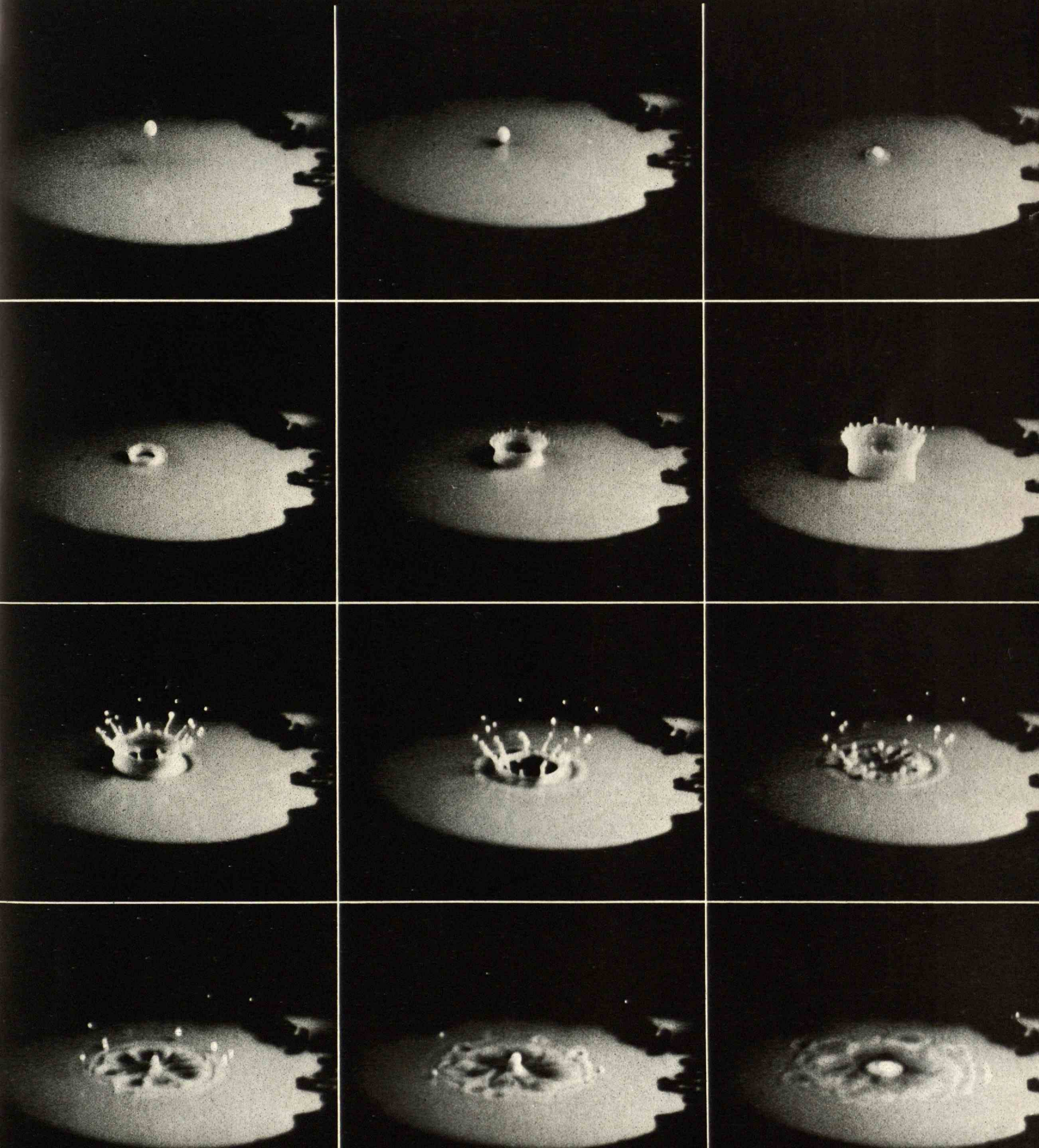
TECHNOLOGY REVIEW

July 1934

Title Reg. in U. S. Pat. Office



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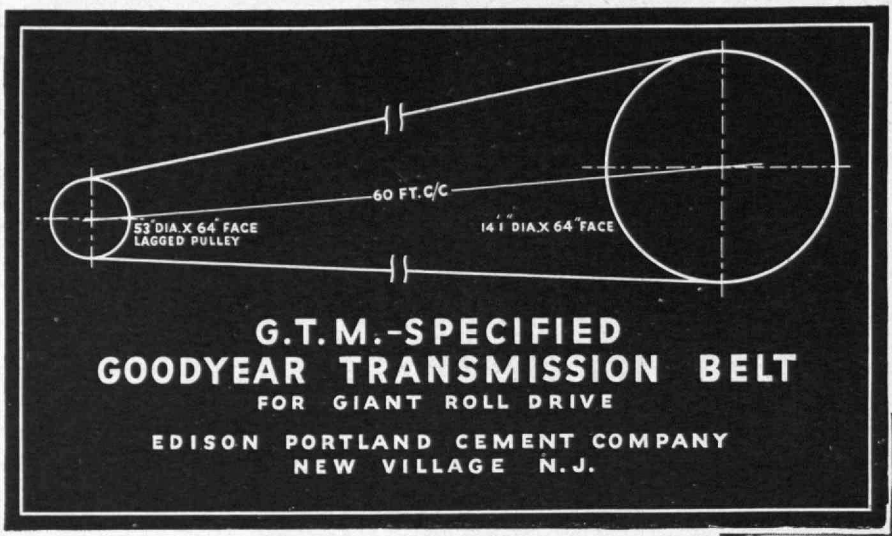
THE TABULAR VIEW

AS INVENTOR of the cathode ray tube, of ductile tungsten, and of new and improved x-ray tubes, WILLIAM D. COOLIDGE, '96, has made seminal contributions to pure science, industrial development, and medicine. His achievements as a physical chemist have carried him to the directorship of General Electric's Research Laboratory (The House of Magic). The article by him in this issue is adapted from a paper presented before the Physics Society at M.I.T. ¶ KARL T. COMPTON is President of M.I.T., Chairman of the Science Advisory Board, and Chairman of the Governing Board of the American Institute of Physics. In the light of Dr. Compton's discussion of national planning, it is interesting to recall President Roosevelt's message to Congress on June 8, when he said: "The extent of the usefulness of our great natural inheritance of the land and water depends on our mastery of it. We are now so organized that science and invention have given us the means of more extensive and effective attacks upon the problems of nature than ever before. . . . Human knowledge is great enough today to give us assurance of success in carrying through the abandonment of many millions of acres for agricultural use and the replacement of these acres with others on which a living can be earned."

AS ONE of a small group of able science press writers who are responsible for the greatly improved kind and quality of science news in recent years, HOWARD W. BLAKESLEE contributes much to the dissemination of scientific information. Before assuming his present position of Science Editor of the Associated Press, Mr. Blakeslee had had more than 20 years experience in newspaper and press association work. In his undergraduate days at the University of Michigan, he was a correspondent for Detroit newspapers, and he has served as news editor of the southwestern, central, and eastern divisions of the Associated Press. He has visited the leading laboratories from coast to coast and has reported scientific meetings in all parts of the country. The Review presents with pleasure the address given by him at the Institute's graduation exercises last month. ¶ B. A. THRESHER, '20, is Assistant Professor of Economics at M.I.T. Before coming to the Institute in 1929, he held the Henry Lee Memorial Fellowship in economics at Harvard University. ¶ L. F. WOODRUFF, '18, is Assistant Professor of Electrical Power Transmission at M.I.T. He will be recalled as the author of the much-discussed article on the mathematics of bridge in The Review for January, 1934.

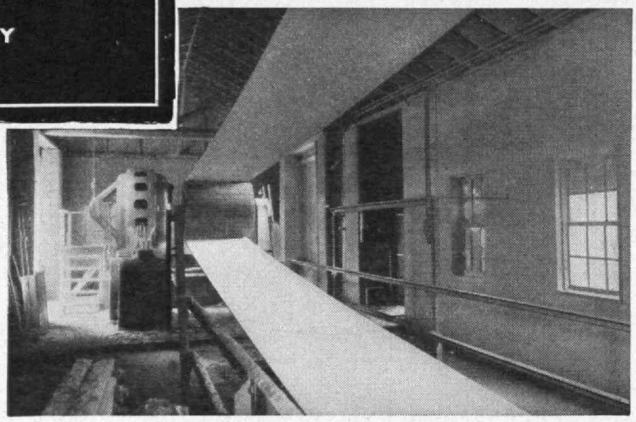
THE Review is not published during the summer months following July. This issue concludes Volume 36. Number 1 of Volume 37 will be published on September 27, and dated October. Readers who bind their copies of The Review are reminded that if they possess nine numbers of Volume 36, their files are complete. An index to Volume 36 will be ready in September and will be supplied post free on request.

NOT A MINUTE'S TROUBLE IN 12 YEARS



650 to 850 horsepower loads at 325 R.P.M.

GOODYEAR TRANSMISSION BELT NEVER FALTERS ON GIANT ROCK-CRUSHER DRIVE



Called "remarkable" after 4 years' service in '26, it is still going strong today

A GTM JOB

HERE is the saga of a belt that should prove eye-opening to anyone vexed with a belt-killing transmission drive.

In 1922 the Edison Portland Cement Company called in the G. T. M.–Goodyear Technical Man–to recommend a belt for the Giant Roll Drive in their crusher plant at New Village, N. J.

This drive operates the great rock crusher that grinds up huge limestone boulders weighing from three to ten tons. The terrific shock and strain of such impacts required a belt with plenty of intestinal fortitude.

SPECIFIED BY THE G. T. M.

Thoroughly analyzing these requirements, the G. T. M. specified a 9-ply Goodyear Transmission Belt 147 feet long and 60 inches wide.

In 1926, after handling 650 to 850 horsepower loads continuously for four years, this belt had already given such unusual service that a company official stated: *"Its performance to date is really remarkable—it has never given a moment's trouble!"*

Today, eight years later—12 years after installation—this belt is still in service without ever having had one minute's "time out" for repairs, save cutting to take up slack. And it looks good for several years' more service!

Records like this are common where the G. T. M. has specified belting to fit exacting jobs. Perhaps he could save you money in equipment and operating costs. To get in touch with him, write Goodyear, Akron, Ohio, or Los Angeles, California—or your nearest Goodyear Mechanical Rubber Goods Distributor.

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HOSE • PACKING
MADE BY THE MAKERS OF GOODYEAR TIRES

THE GREATEST NAME IN RUBBER

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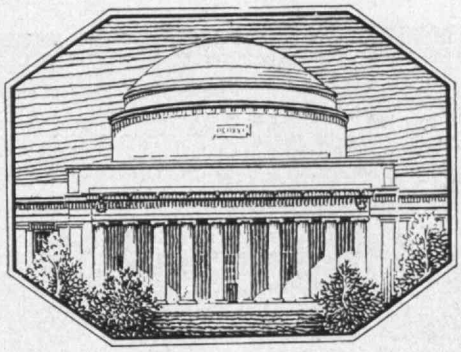

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CONTENTS

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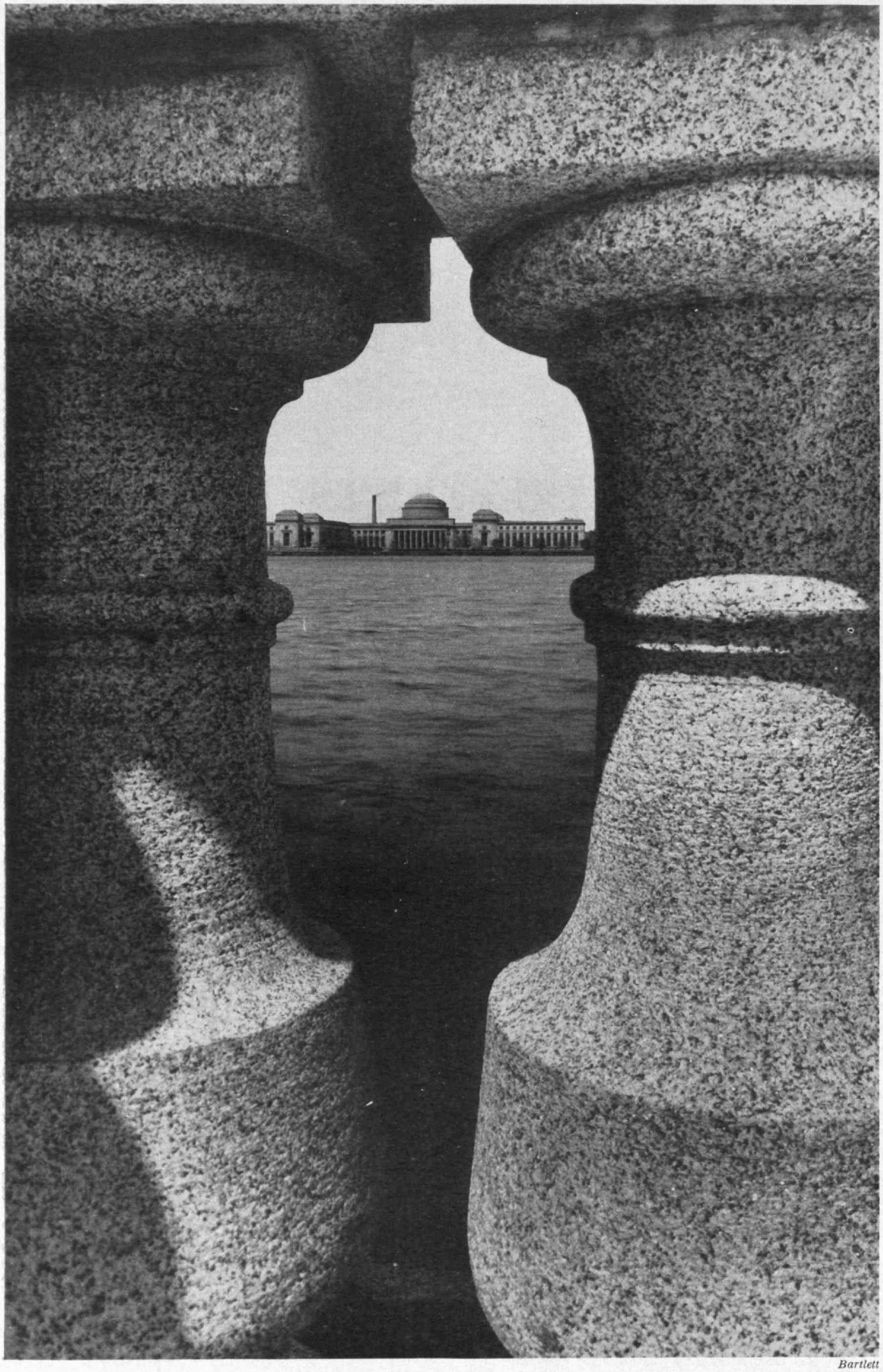
PUBLISHED MONTHLY FROM OCTOBER TO MAY INCLUSIVE AND IN JULY ON THE TWENTY-SEVENTH OF THE MONTH PRECEDING THE DATE OF ISSUE AT 50 CENTS A COPY. ANNUAL SUBSCRIPTION $3.50; CANADIAN AND FOREIGN SUBSCRIPTION $4.00. PUBLISHED FOR THE ALUMNI ASSOCIATION OF THE M. I. T. REDFIELD PROCTOR, PRESIDENT; HARRISON P. EDDY, JR., EDWARD L. MORELAND, VICE-PRESIDENTS; CHARLES E. LOCKE, SECRETARY; J. RHYNE KILLIAN, JR., TREASURER.

PUBLISHED AT THE RUMFORD PRESS, 10 FERRY STREET, CONCORD, N. H. EDITORIAL OFFICE, ROOM 11-203, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE A, MASS. ENTERED AS SECOND-CLASS MAIL MATTER AT THE POST OFFICE AT CONCORD, N. H. THREE WEEKS MUST BE ALLOWED TO EFFECT CHANGES OF ADDRESS. BOTH OLD AND NEW ADDRESSES SHOULD BE GIVEN.



Bartlett

Perspective . . . Focal Depth . . . Scale. On the Boston side of the Charles River, a granite frame; beyond in Cambridge, the main group of M.I.T. buildings

THE
TECHNOLOGY
REVIEW

Vol. 36, No. 9 July, 1934

Research as a Career

Evolution of Industrial Research—Opportunities for Physicists

By W. D. Coolidge

WHEN I stopped teaching in 1905 (28 years ago) to join the staff of the General Electric Research Laboratory I was neither fish nor flesh but a mixture of electrical engineer, physicist, and physical-chemist. I left the shelter of M.I.T. to join Dr. Willis R. Whitney's ['90] new venture — then only four years old — with fear and trepidation, for that laboratory was itself an experiment, representing as it did the first attempt in this country at organized industrial research. So there were for me two uncertainties: first, the question of how I would fit into that laboratory, and, second, the question of how long the Company would continue to operate it. And about the only other opportunity for a physicist at that time seemed to be in teaching. There was then very little research going on in our American colleges. Dr. Arthur A. Noyes' ['86] laboratory of physical chemistry at M.I.T. had been in operation for perhaps three years, but it was quite unique.

I have said that the research laboratory of the General Electric Company represented a pioneer effort in this country. It was really a pioneer effort in a broader sense, for, so far as I know, it was the first laboratory of its kind in the world. There was organized industrial research in Germany, but — at least as I came to know it — of a very different kind. This German industrial research was carried on behind locked doors, the individual worker not knowing what was going on even in the adjoining room of the same laboratory.

Dr. Whitney started out with the idea of coöperative effort, and, to this end, he encouraged every member of the staff to know as much as possible about what every other member was doing. He not only had no locks on the doors, but at one time he took off all the inside doors. And every worthwhile result was published promptly.

Since this laboratory was started, some 1500 others have sprung up in this country and a rapid growth of similar industrial laboratories has taken place in other countries. The dependence of industry upon research has come to be universally recognized. We see the recognition not only in capitalist countries with competing industries, but also in communist Russia with no internal industrial competition.

I have so far spoken only of industrial research; but scientific research in the universities, government institutions, commercial laboratories, and privately endowed research laboratories has also increased by leaps and bounds, and not only increased but done so at an accelerating rate.

And not only has the number of workers increased, but the physical equipment has been enormously improved. Think of the new tools in the modern laboratory. In place of the glass and sealing-wax, the slow Topler or Sprengel vacuum pump and the poorly equipped shop of the old laboratory, we have today hydrogen and oxygen gases, compressed air and rough vacuum piped everywhere, high-speed, high-vacuum pump equipment, the gas-torch for metal cutting, various kinds of welding equipment, including the latest variety of thyratron-controlled spot-welding which lets you literally sew sheets of metal together and with vacuum tight joints; vacuum and hydrogen high-temperature furnaces, copper brazing equipment, liquid air and liquid hydrogen, glass-blowing machinery, machine-shops with wonderful machine-tools, current amplifying devices and portable meters instead of supersensitive galvanometers, carboloy drills for boring holes in glass (this glass drilling with turpentine on the end of an old file used to be such a tedious, ticklish and usually disappointing operation; now you drill safely into glass at the rate of say two inches per minute). I have mentioned only a few of the new tools in the modern laboratory. Then there are the mechanics, professional glass-blowers, and assistants to operate the tools.

It used to be quite essential for the research scientist to be very skillful with his hands — good at glass-blowing and handy with tools. This is still no handicap, but is no longer as necessary as formerly.

We have a large machine shop and carpenter shop and several glass-blowing rooms. Besides this, some of the men have lathes, small milling-machines, upright drills, and so on, in their own rooms. In the Philips laboratory at Eindhoven, Holland, I found not only the main, central machine-shop, but also a small shop or a glass-blowing room, with a mechanic or glass-blower, and a storage battery room, centrally located for each group of seven work-rooms.

There are still men, like R. W. Wood at Johns Hopkins, who can do a lot with glass and sealing-wax. Rutherford has got along in the past with very simple apparatus, but when I visited his laboratory last October I was interested to see that his work was being rapidly and wonderfully mechanized. Even in Russia today, in spite of the hard living conditions, you find laboratories surprisingly well equipped.

Certainly industry has come to recognize its dependence upon fundamental research, to see that its engineering is based entirely upon the facts and principles established in this way. We had a good illustration in our company recently of the fact that radically new developments can come only through fundamental research.

Over a period of about a year we tried to get suggestions for new products from our employees, engineers, and others. Seventeen hundred suggestions came in. These were boiled down by a competent committee to 24 which were deemed worthy of further consideration. Even the 24 all lacked one essential thing: novelty. But this was inherent in the game because, even by definition, for novelty we must have some underlying new fact or principle. The civilian committee formed several years ago to assist the navy in the consideration and investigation of suggestions as to how to increase the safety of our submarine crews, had a similar experience. Of 110,000 suggestions received, only a paltry dozen seemed worth following up.

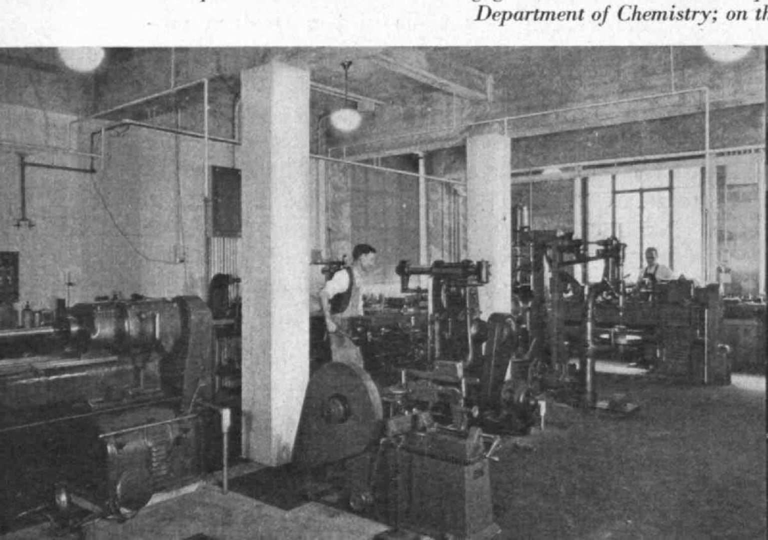
A gentleman came to us recently with a rather naïve and startling suggestion. He wanted to take our staff in hand for the summer to teach us how to make inventions. He said that the process of inventing had always been a sporadic one, but that he could teach us to invent to order. At the beginning of the interview I asked him whether he was dealing with unknown as well as known quantities. He said, "No, only with known quantities." He laid much stress on the need of always considering many different ways of arriving at the desired result. In the course of conversation he referred to the storage battery. I asked him whether a storage battery to have say 10 or 100 times the capacity of our present batteries per unit weight would be a good subject — amenable to his methods. He said, "Certainly." Upon being asked how he would proceed — that is, to name a single method of attack — he said that he would want to start with several methods. Upon being asked then to name two or more methods of attack, he changed the subject. He was certainly right in excluding unknowns, but apparently he did not realize how much they stand in the way of the new.

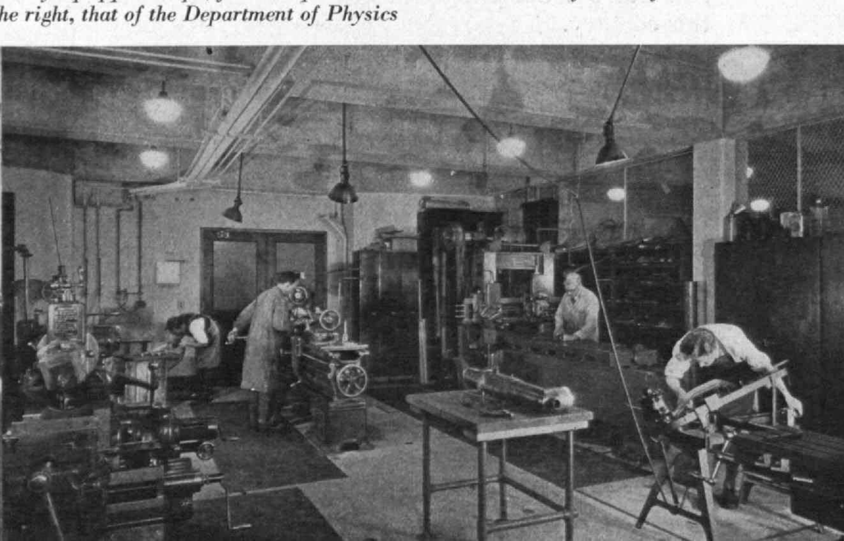
It may be helpful if I outline the scope of our work and of the organization of our laboratory.

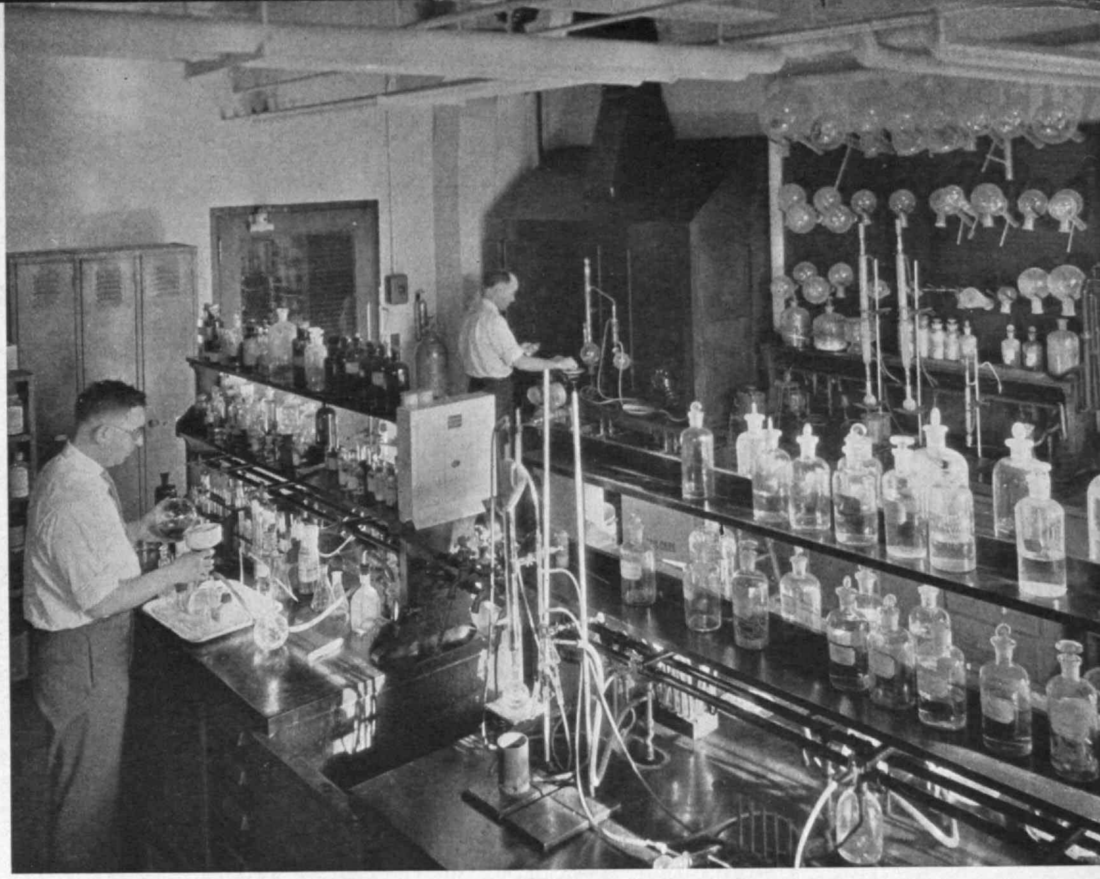
At the start, the work was essentially all original research. But soon new facts were discovered and these new facts were applied in the laboratory in the creation of important new products. When these new products left the laboratory and were taken up by the factory, it was always necessary for the laboratory to help with the difficulties which arise when factory production is started. In this way, contact was established between the staff of the laboratory and the engineers in various departments. And so the work of the laboratory acquired a wider scope, which it has maintained ever since. It carries on the original research work for which it was established, applies new facts and principles discovered by its own staff and by others, and at the same time renders service on special problems brought to it by our engineers and factories.

It is, I think, essential for the success of an industrial research laboratory that it do fundamental research, apply the results of fundamental research, and render

As Dr. Coolidge points out, in the laboratories of today the scientist has at his command adequate accessory equipment. All of the major departments at the Institute engaged in research contain adequately equipped shops, for example. Shown below: *On the left, that of the Department of Chemistry; on the right, that of the Department of Physics*







The George Eastman Research Laboratories, in which the room shown adjacently is in the Organic Section, is supplied with vacuum pumps, thermostats, electrical measuring instruments, mercury arcs, hot closets, blast furnaces, equipment for high-vacuum technique, and operations at high temperatures

expert service to the engineering and manufacturing departments.

The demands made upon such a laboratory by the engineering and manufacturing departments may vary a great deal from time to time, depending upon business conditions, but the other activities of the laboratory can be made to take up the slack.

I have a very strong feeling that the effort which pays the biggest returns is the fundamental research and its application; but the service work, or trouble-shooting (whatever you want to call it), must, of course, be done, and is, furthermore, very helpful in acquainting the staff with the problems of the industry.

Some organization is, of course, necessary in such a laboratory, but it should not be too rigid, as a man may be asked to work in one field today and in quite a different one tomorrow. And for this last reason it is very necessary that the research worker himself should be as well grounded as possible in fundamentals, rather than specialized too closely in some one limited field. In so far as technical details are concerned, he should be competent to direct his own work. Otherwise he is only an assistant, and no large research laboratory can be successful on the basis of a director and a group of assistants. The number of mere assistants, in fact, which can be used to advantage is much smaller than one might think.

Our administrative force consists of a director, associate director, two assistant directors, and an executive engineer. There are 46 research associates and 30 assistants. These, together with the clerical force, mechanics, carpenters, glassblowers, plumbers, electricians and janitors, give us a total force of about 270. Of the research associates, ten are now engaged in fundamental research, and their work will account for about 150,000 of the million dollars that we are spending this year. So about 15% of our effort is now devoted to fundamental research. The other 85% consists of engineering development and investigational work. The staff is organized into several sections, and the head of each section is largely responsible for all of the work in his field. He makes direct contact with the engineers and factory managers whom he serves, and by correspondence and in other ways takes care of outside contacts. He is naturally expected to keep the laboratory management well informed, but he is not hampered by red tape.

Our company has a number of other laboratories, including the Thomson Laboratory at Lynn, Works' laboratories (largely for the control of factory processes) at Lynn, West Lynn, Pittsfield, Bridgeport, Schenectady, Fort Wayne, and Erie; the General Engineering Laboratory and the Illuminating Engineering Laboratory at Schenectady, and the Incandescent Lamp Laboratory at Cleveland. The total number of people employed in all of the laboratories is now between ten and eleven hundred.

From a college course, I think that one might easily get the impression that research work consists in the making of accurate scientific measurements. I want to warn against that mistake, for the man who merely makes the measurements will never be anything but an assistant. The research scientist must be an investigator; he must be capable of taking the problem and getting the answer.

It is also very necessary that the scientists working in an industrial laboratory should be able to coöperate well with other people. In the early days, our laboratory was frequently referred to as the bears' cage, and an important part of the director's job was to keep the bears from fighting. But we found that it did not pay to keep a man, no matter how good he was, if he could not get along well with the rest of the staff.

As I have said, only about 15% of the expenditure of our laboratory is for fundamental research. One reason for this is the scarcity of men who, by birth and training, are adapted to it. What are the qualifications of such a man? Dr. Hull says, "The figure of merit of a research physicist is expressible in degrees of ignorance rather than knowledge." Dr. Whitney says, "The valuable attributes of research men are conscious ignorance and active curiosity."

If these brief statements need clarification, this is to be found in a statement made by Mr. Lawrence A. Hawkins ['99]: "The research man is primarily interested in the unknown. . . . It is his restlessness in the face of the unknown, which (*Continued on page 366*)







The Natural Sciences

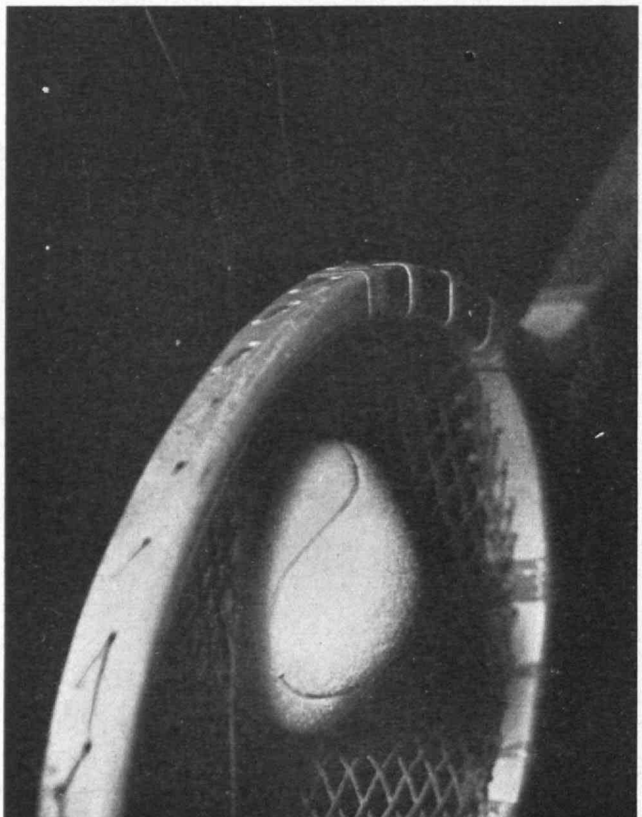
Is Half of One Per Cent of

BY KARL

Above and continued on opposite page: *Mosquito aero-dynamics, an Edgerton high-speed camera study. At the beginning the insect, posed on the thumb of a willing laboratory worker, is withdrawing its proboscis after feeding and is reving up, preparatory to a take-off*

Below: *an instantaneous photograph showing what occurs at the moment of impact of a tennis ball and a swinging racket. Note the great distortion of the ball and the give of the strings. As many as 6,000 pictures per second have been made by this method at Technology — a development deriving from research in electrical transients*

ONE of the most hopeful things in the world at the present time is the extent to which national planning is occupying the attention of governments and their people. We may not always agree with all elements in the objectives of these plans, but they do certainly represent an advanced stage of social consciousness. The five-year plan of Russia was remarkable, not so much because of its objectives as because of the fact that a great people was willing to sacrifice and to work in order to lay the foundations for a better state in the future. The same spirit, though expressed in a different way, has been a predominant part of Italy's renaissance in recent years. Whatever opinion one may have of the details of policy of the present administration in the United States, there is no doubt that national planning on a large scale is the keynote of its activities. This national planning does not always appear a clear-cut picture, for obvious reasons. In the first place, it is mixed with the simultaneous effort to get out of the depression and care for upwards of 10,000,000 people who are unemployed. In the second place, the plan must of necessity be experimental since national planning on a large scale is a new thing with us. Experimenting always involves mistakes, false starts, and discouragements, and anyone who has had any practical experience, for example, as an experimental scientist, will not be disturbed at occasional mistakes and false steps in the progress of any great social experiment.



I think this thought may be worth dwelling on for a moment. As graduate students have come to me for advice in regard to the choice of a subject for their investigations looking toward a doctor's degree, I have always warned them at the beginning that any research which is worthy of the name is a gamble in the sense that its conclusion cannot be foreseen from the beginning. If the end could be foreseen from the beginning, it would not be a research and would not be worth doing because it would not represent any new contribution to knowledge. For this reason, it is certain that a considerable proportion of experiments which are well worth trying will prove to be unsuccessful, whereas others will be successful and some few will be really great contributions. This is well understood by the directors of great industrial research laboratories, who are looking for practical results from research. In their experience they know that much of the work which is done will turn out to be unprofitable, but they realize that it is worth the effort because, out of the whole group of researches, if intelligently carried on, there will be some so successful as to more than justify the entire effort. This is not always realized by the industrialist who has no background in research, who hears research being talked of, and decides that he will try it and then quits in disgust if his first attempt proves unsuccessful.

I believe that there is a very close analogy between research and development in the natural sciences and research and development in political and social science, and that the President is on firm ground when he states that national planning is an experiment in which those efforts which prove unsuccessful should be discarded, and those which prove successful should be developed. There can be no other way of progress, and