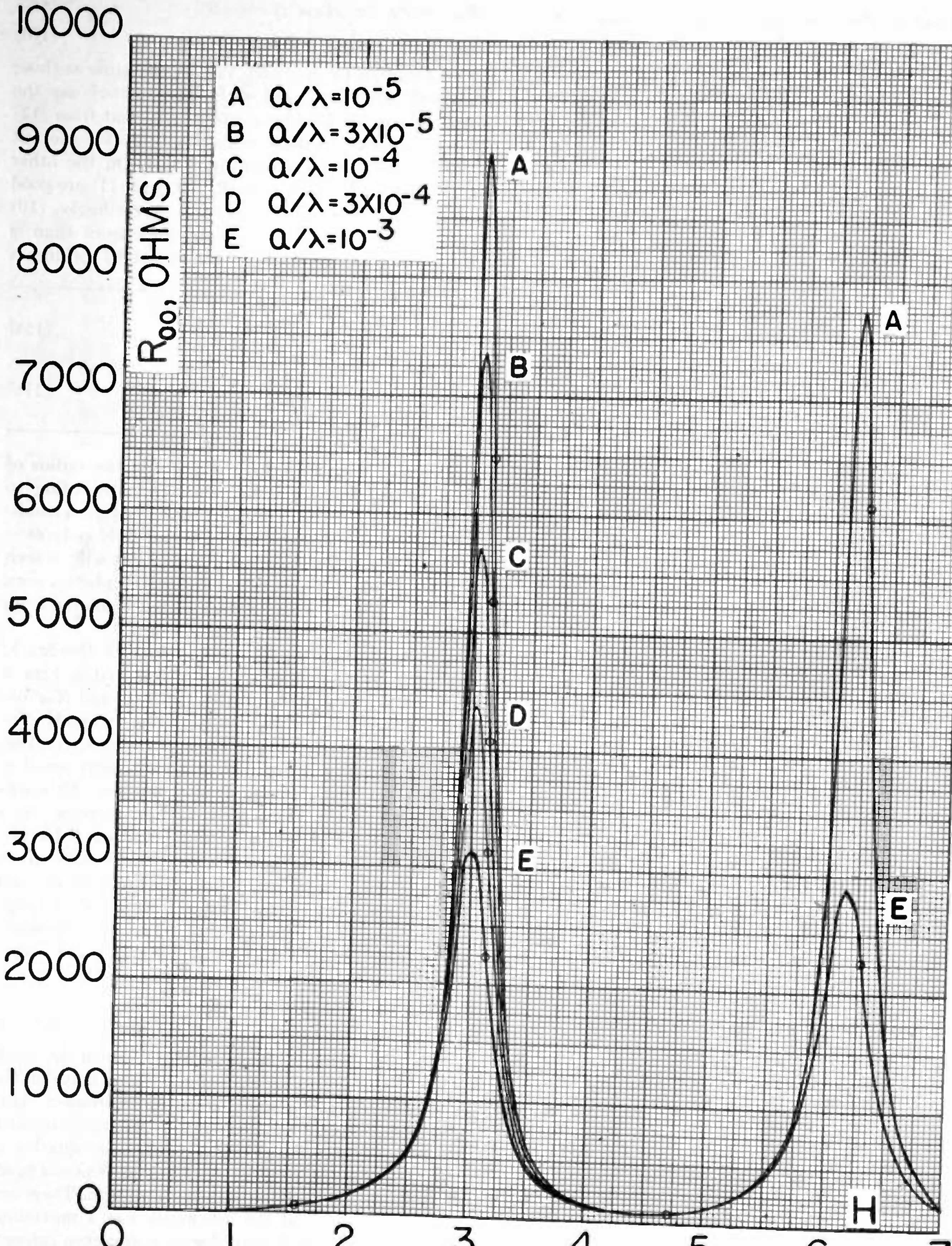


Fig. 4—The input self-resistance R_{00} as a function of $H=2\pi h/\lambda$ with a/λ as parameter. Values at $H=n\pi/2$ are indicated by a small circle.

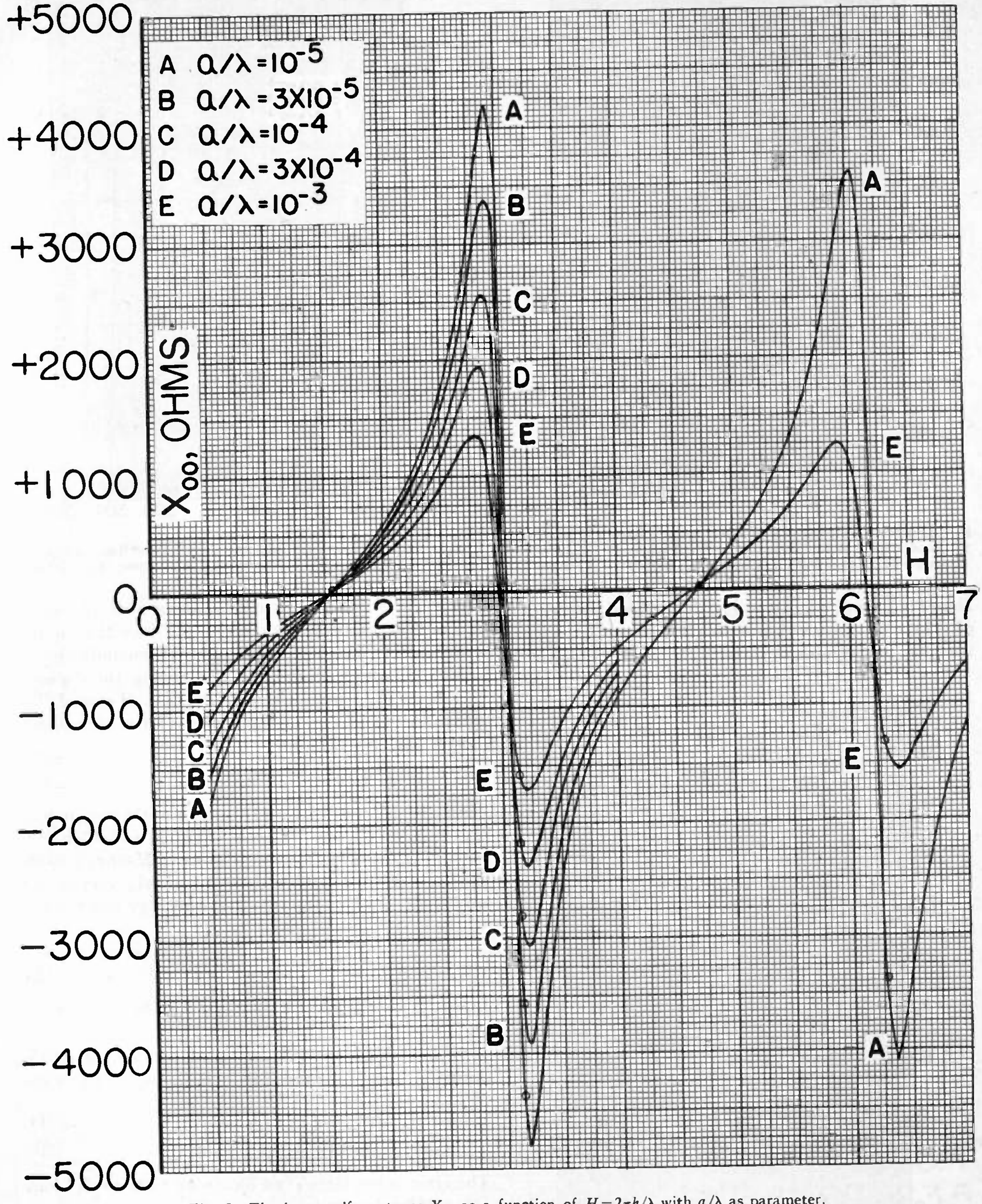


Fig. 5—The input self-reactance X_{00} as a function of $H=2\pi h/\lambda$ with a/λ as parameter. Values at $H=n\pi/2$ are indicated by a small circle.

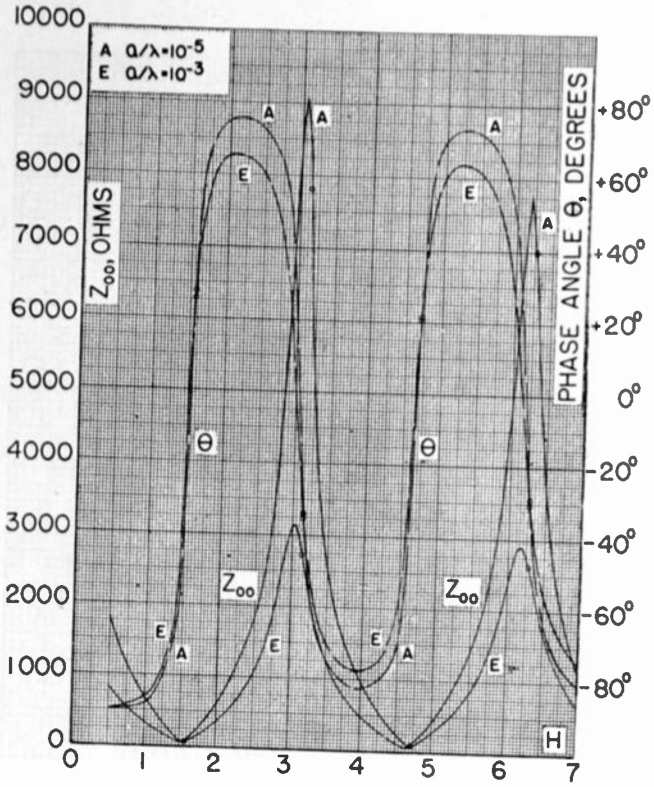


Fig. 6—The magnitude of the input self-impedance $|Z_{00}|$ and its phase angle θ as functions of $H=2\pi h/\lambda$ with a/λ as parameter. Values at $H=n\pi/2$ are indicated by a small circle.

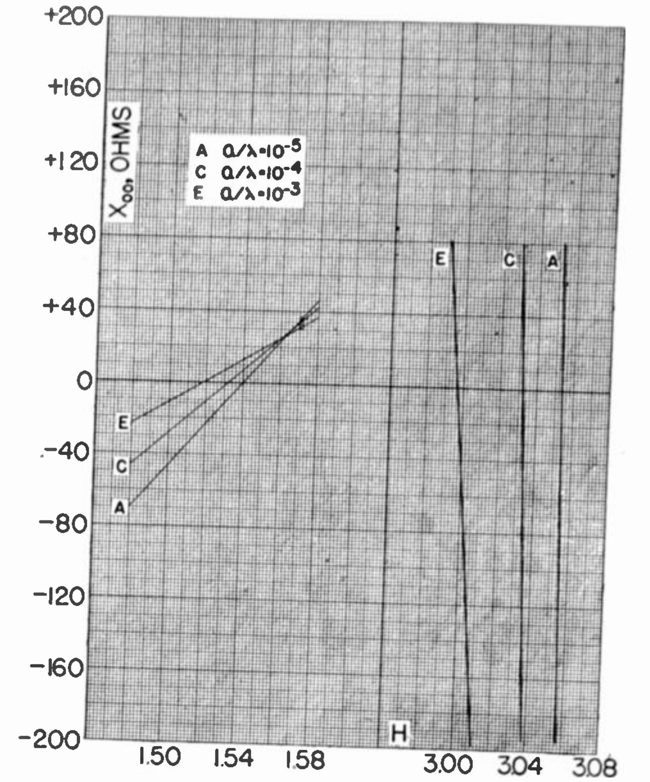


Fig. 8—Same as Fig. 4 for low-reactance ranges. Resonant points at intersections with the horizontal axis where X_{00} vanishes.

Here ϵ is a small quantity to be determined. Inspection of (11a) now reveals that with H_m near $n\pi/2$ the leading term in the numerator is $B_1^{II}\Omega \cos H$. Since $\cos H$

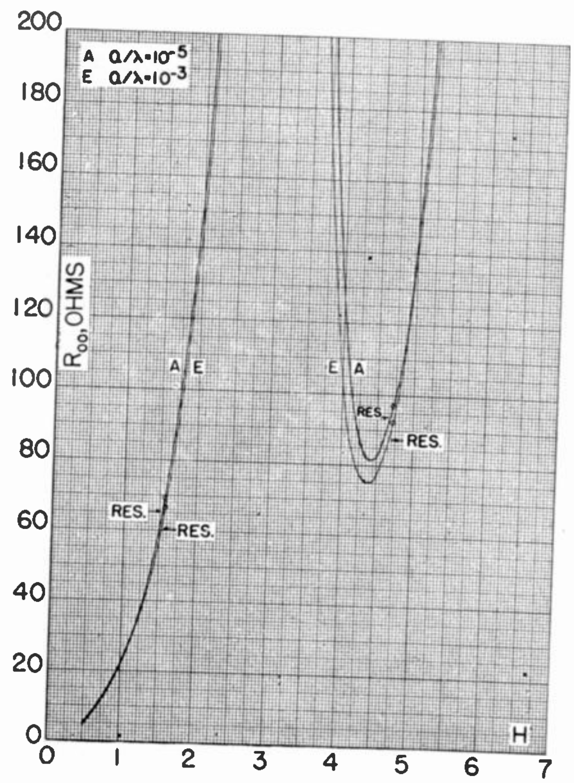


Fig. 7—Same as Fig. 3 for low-resistance ranges. Resonant points are denoted by an arrow.

and B_1^{II} both have extreme values near $H=n\pi/2$, where they are slowly varying, and since Ω is in any case sensibly constant, it follows that maximization of (11a) reduces essentially to minimizing the denominator. As B_1^{II} is slowly varying near $H=n\pi/2$, the denominator will be minimized to a close approximation if one requires that

$$\Omega \sin H + B_1^{I} = 0. \tag{19}$$

Since ohmic resistance contributes a negligible amount for good conductors, one may write β_1 for B_1^{I} in (19) according to (3b). One may also write $H=n\pi/2$ in the integral functions, since these are slowly varying for arguments greater than one. In this way one obtains with (4), (19), (15), and (5)

$$\tan \epsilon \doteq \epsilon \doteq \frac{4 \text{ Si } n\pi - \text{Si } 2n\pi}{4 \log (n\lambda/a) + C + \log \dfrac{n\pi}{2} + 2 \text{ Ci } n\pi - \text{Ci } 2n\pi}. \tag{20}$$

Here $C=0.5772 \cdots$. A very good estimate of (20) is obtained by noting that for large values of the argument

$$\text{Si } x \doteq \pi/2 - \cos x/x \tag{21a}$$

$$\text{Ci } x \doteq \sin x/x. \tag{21b}$$

The error is not large even for $x=n\pi$ with $n=2$. Using (21), (20) reduces to

$$\epsilon \doteq \frac{3\pi/2 - 7/2n\pi}{4 \log (n\lambda/a) + \log \dfrac{n\pi}{2} + C}. \tag{22}$$

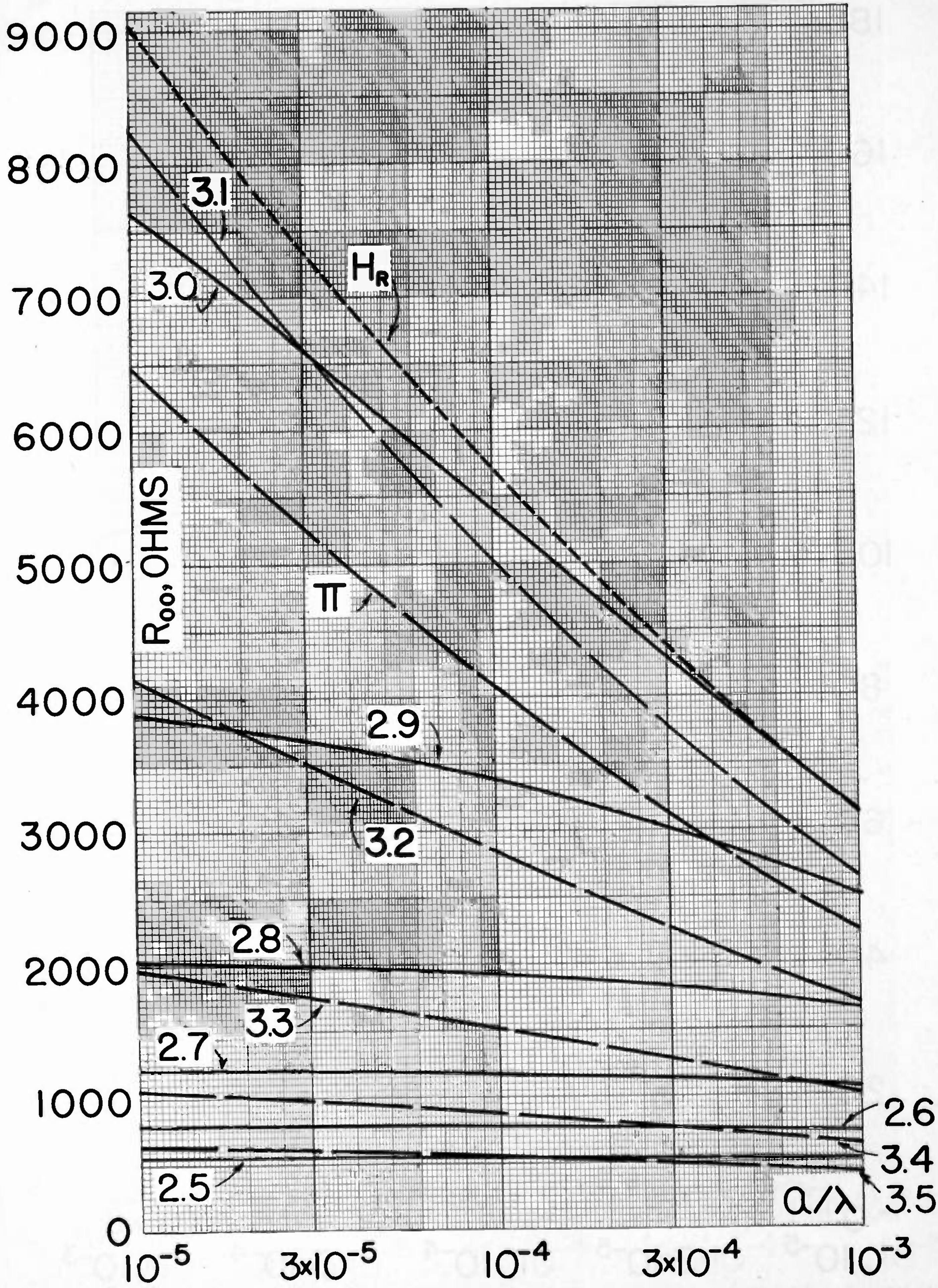


Fig. 9—The input self-resistance R_{00} as a function of a/λ with $H=2\pi h/\lambda$ as parameter. The curve marked H_r is for values of R_{00} when H is adjusted to antiresonance near $H=\pi$ for indicated values of a/λ.

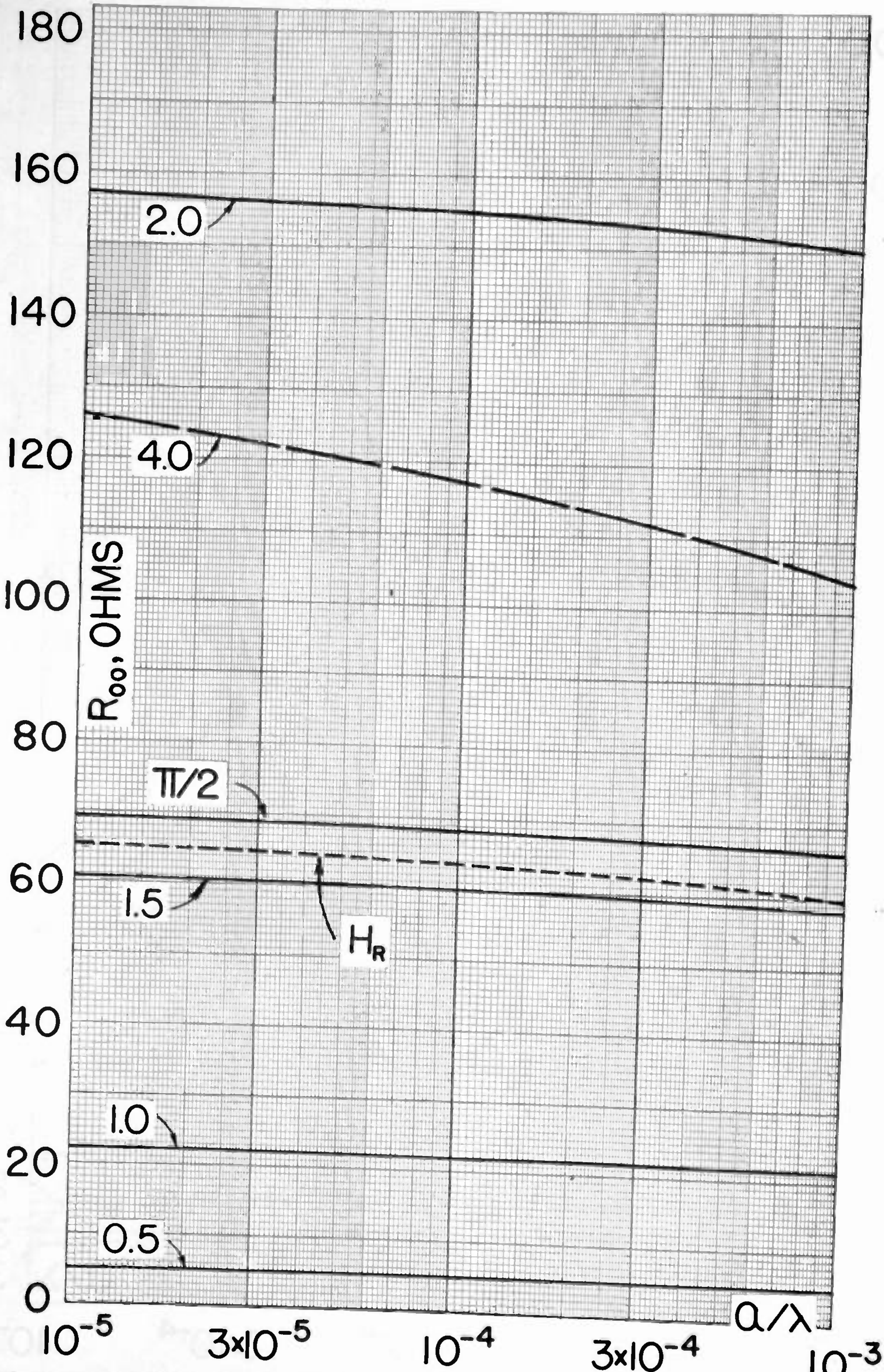


Fig. 10—Same as Fig. 8 for low-resistance ranges. The curve marked H_r is for values of R_{00} when H is adjusted to resonance near $H=\pi/2$ for indicated values of a/λ.

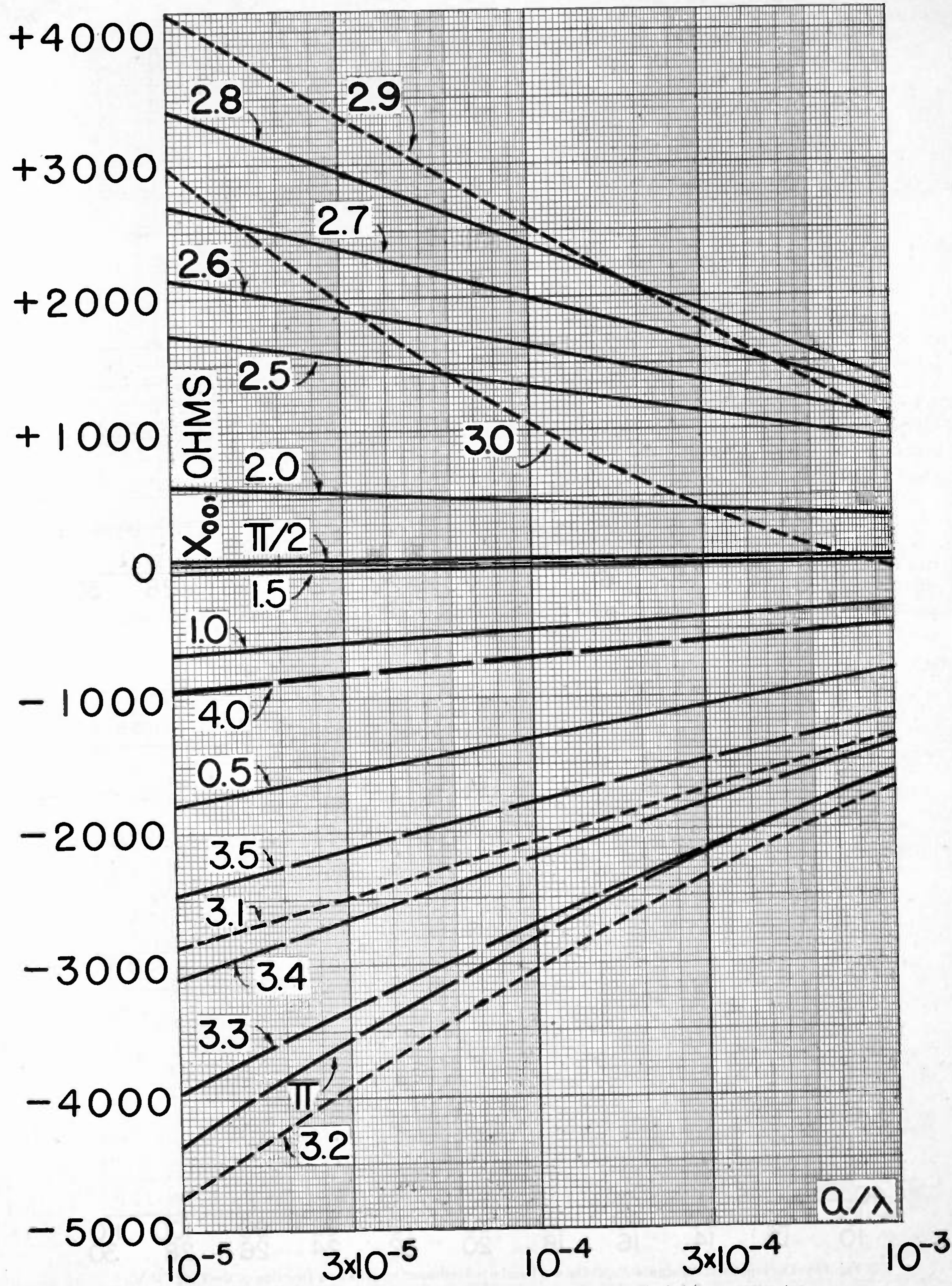


Fig. 11—The input self-reactance X_{00} as a function of a/λ with $H=2\pi h/\lambda$ as parameter.

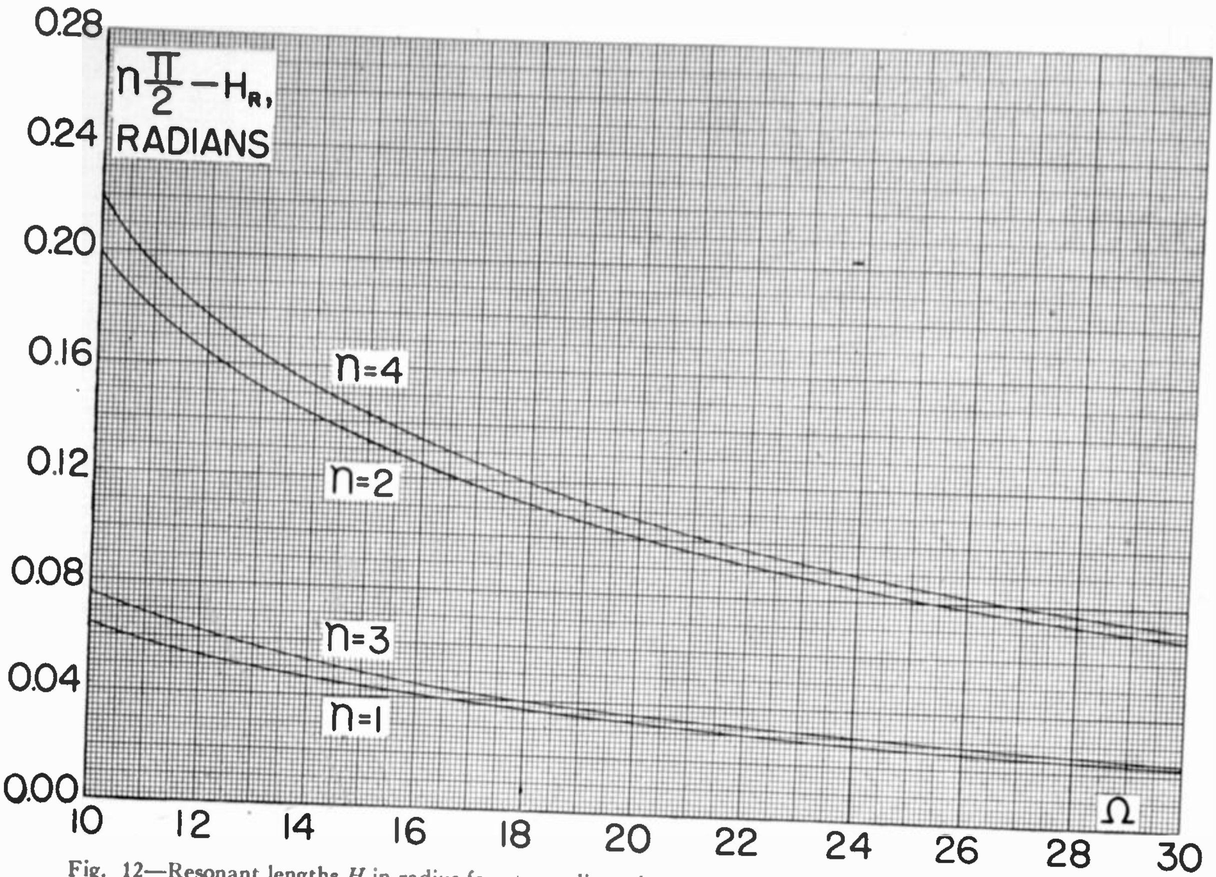


Fig. 12—Resonant lengths H in radius for zero radius minus resonant lengths in radians for nonvanishing radius; viz., $n\pi/2-H_r=2\pi(n/4-h_r/\lambda)$, as functions of $\Omega=2\log(2h/a)$ for $n=1, 2, 3, 4$.

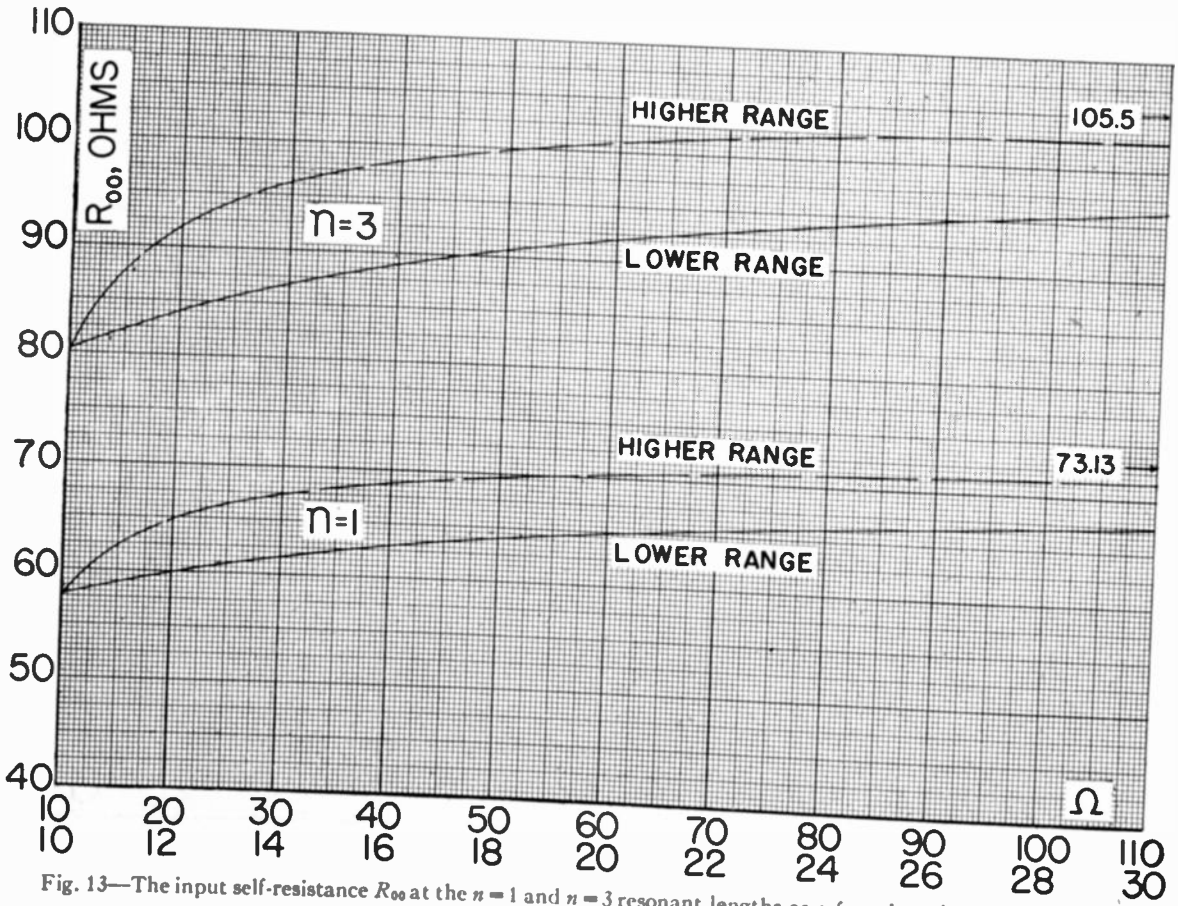


Fig. 13—The input self-resistance R_{00} at the $n=1$ and $n=3$ resonant lengths as a function of $\Omega=2\log(2h/a)$.

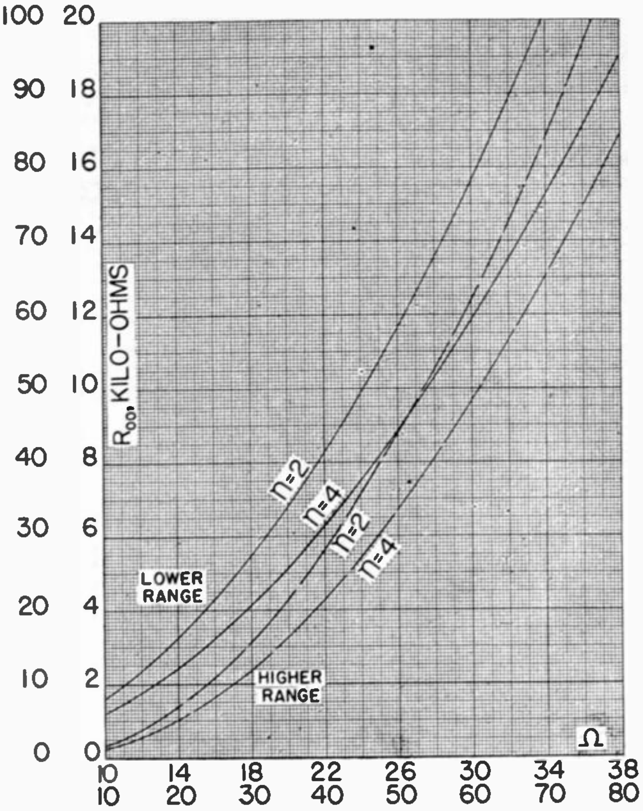


Fig. 14—The input self-resistance R_{00} at the $n=2$ and $n=4$ antiresonant lengths as functions of $\Omega=2\log(2h/a)$.

It will be shown below that $H_m=(n\pi/2)-\epsilon$, with n an even integer, practically defines the antiresonant values of H, as well as those for maximum values of R_{00}.

Upon substituting (22) in (11a) one obtains the following expression for the maximum values of R_{00}:

$$R_{00}(\max) = \frac{60\Omega\left(2\Omega - \log\dfrac{n\pi}{2} - C\right)}{3\left(\log\dfrac{n\pi}{2} + C\right) + 2\log 2 + \epsilon\pi/2}. \quad (24)$$

Numerical values of H_m and R_{00} (max) for the antennas of Table II are given in Table IV.

Conditions for Resonance and Antiresonance

Resonance and antiresonance in an antenna are defined by zero phase angle for the input current or by vanishing input reactance. Accordingly, the resonant and antiresonant values of H must be determined for an antenna of given radius and excited at a given frequency by equating X_{00} to zero. For this purpose the contribution by internal reactance may be neglected since it is always extremely small. The condition for resonance thus becomes

$$(\Omega\cos H + \alpha_1{}^{\mathrm{I}})(\Omega\sin H + \beta_1{}^{\mathrm{I}}) + \alpha_1{}^{\mathrm{II}}\beta_1{}^{\mathrm{II}} = 0. \quad (25)$$

This equation will be satisfied by values of H not very different from those obtained by neglecting all but the leading terms in (25). That is, the resonant values H_r will be near the solution of

$$\cos H \sin H = 0; \quad (26)$$

TABLE II

Resistance R_{00} in ohms versus $H=2\pi\dfrac{h}{\lambda}$ with $\dfrac{a}{\lambda}$ as parameter

H	Neglecting ohmic resistance: $\frac{a}{\lambda}=10^{-5}$	$\frac{a}{\lambda}=3\times10^{-5}$	$\frac{a}{\lambda}=10^{-4}$	$\frac{a}{\lambda}=3\times10^{-4}$	$\frac{a}{\lambda}=10^{-3}$	Including ohmic resistance of Cu: $\frac{a}{\lambda}=10^{-5}$, $\lambda=100$ m., $a=1$ mm.	$\frac{a}{\lambda}=10^{-3}$, $\lambda=5$ m., $a=5$ mm.
0.5	5.02	5.00	4.95	4.90	4.81	5.32	4.83
1.0	22.2	22.1	21.9	21.7	21.4	22.9	21.4
1.5	60.7	60.3	59.8	59.2	58.2	62.2	58.3
2.0	157	156	155	153	150	161	150
2.5	554	550	544	535	520	566	520
2.6	791	785	774	758	729	808	730
2.7	1210	1200	1170	1130	1070	1240	1070
2.8	2030	1990	1920	1820	1650	2080	1650
2.9	3880	3680	3380	3010	2500	3960	2500
3.0	7630	6600	5400	4290	3130	7660	3120
3.1	8250	6600	5020	3780	2640	8070	2640
3.2	4150	3510	2840	2270	1690	4080	1690
3.3	1970	1760	1510	1280	1020	1960	1020
3.4	1060	974	869	765	640	1060	640
3.5	637	595	543	489	422	640	422
4.0	126	122	117	112	104	130	104
4.3	84.2				76.2	88.2	76.4
4.4	81.5				75.3	85.6	75.4
4.5	82.7				77.5	87.0	77.7
5.0	146				139	153	139
5.5	431				397	448	398
5.6	575				523	597	524
5.7	800				712	831	713
5.8	1170				1000	1220	1000
5.9	1850				1460	1920	1460
6.0	3170				2110	3270	2110
6.1	5660				2760	5720	2760
6.2	7750				2800	7540	2800
6.3	5580				2140	5380	2140
6.4	2970				1420	2910	1420
6.5	1630				927	1620	926
6.6	975					984	
6.7	629				433	638	433
7.0	196				183	240	184
$\pi/2$	69.2	68.8	68.2	67.4	66.4	70.9	66.4
π	6480	5260	4080	3130	2240	6310	2240
$3\pi/2$	97.0				92.3	102	92.5
2π	6120				2270	5890	2270

TABLE III

REACTANCE X_{00} IN OHMS VERSUS $H=2\pi\frac{h}{\lambda}$ WITH $\frac{a}{\lambda}$ AS PARAMETER

H	Neglecting internal reactance $\frac{a}{\lambda}=10^{-5}$	$\frac{a}{\lambda}=3\times10^{-5}$	$\frac{a}{\lambda}=10^{-4}$	$\frac{a}{\lambda}=3\times10^{-4}$	$\frac{a}{\lambda}=10^{-3}$	Including internal reactance of Cu $\frac{a}{\lambda}=10^{-5}$, $\lambda=100$ m., $a=1$ mm.	$\frac{a}{\lambda}=10^{-3}$, $\lambda=5$ m., $a=5$ mm.
0.5	−1800	−1560	−1310	−1080	− 825	−1800	− 825
1.0	− 668	− 585	− 495	− 413	− 324	− 667	− 324
1.5	− 46.2	− 37.5	− 28.2	− 20.0	− 11.3	− 44.7	− 11.2
2.0	+ 589	+ 527	+ 459	+ 397	+ 327	+ 592	+ 327
2.5	+1720	+1530	+1320	+1120	+ 900	+1730	+ 900
2.6	+2130	+1890	+1620	+1360	+1070	+2140	+1070
2.7	+2680	+2360	+1990	+1640	+1250	+2690	+1250
2.8	+3410	+2940	+2400	+1900	+1340	+3410	+1340
2.9	+4140	+3370	+2530	+1790	+1050	+4100	+1050
3.0	+2980	+1960	+1040	+ 407	− 48.6	+2810	− 51.6
3.1	−2860	−2500	−2090	−1710	−1310	−2930	−1310
3.2	−4770	−3910	−3060	−2370	−1710	−4700	−1710
3.3	−3960	−3340	−2700	−2150	−1600	−3910	−1600
3.4	−3100	−2670	−2200	−1800	−1370	−3070	−1370
3.5	−2470	−2140	−1790	−1490	−1160	−2450	−1160
4.0	− 943	− 833	− 713	− 604	− 487	− 937	− 487
4.3	− 479				− 247	− 475	− 247
4.4	− 348				− 176	− 343	− 176
4.5	− 222				− 108	− 217	− 108
5.0	+ 408				+ 239	+ 413	+ 239
5.5	+1320				+ 727	+1330	+ 727
5.6	+1610				+ 863	+1620	+ 863
5.7	+1970				+1010	+1970	+1010
5.8	+2420				+1160	+2420	+1160
5.9	+2970				+1250	+2960	+1250
6.0	+3510				+1100	+3440	+1100
6.1	+3160				+ 438	+2960	+ 434
6.2	− 242				− 655	− 441	− 657
6.3	−3700				−1400	−3620	−1400
6.4	−3960				−1560	−3850	−1550
6.5	−3310				−1440	−3240	−1440
6.6	−2690					−2650	
6.7	−2200				−1070	−2160	−1070
7.0	−1150				− 657	−1240	− 657
$\pi/2$	+ 35.9	+ 35.2	+ 34.3	+ 33.3	+ 31.8	+ 37.5	+ 31.9
π	−4360	−3570	−2800	−2170	−1580	−4330	−1580
$3\pi/2$	+ 37.9				+ 34.1	+ 42.7	+ 34.3
2π	−3380				−1320	−3340	−1320

and hence at

$$H_r = n\pi/2 - \delta; \qquad |\delta| < 1 \tag{27}$$

with n any integer.

Upon substituting (27) in (25) and neglecting squares and higher powers of δ, one obtains

$$\Omega^2\delta \pm \Omega(\alpha_1^{\mathrm{I}} + \delta\beta_1^{\mathrm{I}}) + \alpha_1^{\mathrm{II}}\beta_1^{\mathrm{II}} = 0; \ (n \text{ odd}) \tag{28a}$$

$$-\Omega^2\delta \mp \Omega(\beta_1^{\mathrm{I}} - \delta\alpha_1^{\mathrm{I}}) + \alpha_1^{\mathrm{II}}\beta_1^{\mathrm{II}} = 0; \ (n \text{ even}). \tag{28b}$$

For determining the small quantity δ it will be sufficient to retain only the leading terms in Ω, to write $H_r = n\pi/2$ in the integral functions (which are slowly varying for arguments greater than unity), and to write $H_r = n\pi/2$ in Ω (which is very slowly varying). One then obtains

$$\delta = [\mathrm{Si}\ 2n\pi]/[4 \log (n\lambda/a)]; \ (n \text{ odd}) \tag{29a}$$

$$\delta = [4\ \mathrm{Si}\ n\pi - \mathrm{Si}\ 2n\pi]/[4 \log (n\lambda/a)]; \ (n \text{ even}). \tag{29b}$$

The resonant values of H and hence of $h = \lambda H/2\pi$ are thus defined by (27) with (29a), the antiresonant lengths by (27) with (29b). Evaluation of the antiresonant lengths using (29b) and of the lengths for maximum input resistance using (22) reveals that they are very nearly, though not quite the same. Numerical values of H_r and R_{00} (resonant) for the antennas of Tables II and III are given in Table V.

Complete representation of the difference $n\pi/2 - H_r$ is given in Fig. 12 for both the resonant values (n odd) and the antiresonant values (n even) over the practically useful range of $\Omega = 2 \log (2h/a)$. The radiation (input) resistance corresponding to the resonant lengths is plotted in Fig. 13, that corresponding to antiresonant lengths in Fig. 14. In both cases the curves extend over the useful range of Ω. The limiting values of R_{00} for the resonant lengths as the radius of the antenna becomes vanishingly small are seen from Fig. 13 to be precisely those commonly derived for an antenna

TABLE IV

H_m IN RADIANS AND R_{00}(MAX) IN OHMS FOR $n=2$ AND 4

$\frac{a}{\lambda}$	$n=2$ H_m	$n=2$ R_{00}(max)	$n=4$ H_m	$n=4$ R_{00}(max)
(Neglecting ohmic resistence and internal reactance)				
→0	→3.142	→ ∞	→6.283	→ ∞
10^{-5}	3.059	9050	6.200	7750
3×10^{-5}	3.050	7360		
10^{-4}	3.039	5710		
3×10^{-4}	3.027	4380		
10^{-3}	3.009	3130	6.155	2890
(Including ohmic resistance and internal reactance of Cu)				
10^{-5}*	3.056	8940	6.195	7540
10^{-3}**	3.009	3130	6.155	2890

* $\lambda = 100$ m., $a = 1$ mm. ** $\lambda = 5$ m., $a = 5$ mm.

TABLE V

H_r IN RADIANS AND R_{00} (RES) IN OHMS VERSUS $\frac{a}{\lambda}$ FOR $n=1, 2, 3, 4$

$\frac{a}{\lambda}$	$n=1$ resonant H_r	$n=1$ R_{00}(res)	$n=2$ antiresonant H_r	$n=2$ R_{00}(res)	$n=3$ resonant H_r	$n=3$ R_{00}(res)	$n=4$ antiresonant H_r	$n=4$ R_{00}(res)
(Neglecting ohmic resistance and internal reactance)								
→0	→1.571	→73.1	→3.142	→ ∞	→4.712	→105.5	→6.283	→ ∞
10^{-5}	1.540	65.4	3.054	9040	4.681	93.9	6.195	7740
3×10^{-5}	1.537	64.6	3.045	7350				
10^{-4}	1.532	63.5	3.033	5700				
3×10^{-4}	1.527	62.2	3.018	4370				
10^{-3}	1.519	60.3	2.997	3120	4.662	87.5	6.141	2880
(Including ohmic resistance and internal reactance of Cu)								
10^{-5}*	1.539	66.8	3.051	8930	4.678	98.4	6.190	7530
10^{-3}**	1.518	60.3	2.996	3120	4.661	87.6	6.141	2880

* $\lambda = 100$ m., $a = 1$ mm. ** $\lambda = 5$ m., $a = 5$ mm.

with a sinusoidal distribution of current. Since the practical range of antennas lies between $\Omega=10$ and $\Omega=30$ it is clear that the value of 73.13 ohms for the radiation resistance of a symmetrical half-wave antenna is considerably too high. The actual values lie between 58 and 68 ohms depending upon the value of a/λ. The resistance at resonance is also plotted in Figs. 9 and 10 in dotted lines labeled H_r.

Conclusion

It is hoped that the extensive tabulation and graphical representation of the several components of the input self-impedance of a symmetrical, center-fed antenna, as well as of the resonant and antiresonant lengths may prove useful by filling an important gap in the available fundamental data on simple antennas. It is important to note that only the self-impedance has been calculated, so that only the input impedance of an isolated antenna is correctly given by the curves. If an antenna is closely coupled to other antennas as in an array, the input impedance is composed of mutual impedances as well as of the self-impedance here calculated. The determination of mutual impedance to the degree of precision here achieved for the self-impedance has not yet been accomplished. Mutual impedances commonly given in the literature depend upon the assumption of a sinusoidal distribution of current, so that it may be expected that they are reasonably accurate only in the range not excluded by (12).

Institute News and Radio Notes

New York Meeting May 6, 1942

Downtown New York received its belated baptism as the locus of early wireless happenings at an Old Timers' meeting of the Institute of Radio Engineers, held on the evening of May 6, to celebrate the thirtieth anniversary of I.R.E.'s founding. Approximately 125 members met at Fusco's Restaurant, 18 Beaver Street, New York City, to "call the roll" of the past, and to view ancient scenes and personages by means of lantern slides—the television of 1912.

A third of a century ago, explained Robert Marriott, I.R.E.'s first president, the lower end of New York City was greatly favored by the wireless concerns of the day. The Institute itself was incorporated at Sweet's Restaurant, 2 Fulton Street, and meetings were later held there and at Whyte's Restaurant, also on Fulton Street. Forty-two Broadway, just around the corner from Beaver Street, was the home of the United Wireless Telegraph Company, and also the meeting place of the Wireless Institute which Marriott handled before it merged into the I.R.E. De Forest stations graced 17 State Street, Stone Street, and 66 Broadway; the Wireless Specialty Company had a New York office at 81 New Street and later at 149 Broadway; the Wireless Improvement Company was also a tenant of 81 New Street. Dubilier odorized the air with his condenser-impregnating compound at 217 Centre Street. The Telefunken people held out at 111 Broadway; the Atlantic Communication Company at 47 West Street. Colonel John Firth, whom every old-timer remembers, spent his later days at 25 Beaver Street, as does your reporter. The New York *Herald* station OHX was in the Barge Office at the Battery, and within a stone's throw of it was and is the Wireless Operators' Monument. The Marconi Wireless Telegraph Company of America was located

Presidents of the I.R.E.
Standing: R. A. Heising, Arthur Van Dyck, and L. C. F. Horle
Seated: L. M. Hull, Haraden Pratt, R. H. Marriott, and J. V. L. Hogan

Left to right: F. A. Kolster, Keith Henney, H. P. Westman, Austin Bailey, I. S. Coggeshall, B. J. Thompson, Arthur Van Dyck, and Haraden Pratt

at many successive sites, Bridge Street, 37 Water Street, 125 Front Street, 29 Cliff Street, 27 Elm Street, 27 William Street, and lastly at 66 Broadway and 233/326 Broadway. The last-named location also housed the International Radio Telegraph Company, grandchild of Fessenden. These addresses dotted the map of lower Manhattan rather completely.

The Institute of Radio Engineers came into being as a merger of two preceding organizations. The first, and the pioneer wireless engineering club of America, was the Society of Wireless Telegraph Engineers, of Boston, Massachusetts, dating back to 1907. This consisted at first only of members of the Stone Telegraph and Telephone Company, the "loose-coupling" wireless concern with headquarters in Boston, but later it opened its gates to engineers of the National Electric Signalling Company of Professor Fessenden, at Brant Rock, Massachusetts. The second of the merging societies, the Wireless Institute, founded in 1909 in New York City, consisted of operators and installation engineers of the United Wireless Telegraph Company. Charter members of the "Swatties," as the S.W.T.E. was popularly called, attending the I.R.E. meeting were F. A. Kolster and the writer. Bob Marriott was the only representative of the pioneers of the Wireless Institute.

Trouble came to both these early organizations. The demise of the Stone Company in 1909, and the removal of the Fessenden men from "BO" to Brooklyn in 1911, broke up the Boston Club, while in New York the death throes of United Wireless caused the Wireless Institute to lose most of its membership. The result was the merger of both earlier societies into a new, noncompany organization, which has grown to international prominence as the Institute of Radio Engineers. Its membership has risen from about fifty at its inception to over seven thousand at the present time.

The lighter side of the entertainment at the anniversary meeting consisted of the reading of a "report" by Arthur Van Dyck, I.R.E.'s present president, referring to a paper by Dr. Eccles before the I.R.E. in 1919, on the measurement of signal strength by the audibility method. The "report" described various more desirable methods.

The first of these was the "number of rooms" scheme; i.e., how far away in a building of many rooms the signal could be heard; that was matched by J. V. L. Hogan with the plan of placing a telephone at the base of the hollow tower at "BO" and noting how far up the tower an observer must climb before losing the signal. A signal of 3600 inches would have been noted from the Machrahanish station in Scotland, Mr. Hogan reported, if that station had not been wrecked by the falling of its tower some years previously.

General Squier described the Signal Corps method, based on the different sensitivities of various types of trees. Thus, signal strength could be designated as of strength "one pine," or "one elm." A heckler insisted that this be renamed the "deForest Method."

The "Miles-of-Cable" unit was described as that signal, heard over a cable between two points, which would have been heard by a Western Electric radio receiver, "complicated and efficient and critical and big," if it had received any signal at all. Alexanderson, on the other hand, recorded a signal by means of static as well as magnetic exposure on a photographic film, and then identified the intensity in "kodaks." Weagant described the Marconi method of guessing at the signal, the grades being inaudible, partly inaudible, readable with great difficulty, and so on. Dr. deForest, with his usual scientific analysis, disagreed with this nomenclature, naming instead the loudest signal ever heard as a "helluvanoise," and the weakest as one that was never sent.

President Van Dyck stated that the name of the author was not known to him. Perhaps it was just as well. However, in the comparative security of the printed page, I will now admit authorship. (Copies may be obtained by addressing me in care of this station.)

This technical presentation was followed by a display of lantern slides. This soon became a free-for-all, the seated members vying with the lecturer of the moment in identifying old engineers, stations, equipment. Scenes of Marconi's early work in Canada were shown; details of NAA, the Navy's first high-power station; receiving equipment used in Honolulu, before December 7, 1915, when Lloyd Espenschied read wireless telephone signals from the experimental transmitter at NAA; the Babylon hut, first American wireless telegraph station; Marconi and Roy Weagant "inventing the Alexanderson Alternator" at Rocky Point; Weagant alone, beside his nine-mile-long antenna at Lakewood; a scene from "Radio in the Time of King Tut," showing David Sarnoff caressing static's wing, and finally a very trim, dynamically symmetrical arrangement of apparatus which, of course, was the 1908 amateur station of Arthur Van Dyck, who devised the lantern-slide idea for the evening, and who started the ball of identification rolling as Fusco's Blackout began.

It is impossible in this necessarily short account to list all those present, but a few of them, especially the old-timers, must be chronicled. There was E. J. Simon, I.R.E. secretary in 1913, whose radio apparatus was known in the last war to every wireless operator; Jack Hogan, stalwart worker in Institute matters from the beginning, pioneer worker of the heterodyne, and purveyor of highest-fidelity music from WQXR; Bob Marriott, dean of the profession, yet youthful in spirit today as when he founded the Wireless Institute a third of a century ago; Haraden Pratt, who needs no counterpoise, for he is well grounded on all matters of radio fact; Fred Kolster, who wound some wires on a soapbox at the Bureau of Standards in 1916 and gave us the all-essential radio compass of today; Lloyd Espenschied, consultant at Bell Laboratories, as well he might be, for he

Charter Members (Members of the I.R.E. for 30 Years)

Left to right: Arthur Van Dyck, president, 1942; G. H. Clark, Lloyd Espenschied, R. H. Marriott, F. A. Kolster, J. V. L. Hogan, president, 1920; Frank Hinners, and E. J. Simon, secretary, 1913–1914 and radiotelephony grew up side by side; "Larry" Horle, as happy at Fusco's piano as he was in the days of the World War at the Navy's airplane radio headquarters; Arthur Batcheller, who started to have something to say about control of wireless in the beginning and today—as Radio Inspector of New York's busy sector—has very much more to say; W. A. Winterbottom, directing the giant net of R.C.A. Communications, but, as usual, just "Bill" when off duty; and very many others, who must remain anonymous by the mere fact of their multitude.

But space must be found to record the name of one who was not present, Greenleaf W. Pickard, known and loved by all. He, the only charter member of I.R.E. who had been affiliated with *both* of the preceding organizations and who hence bore the apt title of I.R.E.'s "double-jointed" member, expected to be present but was detained in far-off Boston.

As Harold Westman, the I.R.E.'s secretary, carefully packed the portable "Ikonoscope," or slide projector, memories of the past were exchanged by eager groups at the tables, each ancient tale being introduced by the code expression "Remember when . . . ?" Until at midnight the present again took control, and the only thirtieth anniversary that I.R.E. will ever know passed into history.

George H. Clark
Radio Corporation of America
New York, N. Y.

Board of Directors

A regular meeting of the Board of Directors was held on June 3. Those present were A. F. Van Dyck, president; Austin Bailey; C. C. Chambers, I. S. Coggeshall, Alfred N. Goldsmith, editor; F. B. Llewellyn, Haraden Pratt, treasurer; F. E. Terman, B. J. Thompson, H. M. Turner, L. P. Wheeler and H. P. Westman, secretary.

There was received a report of the Awards Committee which designated Dr. S. A. Schelkunoff as the recipient of the 1942 Morris Liebmann Memorial Prize for his contributions to the theory of electromagnetic fields in wave transmission and radiation.

It was agreed that where the exigencies of war prevent a Voting Associate from paying his 1942 dues in time to retain his voting privileges, due diligence having been employed by the Voting Associate to make such payment, the date by which the payment is due may be deferred to one which will retain for the member his voting privileges.

Executive Committee

The Executive Committee met on May 29. Those present were A. F. Van Dyck, chairman; I. S. Coggeshall, Alfred N. Goldsmith, R. A. Heising, guest; F. B. Llewellyn, B. J. Thompson, and H. P. Westman, secretary.

Approval was granted of 51 applications for admission to Associate, 2 to Junior, 109 to Student, and 2 transfers to Associate.

As sponsor of the Sectional Committee on Radio of the American Standards Association, approval was granted of two proposed recommended practices under the titles of "Loudspeaker Testing" and "Volume Measurements of Electrical Speech and Program Waves." These reports will now be submitted to the American Standards Association for final action.

Scrap Salvage

The Institute has recently participated in a meeting sponsored by the War Production Board which was held in the Engineering Societies Building in New York City on April 28 and was devoted to a consideration of the National Industrial Scrap Salvage Program.

An educational sound film on "Mines Above the Ground" was shown through the courtesy of the Western Electric Company. This was followed by a series of speakers who covered the general subjects of "The Roll of Scrap in War Production," "High Lights of the Scrap Salvage Problem," "Management and Economic Considerations," and "The Personal Aspects."

War Production Conference

Secretary H. P. Westman led the panel discussion on the subject: "Solving Problems in Production of Communication Equipment," at the War Production Conference in Newark, New Jersey, on May 29, 1942. The Conference was held under the joint auspices of 15 engineering societies in the vicinity of New York, at the request of the War Production Board.

Mr. Westman, who is secretary of the committee of the American Standards Association currently revising the wartime design standards of radio components and chairman of its important subcommittee on fixed mica capacitators, is a major participant in the Institute's direct collaboration with the Government in this important work. He also represents the Sectional Committee on Radio on the committee, the Institute being represented by Dr. Alfred N. Goldsmith. The Institute's collaboration with the committee has been directed by President Van Dyck, the Board of Directors, and the Executive Committee of the Institute. He pointed out that the radio manufacturing industry, accustomed to dividing its job between the component manufacturer and the equipment producer, slips easily into the desired prime and subcontractor relationships which is so much in favor.

Among the difficulties which have beset the industry and which have to be sloughed off in its streamlining for war production, Mr. Westman mentioned the building of uneconomical units, tendencies to demand greater performance than the size and weight of the component permits, too many odd sizes, and the special marking of identical units which prevents interchange. Excellent prospects exist in the field of standardization. The American Standards Association, at the request of the War Production Board, has initiated the formulation of new specifications for radio parts going into apparatus for the armed services.

Quality of manufacture is one present "bottleneck" of design and manufacture. Factories accustomed to peacetime production face higher quality grades, closer tolerances, and much more extreme service conditions when manufacturing for the Army and Navy. The challenge is being met, however, and, within the limitations of raw materials available, the industry is delivering the goods on the firing line.

Section Meetings

Atlanta

"Reports on Columbus Broadcast Engineering Conference," by Ben Akerman, Engineer, WGST; C. F. Daugherty, engineer, WSB; and A. W. Shropshire, engineer, WSB; March 6.

"Network Testing with Square Waves," Demonstration, by M. A. Honnell, assistant professor in charge of communications engineering, Georgia School of Technology, March 20.

Baltimore

"Directional Antenna Systems," by T. M. Bloomer and A. P. Bock, engineers, Westinghouse Electric and Manufacturing Company, February 20.

"Wartime Radio Communication," by Cedric Lewis, Colonel, Office of the Chief Signal Officer, U. S. Army, March 20.

Boston

"The Electron Microscope and Its Applications in Chemistry," by V. K. Zworykin, associate director, Research Laboratories, Radio Corporation of America, March 12.

"The Behavior of Dielectrics over Wide Ranges of Frequency and Temperature," by R. F. Field, engineer, General Radio Company, April 23.

Buffalo-Niagara

"Radio Magic in War Time," by O. H. Caldwell, *Radio Today*, April 22.

Dallas-Fort Worth

"A High-Efficiency 500-kilowatt Broadcast Transmitter," by J. O. Weldon, Weldon Engineering Company, February 16.

"Measurements at Radio Frequencies," by A. E. Cullum and D. A. Peterson, consulting engineers, A. Earl Cullum Engineering Company, March 20.

Detroit

"Radio Amateur Preparedness Program," by William Watson, chief radio engineer, Wayne County Police, February 20.

"A Special Electron-Coupled Oscillator," by L. R. McDonald, Michigan Bell Telephone Company, February 20.

"The Development of Hearing Aids," by W. C. Bieneman, president, Crystal-Vox Hearing Instrument Company, March 20.

"Electronic Welding Timer," by A. E. Pannuto, development engineer, Weltronic Corporation, March 20.

"Impedance Measurements from 1 to 100 Megacycles," by R. F. Field, research engineer, General Radio Company, April 17.

EMPORIUM

"Radio Magic in Wartime," by O. H. Caldwell, editor, *Radio Today*, April 22.

LOS ANGELES

"The Design, Manufacture, and Operation of Limiting Amplifiers for Audio Frequencies," by J. K. Hilliard, sound department, Metro-Goldwyn-Mayer Studios, March 24.

"Fundamentals of the Doherty Amplifier," by William Comyns, Frank Wiggins Trade School, March 24.

PHILADELPHIA

"The Signal Corps in the War," by M. W. Woodruff, Captain, U. S. Signal Corps and Captain Gates, Fort Monmouth, N. J., April 2.

"The Operation of Mixers and Converters for Superheterodyne Reception," by E. W. Herold, RCA Manufacturing Company, Inc., May 7.

PITTSBURGH

"Electronic Control in the Steel Industry," by P. H. McConaghey, electronic control engineer, March 9.

"A Cavity Resonator as a Tank Circuit," by J. L. Bowers, senior student, Carnegie Institute of Technology, April 13.

"Trigger Circuits," by J. D. Finley, senior student, University of Pittsburgh, April 13.

PORTLAND

"Mechanical Calculation of Horizontal Field Patterns for Two- and Three-Element Vertical Antennas," by Wilson Pritchett, department of electrical engineering, Oregon State College, February 4.

"Trends in Forest Service Communication," by H. K. Lawson, radio engineer, U. S. Forest Service Radio Laboratory, March 25.

"Frequency Multiplication," by Eugene Grant, April 25.

"Sterilizing Solutions Electrically," by Hugh Fleming, April 25.

"Radio Set Demonstrator," by Gil Quimby, April 25.

"Electric Duals," by W. H. Huggins, April 25.

ROCHESTER

"Communications in National Defense," by R. H. Manson, vice president and general manager, Stromberg-Carlson Telephone Manufacturing Company, December 9, 1941.

"Engineering Commercial Frequency-Modulation Receivers," by H. E. Rice, radio engineer, Stromberg-Carlson Telephone Manufacturing Company, January 29.

"Bioelectric Research Apparatus and Bioelectric Phenomena," by Harold Goldberg, engineer, Research Laboratory, Stromberg-Carlson Telephone Manufacturing Company, February 19.

"Artificial Creation of Speech," by J. O. Perrine, assistant vice president, American Telephone and Telegraph Company, April 2.

SAN FRANCISCO

"Gold and the Strategic Minerals of the War Effort," by D. H. McLaughlin, Dean of College of Mining, University of California, February 27.

"Signal Corps Organization," by L. J. Harris, Colonel, U. S. Army Signal Corps, and Lawrence Keith, radio engineer, U. S. Signal Corps, March 18.

SEATTLE

"Recent Advances in the Electron Theory of Photography," by P. M. Higgs, professor of physics, University of Washington, September 19, 1941.

"Industrial Electronic Applications," by Ralph Powers (by transcription), Electronic Control Corporation, October 17, 1941.

"A Mechanical Device to Aid in the Calculation of Class B and C Power-Tube Performance," by R. I. Sarbacher (read by Professor L. B. Cochran), Illinois Institute of Technology, October 17, 1941.

"A Simplified Graphic Method of Designing Impedance-Matching Networks," by R. M. Walker, assistant chief engineer, KOMO-KJR, November 14, 1941.

"Personnel Problems Confronting the Naval Communication Service," by Lieutenant Commander J. E. Parrott, U. S. Naval Reserve, January 30.

ST. LOUIS

"Generalized Description of Ship-Shore Radiotelephone Service," by W. Todd, engineer, Radiomarine Corporation of America, March 5.

TWIN CITIES

"Wave Propagation in Radio Communications," by C. A. Culver, physics department, Carleton College, April 29.

WASHINGTON

"Airport Traffic-Control Equipment Tests," by H. C. Hurley, Civil Aeronautics Administration, April 13.

Membership

The following admissions or transfers (where indicated as such) to Associate grade were approved by the Board of Directors on June 3, 1942.

Allen, M. E., 325 Riverside Dr., New York, N. Y.
Amendola, W. A., 1015 Cherry St., Winnetka, Ill.
Archibald, C. B., Black Point Rd., Niantic, Conn.
Biberman, L. S., 5427 Montgomery Ave., Philadelphia, Pa.
Boyer, K., Bell Telephone Laboratories, Whippany, N. J.
Campoy, H. M., Box 59, Cananea, Sonora, Mexico
Dagle, E. F., 611 W. 10 St., Traverse City, Mich.
Daugherty, R. M., 14433 Mark Twain, Detroit, Mich.
Ernesti, O., Jr., Box 25, Scott Field, Ill.
Evans, H. J., 2322 High St., S.E., Washington, D. C. (Transfer)
Ewing, H. O., Scotland, Md.
Frank-Jones, G., 1335 N. Coronado Ter., Los Angeles, Calif.
Gallonio, A., 108-47—46 Ave., Corona, L. I., N. Y.
Graham, R. C., 512 Dorian Pl., Westfield, N. J.
Greene, S. J., 214 Audubon Ave., New York, N. Y.
Hayes, M. V., Naval Training School, Massachusetts Institute of Technology, Cambridge, Mass.
Hoskins, R. E., 4226—12 Ave., N.E., Seattle, Wash.
Hudson, I., 5442 Telegraph Ave., Oakland, Calif.
Hum, B. W., 416 S. Superior St., Angola, Ind.
Isaak, N. G., Box 583, McMinnville, Ore.
Johnson, R. S., 6606 N. Ashland Ave., Chicago, Ill.
Jorgensen, N. A., 1820 N. Crawford Ave., Chicago, Ill.
Kennedy, R. C., 222 N. Third St., San Jose, Calif.
Kerl, R. C., P. O. Box 14, Scott Field, Ill.
Klein, M., 19 S. 10 St., Newark, N. J.
Kulik, J. J., 1571 Oak St., Wyandotte, Mich.
Le Grand, H. R., 1547 Ardmore Ave., Chicago, Ill.
Littell, C. C., Jr., 308 W. High St., Piqua, Ohio
Loonie, W. P., Jr., 57 Park Ter. W., New York, N. Y.
McArthur, D., 200 Elmwood St., North Attleboro, Mass.
McIntire, T. A., 1902 Ann St., Wilmington, N. C.
McIntosh, J. L., P.O. Box 13, Tinley Park, Ill.
Miller, D. J., Jr., 2935 Robbins Ave., Philadelphia, Pa.
Milster, J. L., Box 272, Poplar Bluff, Mo.
Moldawsky, B. W., 160 E. 65 Ave., New York, N. Y.
Munro, G. M., 527 W. Lovell St., Kalamazoo, Mich.
Nelson, R. A., 79 Sidney St., Cambridge, Mass.
Newman, J., Jr., 20 Waterman Rd., Roslindale, Mass.
Newton, W. L., 921—18 Ave., Seattle, Wash.
Novota, S., Jr., 406 S. Plum St., Moweaqua, Ill.
Rowe, I., 594 E. 93 St., Brooklyn, N. Y.
Sangster, R., 1149 Dovercourt Rd., Toronto, Ont., Canada
Schoessow, R. H., c/o Chief Engineer, Northern Pacific Railway, St. Paul, Minn.
Scullin, F. B., 1328 M St., Fresno, Calif.
Seklemian, R. S., 66 Broad St., New York, N. Y.
Shaw, E. B., Box 870, Macon, Ga.
Shearman, J. C. M., 9 Ripley Rd., Swindon, Wilts, England
Snapp, P. W., 4726 Eighth, N.E., Seattle, Wash.
Sowers, F. E., YMCA Hotel, 826 S. Wabash Ave., Chicago, Ill.
Swanker, W. C., 541 Cahoon Rd., Bay Village, Ohio
Talamini, A., Jr., Fairfield Rd., Little Falls, N. J.
Watine, M. N., 328 E. Eighth St., Brooklyn, N. Y.
Weiner, I., 205 S. Illinois, Belleville, Ill.

Books

Tables of Functions, by Jahnke and Emde 1933, 1938*

Published by B. G. Teubner, Leipzig, Germany. Distributed by G. E. Stechert and Company, New York, N. Y. Third edition, 1938.* 305 pages. 181 figures. 6¼×9¼ inches. Price $6.00.

This volume is a monumental collection of short tables, formulas, and curves of a large variety of transcendental functions. Many of the functions are plotted in three dimensions to give a better picture of the functional relations. The contour method of plotting in two or three dimensions is used in some cases. All subjects are well supported by references to more comprehensive specialized publications.

The text is complete in both English and German, side by side.

Some of the functions which are of greatest interest to radio engineers may be mentioned. The sine-integral, cosine-integral, and exponential-integral are useful in the analysis of transients in idealized filters. The error integral finds application in thermal agitation.

Elliptic integrals are represented by one of the best short collections of formulas, curves, and tables; they find application in the inductance of coils, capacitance of rings, and special problems such as linear detection of modulated waves with unsymmetrical sidebands.

The largest section, about one half of the book, is devoted to an excellent treatment of Bessel functions of integral and fractional orders with real, imaginary, and complex arguments. The essential relations are concisely formulated and illustrated graphically. Special atteniton is given to asymptotic formulas and to special properties such as the roots of the functions and their derivatives. There are 28 tables of the various cases. This section finds application to countless radio problems, from the high-frequency resistance of wires to the propagation in wave guides and attenuation in piston attenuators. Special applications are found in the transients in filters and the sidebands in frequency modulation.

H. A. WHEELER
Hazeltine Service Corporation
Little Neck, L. I., N. Y.

* While the 1938 edition is enlarged and improved in many respects, it does not contain one valuable section of the 1933 edition. This is the 75 pages of the more elementary functions, such as the circular and hyperbolic functions of complex variables. The 1938 preface states that these are to appear as a separate volume.

How to Supervise People, by Alfred M. Cooper

Published by McGraw-Hill Book Company, 330 West 42 Street, New York, N. Y., 1941. 143+vii pages+6-page index. 5¼×7⅞ inches. Price, $1.75.

This is a timely, compact volume. It is based on the author's experience as a consultant in personnel work over a period of twenty years. In these days of rapidly expanding war production, the problem of creating an efficient, capable supervisory staff is not the less important or difficult than that of procuring the machinery with which to turn out the product.

There are good supervision practices which are well grounded in human nature. Failure to act in accordance with them may lead to an inferior product and a labor problem.

The chapter headings are:

How to Become a Supervisor
The Responsibilities that Come with Authority
The Physical Condition of Your Subordinates
How to Develop Group Morale
The Qualities of Leadership
This Thing Called Cooperation
Hiring, Reprimanding, and Firing
When and How to Delegate Authority
The Supervisor as a Teacher

This would seem to be a good book to put in the hands of one who has just received his first promotion to supervisory rank. There are, however, few supervisors, young or old, whose effectiveness will not be increased by a consideration of the suggestions which are made, not many of which can be reasonably disputed. Also, while essentially concerned with factory-type supervision problems, most of the practices which are discussed will apply even though the organization is not a factory in the ordinary sense.

H. A. AFFEL
Bell Telephone Laboratories, Inc.
New York, N. Y.

Contributors

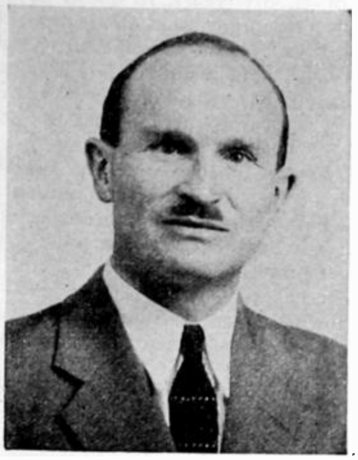
F. G. BLAKE, JR.

F. G. Blake, Jr. (S'39-A'41) was born on April 27, 1917, in New York City. He received the S.B. and A.M. degrees from Harvard University in 1938 and 1940. In 1939 he was at the University of Cambridge, England, and during 1940 and 1941 was a research assistant and teaching fellow at Harvard. Since February, 1941, he has been a special research associate at the Cruft Laboratory.

❖

ALFRED N. GOLDSMITH

Alfred N. Goldsmith (M 12-F'15) received the degree of Ph.D. from Columbia University in 1911, and the Sc.D. (Honorary) degree from Lawrence College in 1935. He was professor of electrical engineering at the College of the City of New York from 1918 to 1923, and became associate professor of electrical engineering at that institution, with life tenure, in 1923. He was consulting engineer, General Electric Company, 1915–1917; director of research, Marconi Wireless Telegraph Company of America, 1917 to 1919; director of research department, Radio Corporation of America, 1919 to 1922; chief broadcast engineer, Radio Corporation of America, 1922–1923; vice president, RCA Photophone, 1928 to 1929; vice president and general engineer, Radio Corporation of America, 1927 to 1933; and subsequently has been consulting engineer. Dr. Goldsmith received the National Pioneer Award in 1940, the Institute of Radio Engineers Medal of Honor in 1941, and the Townsend Harris Medal in 1942.



RONOLD KING

Ronold King (A'30) was born on September 19, 1905, at Williamstown, Massachusetts. He received the B.A. degree in 1927 and the M.S. degree in 1929 from the University of Rochester and the Ph.D. degree from the University of Wisconsin in 1932. He was an American-German exchange student at Munich from 1928 to 1929; a White Fellow in physics at Cornell University from 1929 to 1930; and a Fellow in electrical engineering at the University of Wisconsin from 1930 to 1932. He continued at Wisconsin as a research assistant from 1932 to 1934. From 1934 to 1936 he was an instructor in physics at Lafayette College, serving as an assistant professor in 1937. During 1937 and 1938 Dr. King was a Guggenheim Fellow at Berlin. In 1938 he became instructor in physics and communication engineering at Harvard University, advancing to assistant professor in 1939.

❖

NOEL C. OLMSTEAD

Noel C. Olmstead (A'27) was born at Glasco, Kansas, on September 12, 1904. He received the B.S. degree in electrical engineering in 1928 and the M.S. degree in 1929 from Massachusetts Institute of Technology. From 1929 to 1930 he was a research assistant in the electrical engineering department of that institution, and from 1930 to 1934 he was a member of the high-frequency transmission group of the department of development and research of the American Telephone and Telegraph Company. Since 1934 Mr. Olmstead has been in the commercial products department of the Bell Telephone Laboratories where he has been engaged in the development and design of high-power broadcast transmitters.

❖

A. A. SKENE

A. A. Skene (M'41), following service in the U. S. Army during 1918 and 1919, received the degree of B.S. in electrical engineering from Pennsylvania State College in 1920. He at once joined the engineering department of the Western Electric Company, where he was engaged in apparatus design and radio development until 1923. He then spent some six years with the Union Switch and Signal Company, concerned with the engineering of railway signaling and automatic train control systems and equipment. In 1930 Mr. Skene joined the technical staff of the Bell Telephone Laboratories, where he has been occupied in the design and development of radio broadcasting transmitters and associated apparatus.

❖

ARTHUR VAN DYCK

Arthur Van Dyck (A'13-M'18-F'25) was born on May 20, 1891, at Stuyvesant Falls, New York. He received the Ph.B. degree from Sheffield Scientific School, Yale University in 1911. From 1907 to 1910 Mr. Van Dyck was an amateur experimenter and commercial operator at sea. He was associated with the National Electric Signalling Company, Brant Rock, Massachusetts, 1911–1912; research department, Westinghouse Electric and Manufacturing Company, 1912–1914; instructor in electrical engineering, Carnegie Institute of Technology, 1914–1917; expert radio aide, U. S. Navy, 1917–1919; Marconi Company, Aldene, New Jersey, 1919–1920; in charge, radio receiver design, General Electric Company, 1920–1922. Since 1922 he has been with the Radio Corporation of America.

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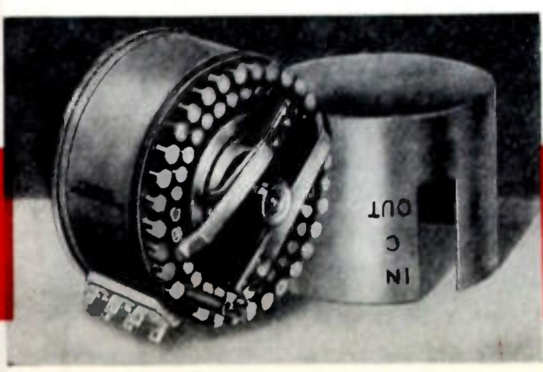

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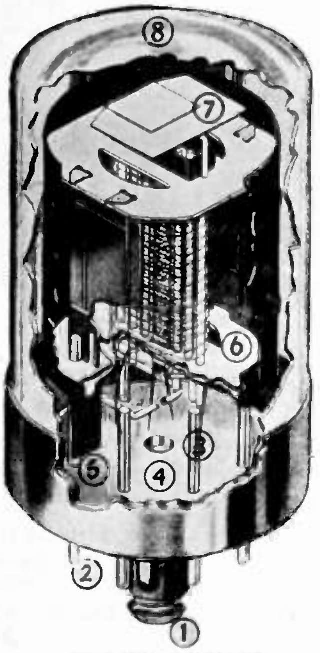

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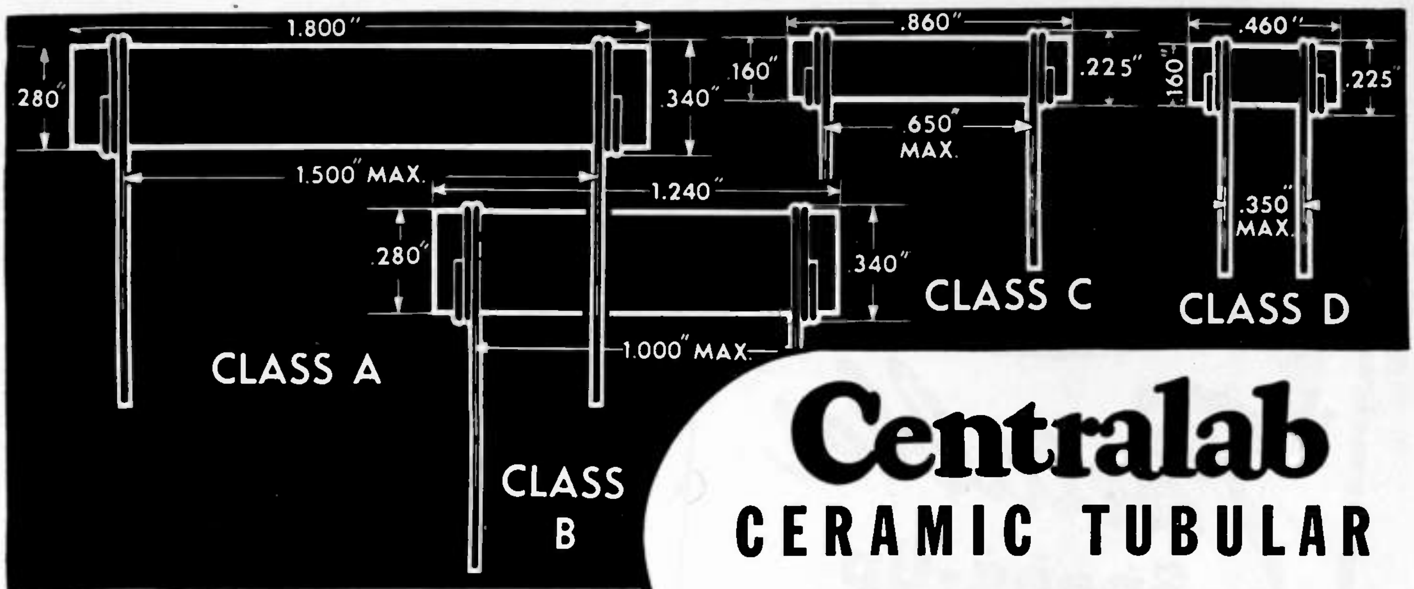

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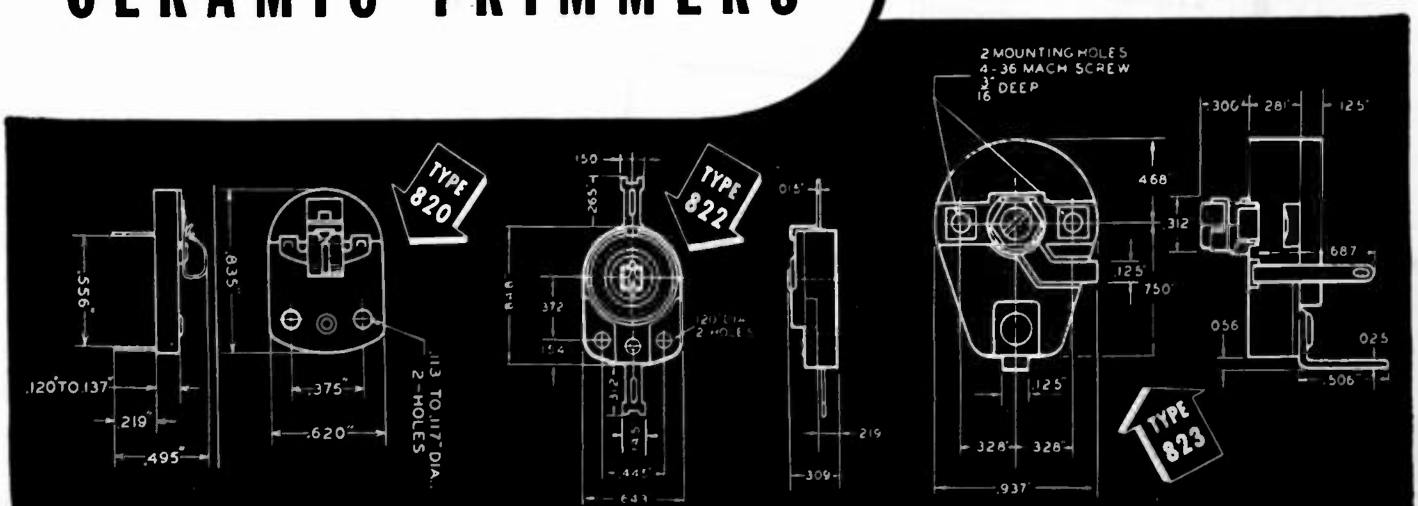

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And whether your particular interest lies in laboratory service, production line testing, experimental work, field service, or plant maintenance, you will find your need provided for, with exacting and lasting accuracy in the expanded line of Triplett Portables.

In the drive of production-line testing, Triplett Portables supply the full-scale accuracy, the consistent performance, the hair-trigger answers that result from the Triplett method of safe-guarding quality, by making every essential part in the Triplett plant.

If you, like the writer of the letter quoted below, want to back up our armed forces with time-saving production practices, write for complete details on other Triplett Portables, panel electrical measuring and test equipment.

Excerpt from letter of a prominent manufacturer (original in our files):

"With the Ohm Meter we have on order we can do in . . . . seconds, what now takes a couple of hours."

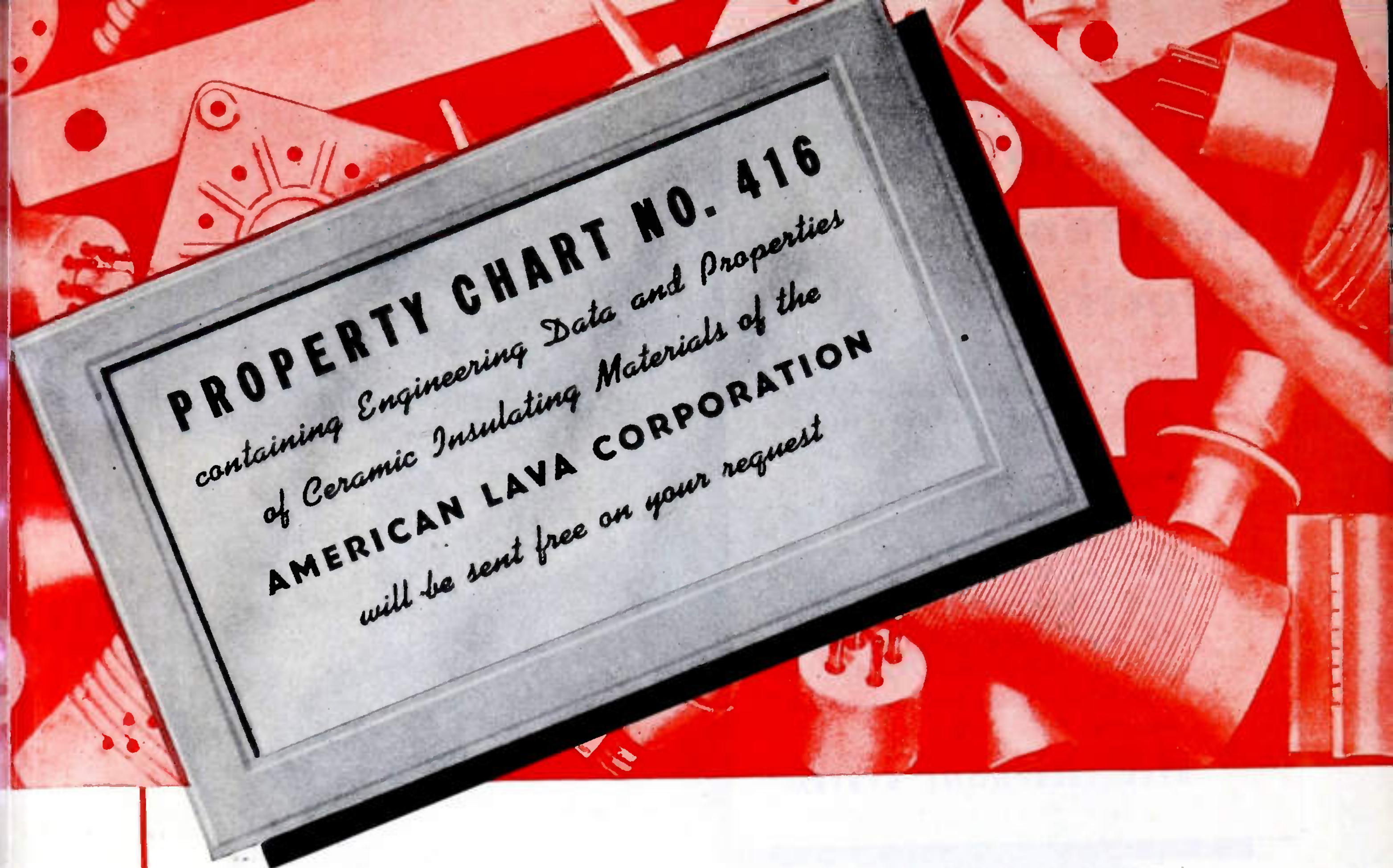
Model 625

Models 625 D.C. and 635 A.C. Portables are unequalled for today's rush in production testing or the rigid requirements of laboratory checking. These highly attractive molded case instruments have long 4.58" hand calibrated mirror scales. The hinged cover closes when instrument is not in use, for added protection. Black molded case for D.C. instruments; A.C. is red. Size is 6" x 5½" x 2½". Has detachable leather strap handle.

Model 425

Another new Portable combining attractive symmetrical case proportions, a long readable scale, and requiring a minimum of bench space when in use. A real beauty in design for those preferring something different. Case and base are molded; base size 5" x4⅜". Model 425 D.C. (3.12" hand calibrated mirror scale); Model 435 A.C. (2.88" hand calibrated mirror scale.)

THE TRIPLETT ELECTRICAL INSTRUMENT CO.
BLUFFTON, OHIO



YOU will find these data most helpful in specifying the correct steatite ceramic insulation for your requirements. The chart eliminates guesswork and might save you many hours or days of laboratory tests.

You will also find from this chart that American Lava Corporation offers ceramic insulating materials with the widest range of physical characteristics available from any single source.

If you do not find the exact combination of physical characteristics you desire, our Research Division will be glad to work with you if you will detail your requirements. The skill of these engineers in developing special products for special purposes is favorably known to leading designers.

ALSIMAG
Trade Mark Reg. U.S. Pat. Off.

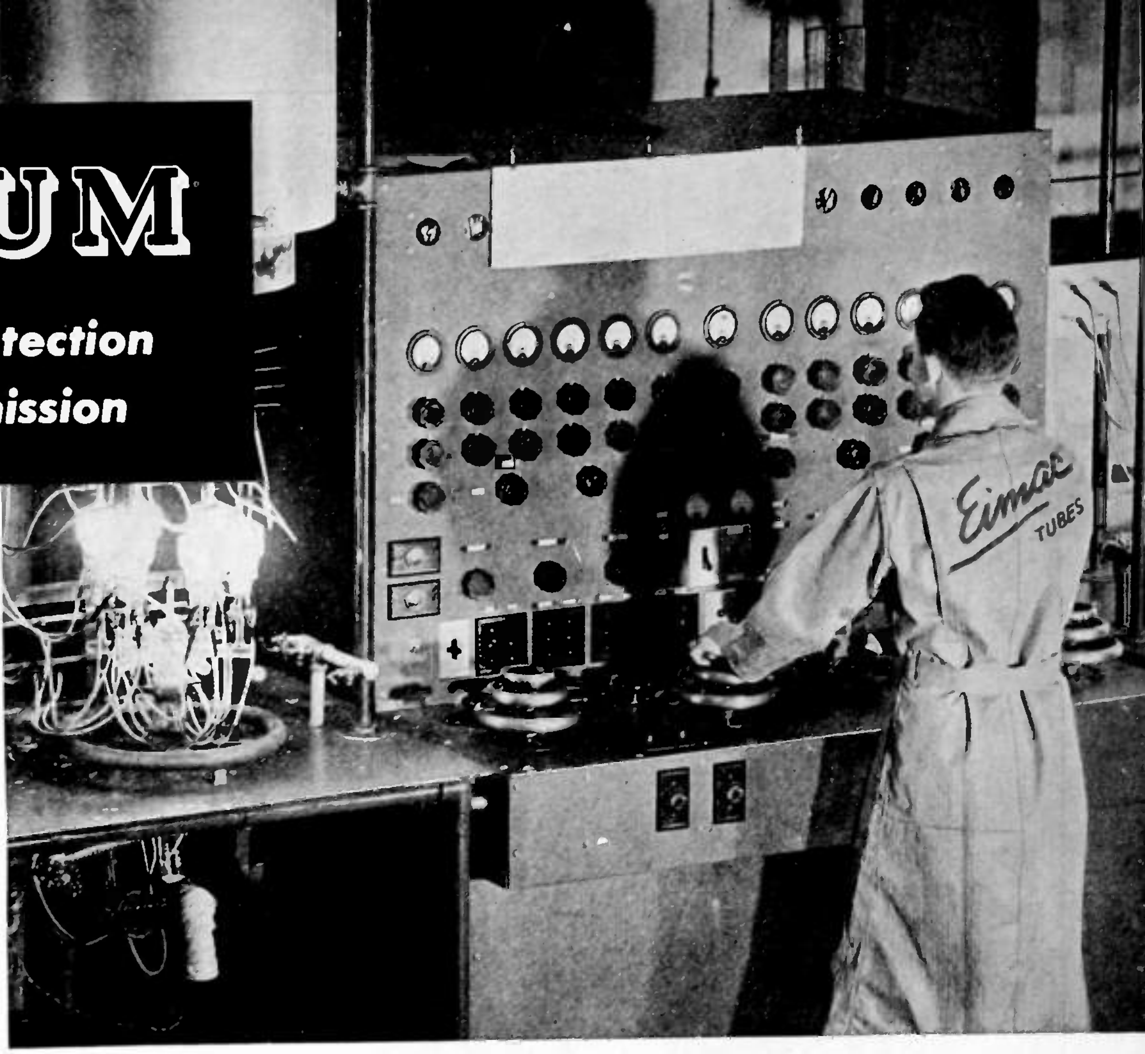
AMERICAN LAVA CORPORATION

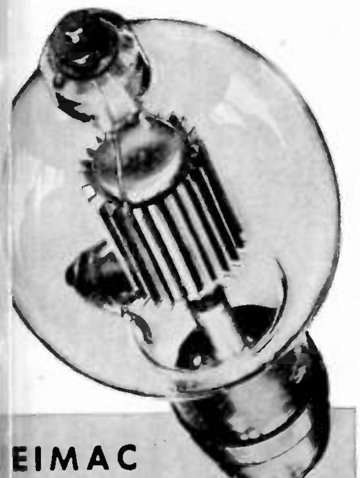
CHATTANOOGA, TENNESSEE

CHICAGO • CLEVELAND • NEW YORK • ST. LOUIS • LOS ANGELES • SAN FRANCISCO • BOSTON • PHILADELPHIA • WASHINGTON, D. C.

VACUUM

The Invisible Protection for Filament Emission

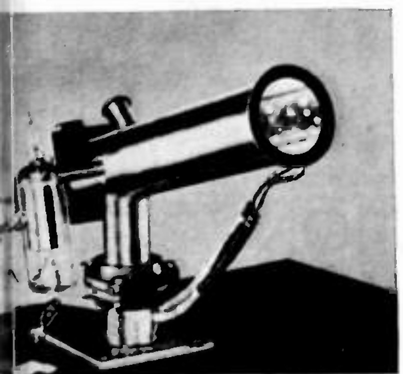




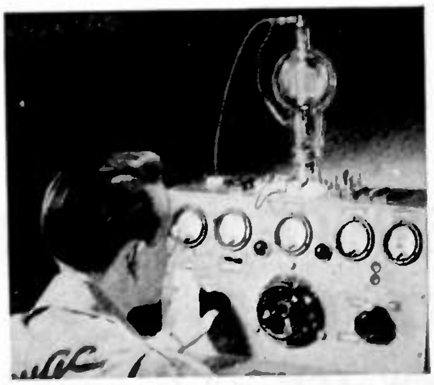
EIMAC 2000T

Filament Voltage . .	10 volts
Plate Voltage .	up to 6000 volts
Plate Dissipation . .	2000 watts
Power Output (75% eff.)	6000 watts

Like a solid coat of armor-plate, hard, high vacuum protects filament emission in every Eimac tube. Extremely efficient evacuating pumps developed and built in the Eimac laboratories for the precise purpose of producing the highest possible degree of vacuum are shown in action above. It is this excellent vacuum that proved the idea fallacious that plate temperature destroyed emission...caused premature failures. Chiefly because of this processing, Eimac tubes today, and for the past number of years, have provided longer life, greater stamina and vastly superior performance.



LECTRON MICROSCOPE virtually gives a noving picture projection of the action of electrons being emitted from a ieated filament. Such observations enble Eimac engineers to constantly roduce better filaments.



PEAK EMISSION TESTER measures the flow of electrons from the filaments of completed Eimac tubes. Of the long series of gruelling tests made to insure more efficient filament emission in every Eimac tube, this is the final test.

FLASH FILAMENT TESTER checks filaments before tubes are assembled and pumped. Here tubes are placed under a temporary vacuum, heated to much higher temperatures than will ever be required in normal use. Only perfect filaments reach the final stages of manufacture.

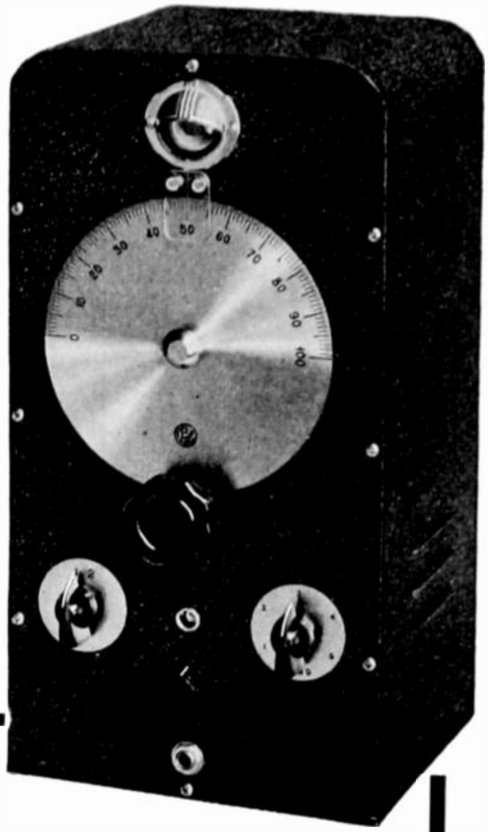
n Peacetime or Wartime...wherever you look...in he air, on land and at sea...you'll find Eimac tubes oing their bit. Right now the Armed Forces get rst call on our facilities and Eimac tubes are reeiving enthusiastic acceptance from all quarters.

Follow the Leaders to **Eimac TUBES**

Eitel-McCullough, Inc.
San Bruno, California, U.S.A.


KENNY

BROWNING TYPE S-2 FREQUENCY METER



CHECK FREQUENCY *Accurately*

Designed Especially for Emergency, Police and Similar Services. This Instrument Is Custom Built for Individual Frequencies

1. Accuracy better than .005%.

2. Will meet the F. C. C. requirements for checking the frequencies of any transmitter which requires a frequency meter accurate to .005%.

3. For more accurate zero beat setting a cathode ray indicator is employed. A jack is provided for aural indication of zero beat.

4. The Browning Frequency Meter is so designed that the precision of the apparatus at any time can be checked to at least fifty parts in five million against the Bureau of Standards Station WWV or against any reliable station operating on frequencies which are an even multiple of 100 KC.

5. Custom-built for specified frequencies. Models from 1 to 5 bands inclusive.

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BL BROWNING Laboratories INC.

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Designers and manufacturers of custom built Radio and Electronic Equipment for national defense and commercial use.

THE INSTITUTE serves those interested in radio and allied electrical communication fields through the presentation and publication of technical material.

THE PROCEEDINGS has been published without interruption since 1913 when the first issue appeared. The contents of each paper published in the PROCEEDINGS are the responsibility of the author and are not binding on the Institute or its members. Material appearing in it may be reprinted or abstracted in other publications on the express condition that specific reference shall be made to its original appearance in the PROCEEDINGS. Illustrations of any variety, however, may not be reproduced without specific permission from the Institute.

STANDARDS reports are published from time to time and are sent to each member without charge. The four current reports are on Electroacoustics, Electronics Radio Receivers, and Radio Transmitters and were published in 1938.

MEMBERSHIP has grown from a few dozen in 1912 to about seven thousand. Practically every country in the world in which radio engineers may be found is represented in our roster. Dues for the five grades of membership range from $3.00 to $10.00 per year. The PROCEEDINGS is sent to each member without further payment.

SECTIONS in twenty-six cities in the United States, Canada, and Argentina hold regular meetings. The chairmen and secretaries of these sections are listed on the page opposite the first article in this issue.

SUBSCRIPTIONS are accepted for the PROCEEDINGS at $10.00 per year in the United States of America, its possessions, and Canada; when college and public libraries order direct from the Institute, the subscription price is $5.00. For other countries there is an additional charge of $1.00.

The Institute of Radio Engineers, Inc.
Harold P. Westman, Secretary
330 West 42nd Street
New York, N.Y.

The Institute of Radio Engineers

Incorporated

330 West 42nd Street, New York, N.Y.

To the Board of Directors

Gentlemen:

I hereby make application for ASSOCIATE membership in the Institute of Radio Engineers on the basis of my training and professional experience given herewith, and refer to the sponsors named below who are personally familiar with my work.

I certify that the statements made in the record of my training and professional experience are correct, and agree if elected, that I shall be governed by the Constitution of the Institute as long as I continue a member. Furthermore I agree to promote the objects of the Institute so far as shall be in my power.

....
(Sign with pen)

....
(Address for mail)

....
(City and State)

....
(Date)

SPONSORS

(Signatures not required here)

Mr. ....

Address ....

City and State ....

Mr. ....

Address ....

City and State ....

Mr. ....

Address ....

City and State ....

REMITTANCE SCHEDULE

Month During Which Application Reaches I.R.E. Headquarters	Amount of Remittance (=Entrance Fee+Dues) Which Should Accompany Application	
Grade →	Associate	Period Covered by Dues Payment
Jan., Feb.	$7.50 (=$3+$4.50*)	Apr.-Dec. (9 mo. of current year)†
Mar., Apr., May	6.00 (= 3+ 3.00*)	July-Dec. (6 mo. of current year)†
June, July, Aug.	4.50 (= 3+ 1.50*)	Oct.-Dec. (3 mo. of current year)†
Sept., Oct., Nov.	9.00 (= 3+ 6.00*)	Jan.-Dec. (entire next year)
Dec.	7.50 (= 3+ 4.50*)	Apr.-Dec. (9 mo. of next year)†

† You can obtain the Proceedings for the entire year by including with your application a request to that effect and a remittance of $9.00.

* Associate dues include the price of the Proceedings, as follows: 1 year, $5.00; 9 months, $3.75; 6 months, $2.50; 3 months, $1.25. This may not be deducted from the dues payment.

TO APPLY FOR ASSOCIATE MEMBERSHIP

To Qualify for Associate membership, an applicant must be at least 21 years of age, of good character, and be interested in or connected with the study or application of radio science or the radio arts.

An Application should be filed, preferably on blanks obtainable on request from I.R.E. Headquarters or from the secretary of your local Section. If more convenient, however, the accompanying abbreviated form may be submitted. Additional information will be requested later on.

Sponsors who are familiar with the work of the applicant must be named. There must be three, preferably Associates, Members, or Fellows of the Institute. Where the applicant is so located as not to be known to the required number of member sponsors, the names of responsible nonmembers may be given.

Entrance Fee and Dues: The Associate entrance fee is $3.00. Annual dues are $6.00 per year, which include the price of the Proceedings as explained in the accompanying remittance schedule.

Remittance: Even though the I.R.E. Constitution does not require it, you will benefit by enclosing a remittance with your application. We can then avoid delaying the start of your Proceedings.

Your Proceedings will start with the next issue after your election, if you enclose your entrance fee and dues as shown by the totals in the accompanying remittance schedule. Any extra copies sent in advance of the period for which you pay dues (see last column) are covered by your entrance fee.

Should you fail to be elected, your entire remittance will be returned.

OTHER GRADES are available to qualified applicants. Those who are between the ages of eighteen and twenty-one may apply for Junior grade. Student membership is for full-time students in engineering or science courses in colleges granting degrees as a result of a four-year course. A special application blank is provided and requires the signature of a faculty member as the sole sponsor. Member grade is open to older engineers with several years of experience. Fellow grade is by invitation only. Information and application blanks for these grades may be obtained from the Institute.

SUPPLIES

BACK COPIES of the Proceedings may be purchased at $1.00 per copy where available. Members of the Institute in good standing are entitled to a twenty-five per cent discount.

VOLUMES, bound in blue buckram, may be purchased for $14.25; $11.25 to members.

BINDERS are $1.50 each. The volume number or the member's name will be stamped in gold for fifty cents additional.

INSTITUTE EMBLEMS of fourteen-carat gold with gold lettering on an enameled background are available. The lapel button is $2.75; the lapel pin with safety catch is $3.00; and the watch charm is $5.00. All of these are mailed postpaid.

(Typewriting preferred in filling in this form) No. ....

RECORD OF TRAINING AND PROFESSIONAL EXPERIENCE

Name ....
(Give full name, last name first)

Present Occupation ....
(Title and name of concern)

Business Address ....

Home Address ....

Place of Birth .... Date of Birth .... Age ......

Education ....

Degree ....
(College) (Date received)

TRAINING AND PROFESSIONAL EXPERIENCE

(Give dates and type of work, including details of present activities)

Record may be continued on other sheets this size if space is insufficient.

Receipt Acknowledged .... Elected .... Notified ....

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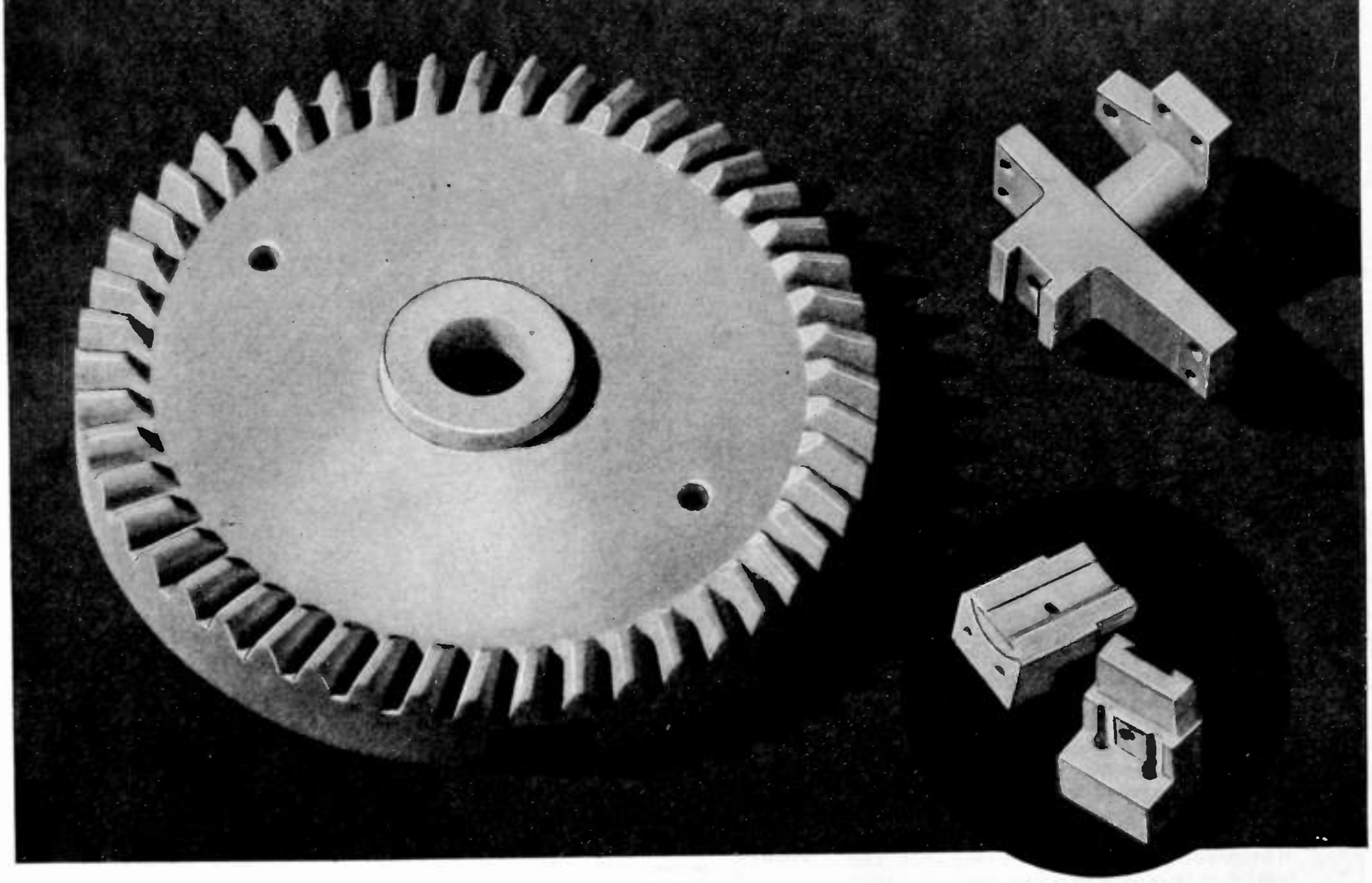
PRODUCED WITHOUT SPECIAL TOOLS



WHEN special ceramic parts are required in small quantities for vital wartime applications, the adaptability of Isolantite* to the production of intricate shapes is a feature of major importance.

Through years of experience in the manufacture of steatite ceramics, Isolantite Inc. has developed fabricating techniques that permit the production of intricate shapes without the necessity of providing expensive special tools. In addition, Isolantite's manufacturing processes permit extremely close dimensional tolerances as compared with general ceramic requirements. Critical dimensions can be held within close limits to facilitate equipment assembly.

Suitability for the production of intricate shapes to accurate dimensions is only one of Isolantite's many advantages. Uniformity of product, high mechanical strength, electrical efficiency, nonabsorption of moisture—these factors all contribute to dependable insulation performance. Because of its unique combination of properties in a single ceramic body, Isolantite is the choice of leading manufacturers, not only in the high-frequency fields, but for all applications where high-grade insulation is required in intricate shapes.

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ISOLANTITE INC., BELLEVILLE, NEW JERSEY

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POSITIONS OPEN

The following positions of interest to I.R.E. members have been reported as open. Apply in writing, addressing reply to company mentioned or to Box No. . . . .

PROCEEDINGS of the I.R.E.
330 West 42nd Street, New York, N.Y.

NOTICE TO APPLICANTS

All men having employment records on file at Institute headquarters are requested to notify us immediately of their continued availability and at least every three months thereafter. Failure to receive notification will void application, as we are endeavoring to keep accurate files of only those men still available for placement.

I.R.E. ASSISTANT SECRETARY

The Institute has immediate need for the services of a man with some business experience and a good general knowledge of communications engineering for the position of Assistant Secretary. Duties include carrying on correspondence, assisting the Secretary in conducting the Institute's activities, acting as secretary to technical committees, etc. Writing ability and publication experience desirable. Apply in writing to the Secretary, Institute of Radio Engineers, 330 West 42nd Street, New York, N.Y.

INSTALLATION ENGINEERS

An agency of the U. S. Armed Forces is seeking radio installation engineers. Men who are just graduating or with only 2 years of college as well as experienced men can qualify. Location: Metropolitan New York. Box 270.

RADAR LABORATORY

The Signal Corps Radar Laboratory has urgent need for Physicists and Engineers with Mechanical, Electrical, and Radio training. Inexperienced engineering graduates can also qualify.

Salaries range from $2000 to $3200 and up.

Draftsmen, Engineering Aides, Electricians, and Radio Mechanics also are wanted.

Apply in writing stating full qualifications to: Civil Service Representative, Signal Corps Radar Laboratory, Camp Evans, Belmar, New Jersey.

CIVILIAN ORDNANCE ENGINEERS

The Naval Ordnance Laboratory of the Washington Navy Yard is seeking research and engineering men holding Ph.D. degrees or like calibre to head up new research problems—Salaries are very attractive.

Also—men with proven ability as Mechanical Engineers, Electrical Engineers, Physicists and Draftsmen are urgently needed.

An unusual opportunity as the work is among men proven leaders in their respective fields who have been loaned to the Navy by their civilian employers, and excellence of war-time work will certainly receive recognition in peacetime industry.

Only American citizens can be considered. Apply by letter—stating full experience, education and qualifications to Robert F. Moore, Naval Ordnance Laboratory, Washington, D.C.

Attention Employers . . .

Announcements for "Positions Open" are accepted without charge from employers offering salaried employment of engineering grade to I.R.E. members. Please supply complete information and indicate which details should be treated as confidential. Address: "POSITIONS OPEN," Institute of Radio Engineers, 330 West 42nd Street, New York, N.Y.

The Institute reserves the right to refuse any announcement without giving a reason for the refusal.

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Extra quality and *extra* dependability have always been an integral part of Ohmite Resistance Units. Electrical and physical fitness for heavy-duty service in exacting applications are built-in from the very beginning. Research, engineering, testing, production and inspection all work together to make Ohmite Products always a little better.

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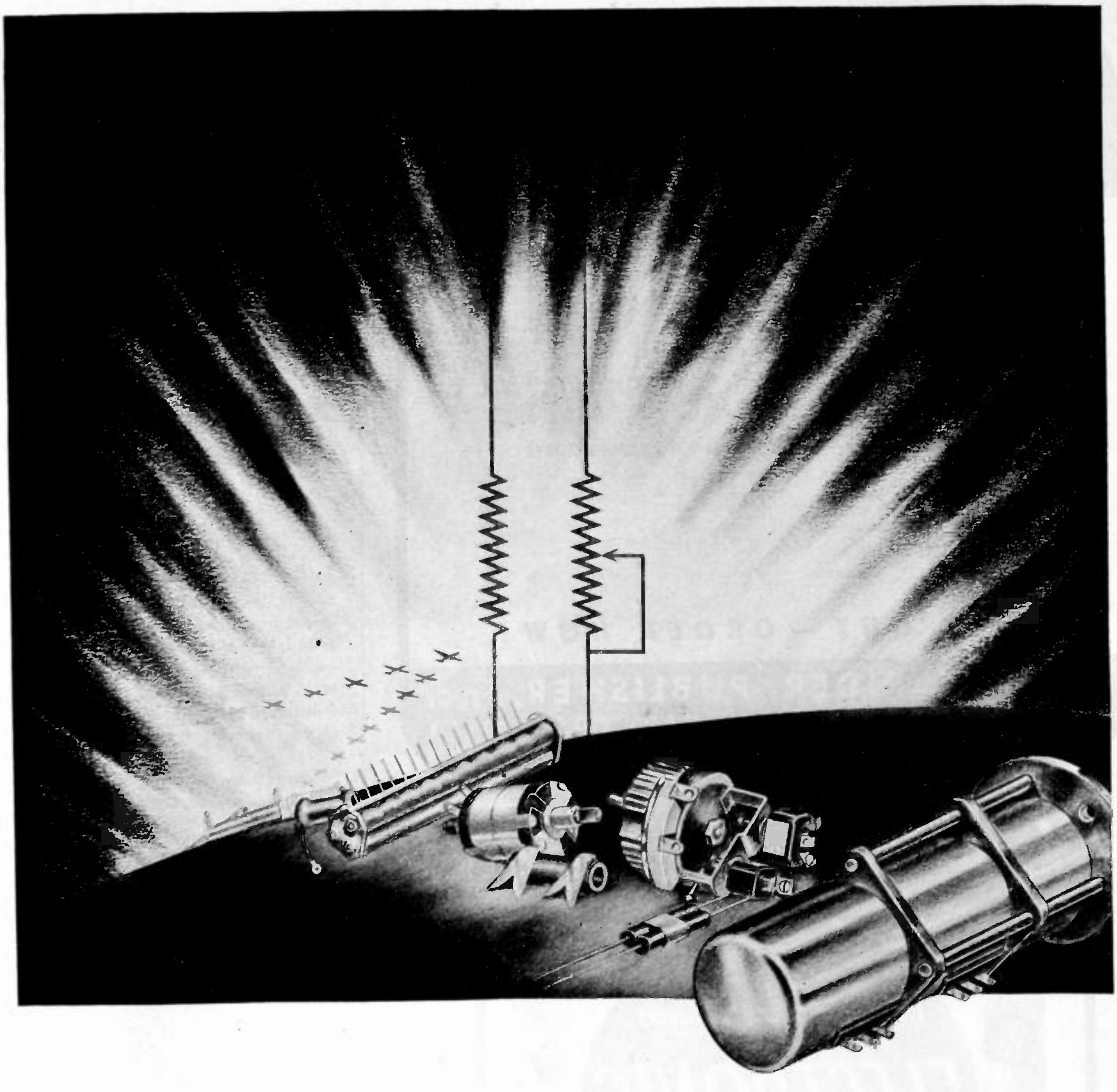


TOMORROW'S RESISTORS

The war has not stopped IRC engineering and development work. It has only intensified it. One exacting requirement after another has been met. New requirements will be met as they arise.

Thus, just as IRC has pioneered the most important fixed and variable resistor developments of the past two decades, you can look to IRC for continued leadership, both in resistor development and in the all-important "Know-how" of resistor application and use under all conditions and in all parts of the world.

Tomorrow's resistors are being born in today's crucible of War—and, as in the past, they will bear the trademark "IRC."

IRC

INTERNATIONAL RESISTANCE COMPANY, 431 N. BROAD ST., PHILA., PA.

Booklets, Catalogs and Pamphlets

The following commercial literature has been received by the Institute.

G.A.W. CARBONYL IRON POWDERS (Booklet). Advance Solvents & Chemical Corp., 245 Fifth Ave., New York, N. Y. A well presented and illustrated report on characteristics and applications of Iron Powders useful to radio engineers. 24 pages and cover, $8\frac{1}{2}\times 11$ inches.

INDUSTRIAL APPLICATIONS OF ELECTRONIC DEVICES (Part III, House Organ, Jan. 1942). By the Engineering Department, Aerovox Corp., New Bedford, Mass. Discusses Inverters, Direct Current Transformers, Thyratron Temperature Control Circuits, Arc Light Timer, Radio Interference, etc. 8 pages, illustrated, $8\frac{1}{2}\times 11$ inches.

AN ENGINEERING CHART OF IRC FIXED AND VARIABLE RESISTORS (Wall Chart). International Resistance Company, 401 North Broad St., Philadelphia, Pa. Helpful and time saving tables of specifications and characteristics of fixed and variable resistors for use of radio engineers in designing. Folded for file, $9\frac{1}{2}\times 11\frac{1}{2}$ inches, opens up to $18\frac{1}{2}\times 22\frac{1}{2}$ inches for wall use.

RADIO COILS AND ALLIED PRODUCTS (Catalog No. 42). J. W. Miller Co., 5917 South Main St., Los Angeles, Calif. Includes complete listing of radio interference filters and coils for mobile equipment. 48 pages, illustrated with specifications and prices, $8\frac{1}{2}\times 11$ inches.

RHEOSTATS, RESISTORS, TAP SWITCHES, CHOKES AND ATTENUATORS (Catalog No. 18). Ohmite Manufacturing Co., 4835 W. Flournoy St., Chicago, Ill. Very complete and useful to radio and television engineers. 16 pages, illustrated, with specifications and prices, $8\frac{1}{2}\times 11$ inches.

METAL SHIELDED WIRE (Booklet and Catalog) Precision Tube Co., 3824 Terrace St., Philadelphia, Pa. Discusses a new method of protecting insulated wires. 8 pages, illustrated, contains specifications, $8\frac{1}{2}\times 11$ inches.

LONG LIVE YOUR MICROPHONE (Booklet). Shure Brothers, 225 W. Huron St., Chicago, Ill. Popular style "maintenance" story on how to get the best service from your microphone. 16 pages, cartoon illustrations, 4×7 inches.

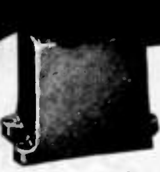
SYLVANIA NEWS (House Organ, March-April, 1942). Hygrade Sylvania Corp., Emporium, Pa. Technical Section reports on—"Lock-In," A Study in Radio Tube Quality—On Servicing Record Players—and gives three simplified and practical charts on reactance. 8 pages, illustrated, $9\frac{1}{2}\times 12\frac{1}{2}$ inches.

ENGINEERS . . . ATTENTION! (Catalog). John Wiley & Sons, Inc., 440 Fourth Ave., New York, N. Y. Describes Wiley's Engineering Handbooks with reference to their value in war engineering work. 16 pages, illustrated, gives prices, $8\frac{1}{2}\times 11$ inches.

Continuous Service Rating Data

TYPES 1550-1560-1570-1580-1590

Maximum Current in Amperes — Maximum Ambient Temperature 60° C

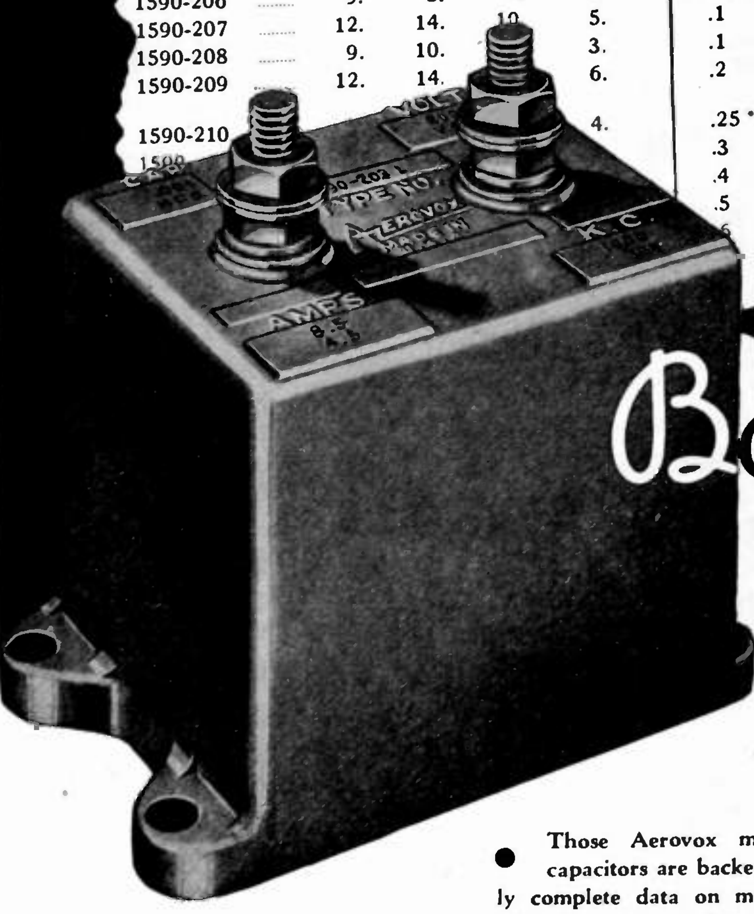


Type 1590

TYPE 1590

Catalog Number	10,000 kc.	3000 kc.	1000 kc.	300 kc.	100 kc.
590-200	....	7.	4.5	1.5	.5
590-201	....	8.5	6.	3.	1.
1590-202	....	6.	4.	2.	.7
1590-203	....	10.	8.5	4.5	1.5
1590-204	....	8.	7.	3.5	1.2
1590-205	....	11.	11.	7.5	2.5
1590-206	....	9.	8.	6.	2.
1590-207	....	12.	14.	10	5.
1590-208	....	9.	10.	[illegible]	3.
1590-209	....	12.	14.	[illegible]	6.
1590-210	[illegible]	[illegible]	[illegible]	[illegible]	4.

Cap. Mfds.	Test Volts Eff.	Catalog Number	10,000 kc.	3000 kc.	1000 kc.	300 kc.	100 kc.
.01	8000	1590-217	....	16.	20.	15.	8.
.01	6000	1590-218	....	16.	20.	15.	8.
.02	5000	1590-219	....	18.	20.	17.	10.
.03	4000	1590-220	....	18.	20.	18.	12.
.04	4000	1590-221	....	18.	23.	20.	12.
.05	4000	1590-222	....	18.	25.	22.	12.
.05	2000	1590-223	....	18.	25.	22.	12.
.1	2000	1590-224	....	18.	25.	22.	12.
.1	1000	1590-225	....	18.	25.	22.	12
.2	600	1590-226	....	18.	25.	22.	12.
.25	600	1590-227	....	18.	25.	22.	12.
.3	600	1590-228	....	18.	25.	22.	12
.4	600	1590-229	....	18.	25.	22.	12.
.5	600	1590-230	....	18.	25.	22.	12
[illegible]	600	1590-231	....	18.	25.	22.	1
[illegible]	600	1590-232	....	18.	25.	22.	1



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Aerovox mica transmitting capacitors are available in the widest range of types, capacities, working voltages. Type here shown is the bakelite-cased 1590 series for medium-duty high-frequency current-handling functions.

● Those Aerovox mica transmitting capacitors are backed by exceptionally complete data on maximum current-carrying ratings at five different frequencies, in addition to capacity and test-voltage ratings. The unit best suited for given current at given voltage and frequency may thus be selected quickly and precisely. This data, the accumulation of years of research and experience based on extensive tests conducted with special test equipment, was determined in connection with standard circuits in which such units are extensively used.

Good capacitors, *plus* good application data, account for the tremendous popularity which Aerovox transmitting capacitors enjoy today.

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A NEW BOOKLET . . .

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This booklet should be of the greatest interest to all engineers and designers of communications equipment.

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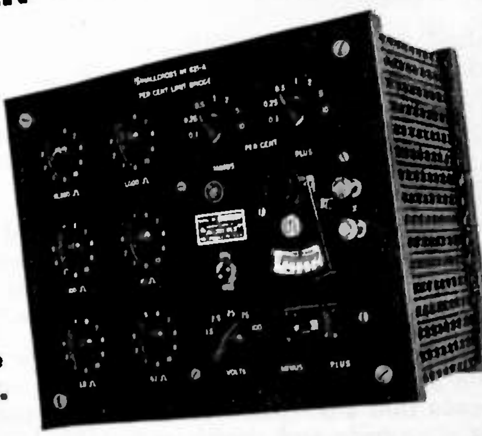
By setting the independently operated percentage dials to the "M" position this modern bridge is instantly ready for use as a Wheatstone Bridge (unity ratio) . . . and the actual resistance of the units under test can be readily measured.

This new #621-A Per Cent Limit Bridge is completely self-contained. A standard #6 dry cell furnishes the power for measuring low resistances. For higher resistances, an AC-operated rectifier tube supplies the power.

No. 621-A PER CENT LIMIT BRIDGE

This is a new instrument for rapid and precise inspection of resistors to determine if they are within the specified percentage tolerance. Write for Bulletin D 23.



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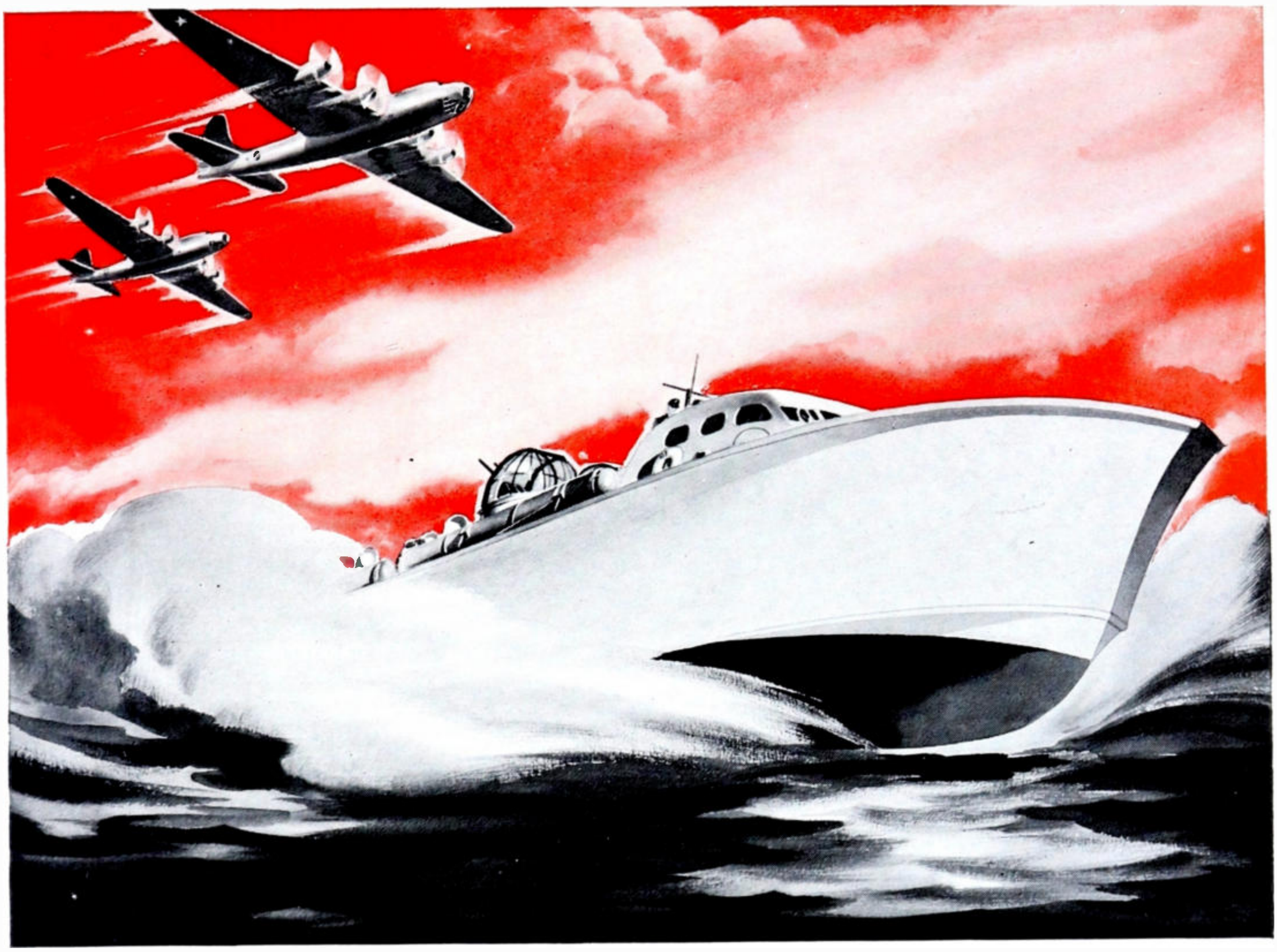


C-Ds serve MacArthur today...You tomorrow!

more capacitors for victory . . .
more hours of capacitor use
per dollar for American industry.

Unfailing communication between plane and mosquito boat made possible the successful evacuation of General MacArthur from Corregidor; the successful attack on Jap warships in Subic Bay . . . Whether C-Ds are used in relaying MacArthur's messages "down under" or in helping "ham rigs" stand watch on our own seaboard, they are meeting the enemy challenge with the *finer* performance and *extra* dependability that Cornell-Dubilier has learned to build into them in its 32 years' experience as the world's largest manufacturer of capacitors exclusively.

While you may not now be able to enjoy the efficient performance of C-Ds, Cornell-Dubilier's contribution to America's war effort does assure more hours of capacitor use per dollar for industry in time to come.

Cornell-Dubilier Electric Corporation, South Plainfield, New Jersey; New England Division, New Bedford, Mass.

LOW POWER TRANSMITTER CAPACITORS
Copied, imitated — but never duplicated.

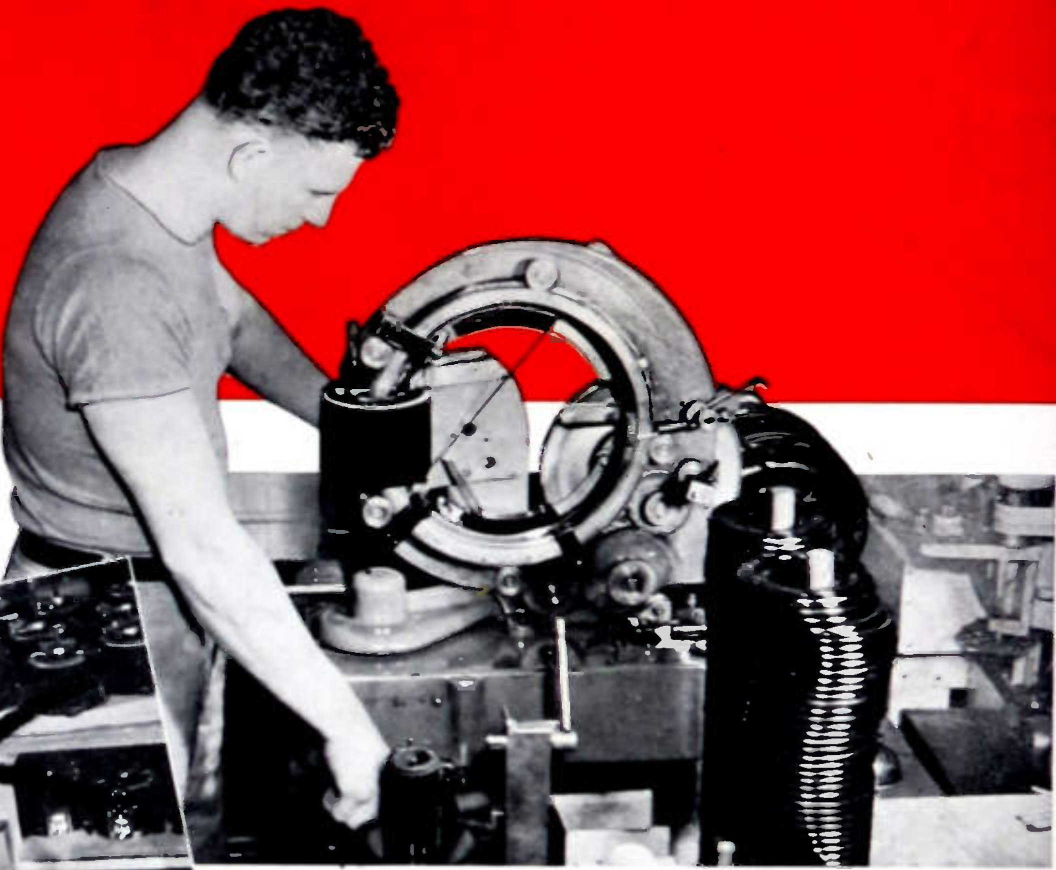
Types 4 and 9 Moulded Mica Transmitter Capacitors are designed to meet the requirements of power amplifiers and low power transmitters. They are used principally for grid and plate blocking purposes and for r.f. by-pass functions.

Types 4 and 9 are available in a wide range of capacities at 600, 1200 and 2500 V.D.C. working.

Cornell Dubilier Capacitors

MICA • PAPER • DYKANOL • WET & DRY ELECTROLYTIC CAPACITORS

MORE IN USE TODAY THAN ANY OTHER MAKE



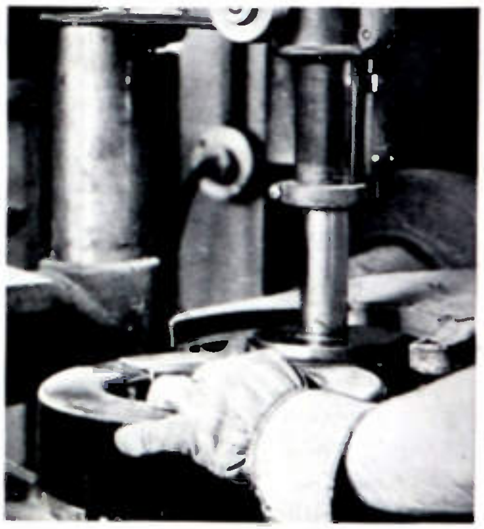
Semi-automatic machines wind cores in a fraction of the time formerly required by hand-winding.

THE PRODUCTION OF VARIACS

HAS BEEN STEPPED UP AGAIN!

The need for Variacs was never greater than it is today. If you could glance along our speeded up production line, you would conclude that General Radio is doing what it can to meet that need. Laminations are swiftly stacked to form the toroidally-shaped cores. Formerly, these cores were wound by hand; today a production line of specially designed automatic machines wind cores faster and more uniformly than skilled hand-winders. Spoilage is decreased, copper is conserved and, what is even more important, uniform tension and spacing of the wound copper wires are achieved, resulting in a better Variac than ever before.

After other machines grind the brush contact surface of the wound coils to a uniform smoothness, the assembly and wiring are quickly completed. Uniformly high quality is maintained by a rigid inspection and testing procedure. Increased speed and facilities have jumped the daily production of Variacs many times that of former methods.



Grinding the commutator surface on a type 50 Variac winding.

Variacs are made in 15 models with power rating from 90 watts to 7,000 watts; prices on the stock models range from $10 to $100.

Variac

WRITE FOR BULLETIN #776 FOR COMPLETE DATA.

the original continuously variable autotransformer supplying an out-put voltage from zero to above line voltage.

. . . a product of **GENERAL RADIO COMPANY**
Cambridge, Massachusetts

Because practically all of our manufacturing facilities are devoted to war projects, to secure this equipment a preference rating certificate or other approved priority rating will be necessary.