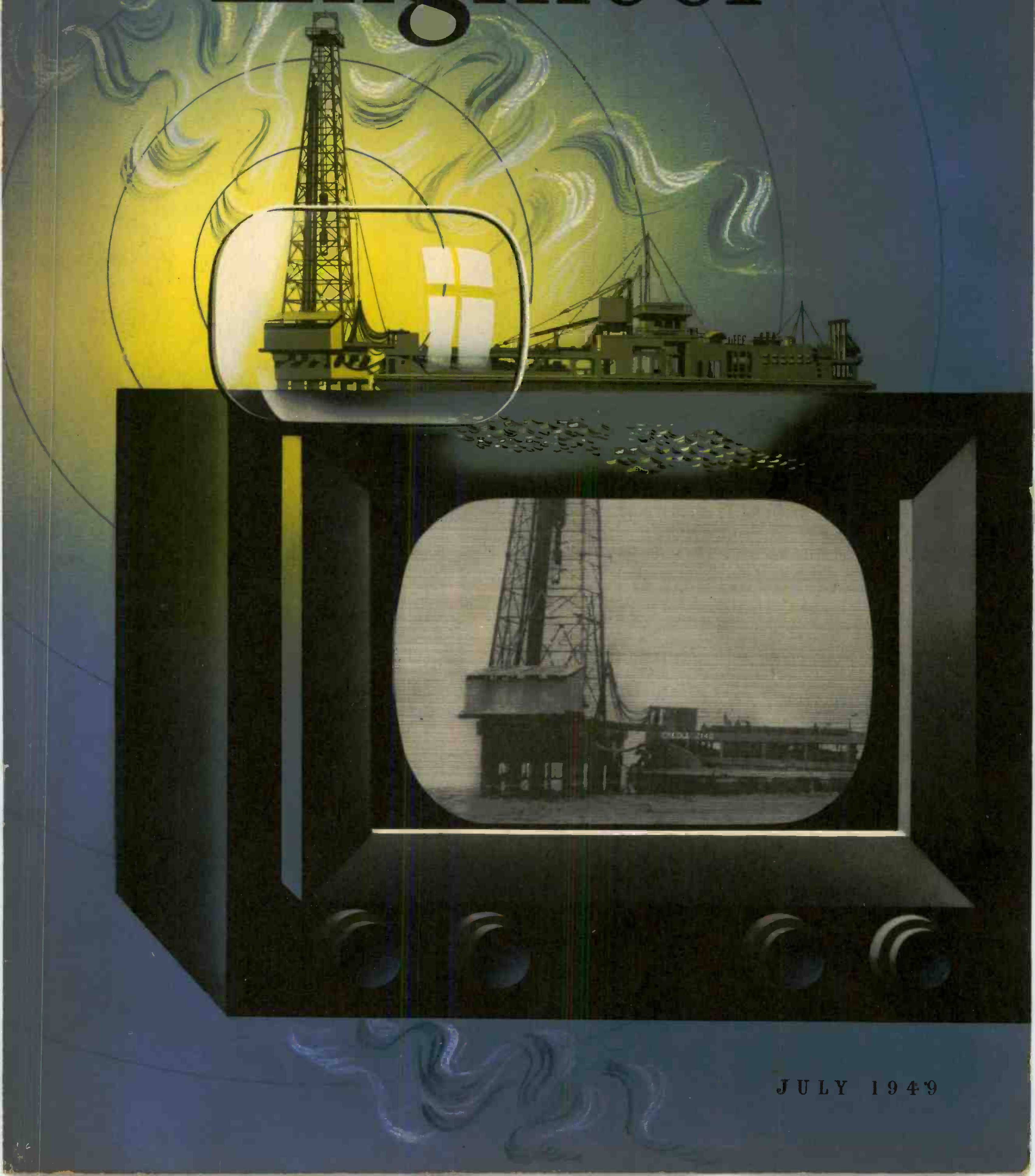
WESTINGHOUSE

Engineer



JULY 1949

INDUSTRIAL HYGIENE

—A FLEDGLING SCIENCE GROWS UP

A few decades ago a new science was born, almost unnoticed among the rapid discoveries of modern engineering. As usual it was an off-shoot of an older branch of science—in this case, medicine, but with a sizable chunk of engineering thrown in. This fledgling, now known as industrial hygiene, could trace its ancestry back for centuries—Aristotle's interest in the diseases of runners, and Hippocrates' work with lead poisoning were some of its predecessors.

But these learned gentlemen would be aghast at the problems of industrial-hygiene engineers. The ingredients and by-products of many modern industries are undoubtedly more dangerous than even the weapons of warfare of those ancient days. Involved in present-day processes are such potentially dangerous gases as carbon monoxide, hydrogen, phosgene, and chlorine; such vapors as those of aniline, carbon tetrachloride, benzol, and carbon disulfide; and metals such as mercury, manganese, cadmium, and lead. Each can be a deadly killer—yet harmful results from them are far less numerous than those from common everyday living. Automobile accidents and home mishaps far outdistance them.

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Industrial hygiene in any industry is a field requiring a broad knowledge of engineering as well as of the medical implications of processes and techniques. But perhaps nowhere is the challenge as great as in electrical manufacturing. For this industry is actually a composite of many: the chemical, metal-working, casting, plastics, paint, and numerous others. Thus nearly every potential hazard common to other industries is found to some extent in the electrical industry. These range from dust-filled air to toxic metals, and from poisonous gases to radiation.

In 1933, realizing that industrial processes were becoming more and more complex, and recognizing the increasing necessity for the use of potentially hazardous materials, Westinghouse founded an Industrial Hygiene Section to supplement other medical activities. Its prime function was to institute preventive hygiene measures—to survey each new manufacturing process and recommend necessary health-protection measures. But this job was not to stop with recommendations—it was to follow through with frequent checks of the areas concerned and of the personnel involved to make certain the measures were effective. In these functions this department has been outstandingly successful and is now recognized as one of the most prominent in the United States.

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A brief glance at representative problems of Westinghouse industrial-hygiene engineers illustrates the diversity of their activity. During the war a paradoxical situation became apparent when Westinghouse was called on to manufacture DDT-filled bug bombs for the armed services. This substance is an extremely useful insect killer and harmless to humans when used in small quantities and with the proper precautions. But in the manufacture of these bombs, engineers were faced with the prospect of huge quantities of DDT, some of which might find its way into the air as dust or mist, and most of which would be handled day in and day out by workers. Tests showed that DDT handled in this manner might be dangerous. But the solutions recommended by hygiene engineers, and instituted at the plant concerned, effectively eliminated the danger. Totally enclosed systems were implemented by using ventilation hoods over areas where large quantities were handled; personal protective equipment was utilized where necessary. As a result no serious effects occurred.

A short time later in another plant a different problem arose, seemingly minor, but actually more serious than the first glance would indicate. Located in a swampy area, this plant was subject to nighttime forays by swarms of mosquitoes. Their hours of attack were ordinarily somewhere between midnight and dawn, so third-shift workers were in a constant state of arm-swinging. But though their appearance was much like a slapstick comedy, the severeness of the problem was such as to promote absenteeism, work stoppages, slower production, and ruined materials. An intensive survey was carried out, and the mosquito population was actually counted by means of an ingenious mosquito-trapping device. With the habits of the enemy known, plant supervisors working with hygiene engineers put to work another ingenious device, an insecticide dispenser on wheels that scooted through the plant at routine intervals spreading a lethal (to mosquitoes) spray. Arm-swinging energy reverted to productive energy in short order.

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Many industrial dusts and fumes are harmless in the quantities normally breathed, but some are potentially dangerous in the right compositions. To determine what particles are present, and to keep tab on the ever-changing compositions, air sampling is necessary. Two Westinghouse men, E. C. Barnes, an industrial-hygiene engineer, and Gaylord Penney, a research engineer, combined their talents in 1934 to devise such a machine, and came up with the now well-known "electrostatic dust and fume sampler." As its name implies, this device precipitates dust or fume particles from the air and deposits them on cylindrical tubes. These tubes are then taken to the laboratory, washed, and the chemical composition of the dust quickly determined. Since air is drawn into the machine at a measured rate, the exact concentration of particles in the air can be readily discovered. This apparatus has found industry-wide application in many dust-filled areas, from mines to foundries, and has led to the institution of proper air-cleaning or ventilation in such areas.

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By far the biggest problem to confront the industrial-hygiene engineer has been radiation. Strictly speaking this is not a new problem—it has been handled with ease in the case of x-ray machines and some radioactive substances for years. But now the problem has assumed gigantic proportions; atomic-energy plants and those handling radioactive substances are sprouting throughout the country. Personnel involved already number in the thousands, with many more to come. But although this poses huge problems to the industrial hygienist, he is confident that application of his well-laid plans for preventive measures will solve all difficulties. Previous results on a smaller scale provide a sound basis for this confidence.

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From these short random examples the latitude of the industrial-hygiene engineer's job is apparent. Often he is called upon to be a medical man, an engineer, a physicist, a chemist, all at once. Occasionally, even a magician. But his goal is always clear—it is preventive hygiene. The hygiene engineer well realizes that his function is to form a protective wall of safety between the industrial worker and the processes with which he works. The recent statement by a prominent educator that most industrial plants are freer from health hazards than the average home serves as evidence of the effectiveness of the industrial-hygiene engineer.

WESTINGHOUSE Engineer

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On the Side

The Cover—A problem presented itself when the cover for this issue was discussed with the artist, Dick Marsh. Should it feature television or modern oil-well drilling equipment, both described in this issue? We ducked the question by telling Dick he could take his choice. He, too, dodged the issue by cleverly featuring both. The result suggests that future day when world events anywhere will be telecast.

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A decision to purchase 25 electric locomotives is not made every day. However, this happened recently as part of the program to rehabilitate the Netherlands State Railways. Drawings, castings, and certain components will be supplied by Baldwin and Westinghouse. Some manufacture and all assembly will be done in Holland. These will be 2000-hp locomotives, each with six powered axles.

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Bad weather is becoming less of a handicap to flight operations. A new landing aid, now in production, will permit operations down to one-quarter mile forward visibility and a 200-foot ceiling.

This system—called the "slopeline"—was conceived by engineers of the CAA. Two rows of lights, each containing up to 30 fixtures, flank the airport approach. Each fixture holds 10 lamps and is erected at a 45-degree angle to the ground. From the air the lights appear as two continuous lines—if the pilot is on the correct course. If not, fixtures appear individually.

The Westinghouse design is capable of withstanding 100-mile winds, and yet will collapse readily if hit by a plane.

The contents of the *Westinghouse* ENGINEER are analyzed and indexed in the INDUSTRIAL ARTS INDEX.

In This Issue

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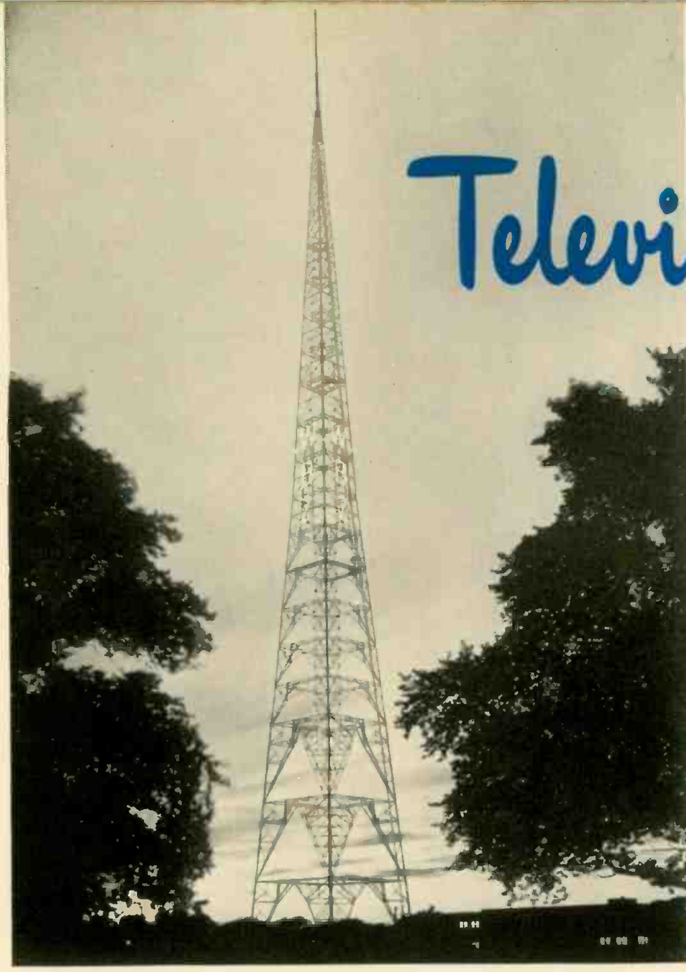


The television antenna of Westinghouse Station WBZ in Boston.

Television Today

Television has joined the industrial big time—this year becoming a billion-dollar industry. And as it grew in three years from infancy to gianthood, television is surrounded by a welter of questions as to what it means to engineering, employment, politics, entertainment, and scores of seemingly unaffected industries.

Television had a tantalizingly long period of promise of being just around the corner. At the war's end it suddenly turned that corner and started down the street, pausing in every tavern. Now it is overrunning the place with breathtaking speed. Its growth in three years has surprised everyone—including those in the industry that gave it birth—and has given pause to many. It is apparent that television will have major effects on many long-established aspects of our national life: motion pictures, radio, sports, publishing, politics, and home life in general. Even the automotive industry is taking note of this aggressive young giant, as was indicated by the recent remark by Henry Ford II, "The automobile took people out of their homes; television is bringing them back." What the various effects will be is still a matter of vigorous debate, but that television is fast becoming an influential factor in our national life and economy is no longer questioned.

Television was delayed several years by the war. On the other hand, it has profited tremendously by many wartime developments in electronics, particularly those at the higher frequencies. The first New Year's after V-J Day found three stations in New York City telecasting to some 5000 receivers in a 30-mile radius on the average of three evening hours daily, in addition to two stations in Los Angeles and one each in Chicago, Schenectady, Philadelphia, and Washington. No more stations took to the air in 1946, but in 1947 the upsurge really began. Another 8 stations began service, and manufacturers turned out about 200 000 video sets. That year, too, brought the beginnings of a television network with the laying of the first coaxial cable from New York to Philadelphia and Washington, construction of a radio link to Boston, and the establishment of stations in those cities.

The rapid spread of television continued in 1948 with the inauguration of 32 stations. Manufacturers really got into production on receivers, making nearly one million; another two million are expected in 1949. Estimates have it that between one and a half and two million television sets are now in service. Some predict six million sets by the end of 1950. On January 19 of this year, television history was made with the completion of the coaxial-cable link from Philadelphia to Chicago through Pittsburgh, Cleveland, and Toledo, thus linking the Eastern seaboard with the Midwest. As matters stand now, in mid-1949, coaxial cables take in Richmond, Erie, Buffalo, and St. Louis; also with radio links to Detroit and Milwaukee. In addition there are numerous other television "islands" not yet connected to the northeastern relaying chain. Altogether, 56 stations were broadcasting pictures on May 1. By the end of this year approximately 90 stations will be telecasting in 71 cities. This will place approximately two thirds of the nation's population within signal range of one or more television stations.

By the year's end some of the present "islands" will be tied to the growing network. These will include Columbus, Cincinnati, Indianapolis, and Louisville. San Francisco and Los Angeles are beginning a West Coast network with the construction of a radio link between them to be completed in early 1950. It will, however, be some time before residents of San Francisco can view a prize fight in Madison Square Garden or Bostonians can watch a Rose Bowl game. Looks like about 1953.

Television Is Already Big Business

Television is already edging into the major leagues of industry. It joined the billion-dollar class this year. In the receiver end of the business, the 1949 goal is two million sets. At an average retail cost of $350, we have 700 million dollars to which must be added another 100 million for installation, auxiliaries, and parts. That makes television receivers already bigger in dollars than the radio-receiver business, which last year turned out 14 million, retailing for a gross of 707 million dollars. About 120 manufacturers are in the receiver business. An annual production of five million receivers within five years has been predicted. By the end of 1949 an estimated 25 million dollars will have been invested in transmitter facilities, other millions in relaying facilities, and still other millions in manufacturing facilities.

The television audience has in the last year or so reached the point of becoming attractive in a big way to advertisers, which has led to more and better programs, which in turn

Written by Charles A. Scarlott, based on published material and supplemented with information provided by the television staffs of Westinghouse, Columbia Broadcasting System, Radio Corporation of America, and the American Telephone and Telegraph Company.

increases set sales, that has led to more advertising revenue, to more programs, and so on. Thus the flywheel—difficult to start and at great cost—is at last moving. And how! Last year advertisers spent about 10 million dollars to sponsor video (as compared to radio's take of about 530 million). This year the money to be spent for television advertising is expected (or hoped) to pass 30 million for station and network time alone and does not count costs of talent. The amount of time video programs are on the air has steadily increased. In New York—definitely the television capital—something is to be seen on a television receiver for about 10 to 15 hours daily, forenoon video programming having been begun last year.

Money! Cost, not technology, has been the obstacle to television. Manufacturers have literally been investing millions annually for many years with no interim return. Even now, no money is being made in television except by receiver manufacturers. No station has yet made money out of its television activities and the annual losses are sizable, seldom below six-digit figures. Everything about television is a blue-chip operation. To build and equip an average studio and station costs about $350 000. Generally the cost of a television station is five to seven times that of a modern radio station of comparable ranking. A coaxial cable costs five dollars a foot when laid—$25 000 per mile. To rent the services of a cable link for eight hours of television daily costs $35 per mile per month plus some terminal charges. The total cost to the sponsor of a first-class, hour-long television program runs to about $20 000. Televising time and programming facilities probably will run in the neighborhood of 3½ times those for radio broadcasting. The major factor that must be considered when interpreting any aspect of television is money—money in huge amounts.

Television Standards and Channel Allocations

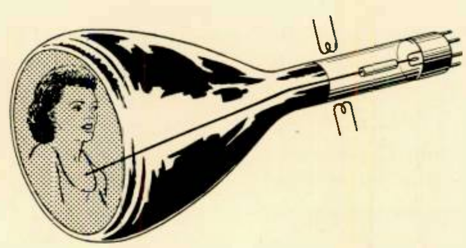
The present system and standards of black-and-white television were fixed in May, 1941 by the Federal Communications Commission after much experimentation by manufacturers and telecasters. The band from 44 to 88 and 172 to 216 megacycles was set aside for television. Within this band there were 13 channels, each of 6 mc. (Channel 1 was subsequently withdrawn by the FCC and assigned to other purposes, leaving 12 channels for television, numbers 2 to 13 inclusive.) A 6-mc bandwidth allows the transmission of a picture divided into 525 lines plus the necessary synchronizing and blanking signals. There is a definite and immutable relationship between the number of picture lines and bandwidth required. A picture of higher definition—that is, more picture elements—consumes a larger portion of the frequency spectrum. The 1031-line picture with which the single government-owned French station is experimenting "costs" a channel width of about 11 mc. The English standard of 441 lines, on the other hand, is noticeably inferior but is less costly of the frequency spectrum. Television planners, in setting standards, must effect a balance between definition and number of channels.

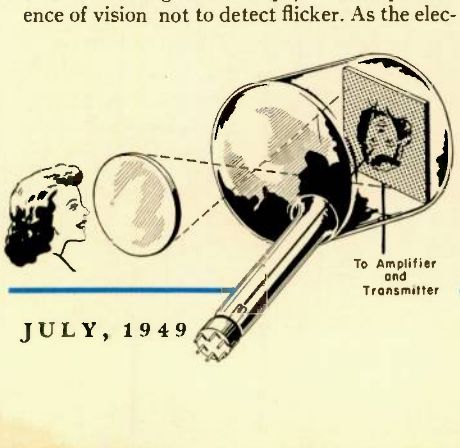
Advocacy of "high-definition" black and white, i.e., more lines per picture, is on the decrease. Television authorities in general agree that the present standards allow ample opportunity for presentation of high-quality pictures. The limit of picture quality with present standards has by no means been reached. Much improvement is expected.

The original intent of the FCC was to assign the 12 channels to applicants for television stations on a basis that would give complete coverage of the United States without interference, giving to each home a choice of 2 to 7 stations. Because of approximate line-of-sight characteristics of 44 to 216

The Trick That Is Television

Television is a light-to-electricity-to-light conversion process, but fast. The scene to be transmitted is focussed with lenses onto the front of picture mosaic of a camera tube, of which the Iconoscope is a common type. The picture mosaic is a rectangular sheet of mica on which are deposited microscopic, electrically separated "islands" of a caesium-silver compound. The back of the mica plate is covered with an electrically conducting sheet. Each silver-caesium "island" or globule when struck with light emits electrons in proportion to the light intensity, becoming thereby positively charged and thus making of the mosaic structure an electrical condenser. A cathode-ray beam (electrons)—no thicker than the lead in a pencil—is swept continuously back and forth across the face of mosaic on which the picture is focussed, "reading" from left to right, and scanning a complete picture in 525 lines. This is repeated 30 times per second, which is more than fast enough for the eye, with its persistence of vision not to detect flicker. As the electron beam strikes each picture element in turn, the electron-deficiency of that element of caesium-silver is neutralized. Because of capacity effect, each time a charge of a picture element is reduced to zero, an impulse appears in the output circuit connected to the back of the mosaic plate. This impulse is proportional to the amount of light on the picture element. This series of impulses, which every 1/30 second forms an exact electrical representation of the picture, is amplified, combined with cathode-ray synchronizing and sweep impulses, and superimposed on the carrier frequency assigned to that station and broadcast.





At the receiver they are "stripped off" the carrier and applied to the cathode-ray tube (kinescope). Here the beam is swept back and forth on the fluorescent screen in step with the beam in the Iconoscope, its intensity at each point being proportional to the intensity of the light falling on the corresponding point on the camera-tube picture mosaic. Thus electrical impulses, by modulating the cathode-ray beam, convert to a light pattern on the fluorescent screen, duplicating the original picture, and repeat this thirty times per second.

Television's Frequency Balance Sheet

Separate light-sensitive elements per line on mosaic	=	400
Number of lines scanned per picture	=	525
Number of times picture is scanned per second	=	30
Thus, number of impulses transmitted per second 400×525×30	=	6 300 000
Equivalent frequency in cycles per second	=	3 150 000
(Each cycle consists of two half cycles or two impulses)		
Frequency band allowed for picture transmission 3.15 mc+0.85 mc spare	=	4.00 mc
Necessary for lower sideband of frequencies generated that cannot be completely filtered out	=	1.25 mc
Frequency band allowed for sound	=	0.5 mc
Frequency band separation necessary between video and audio bands	=	0.25 mc
Total spectrum required for one television channel	=	6.00 mc

mc radiation, it was believed that stations operating on the same channels could be as close as 150 miles without interference. Allocations were begun on this basis.

Then came a hitch. In 1947 and 1948, as more stations took to the air, it became progressively apparent that television signals do not behave as had been expected. On occasions—not consistently, but frequently enough to be troublesome—television signals are picked up several hundred miles away. And when that happens on channels identical to those of local stations, you have interference.

This led the FCC in the summer of 1948 to freeze television-station applications until further data could be obtained. Except for the 123 that had already been granted permits, all other applications (310) were tabled to give opportunity for further study of the situation. This freeze is still (June) in effect but is expected to be lifted this year.

Engineers now understand reasonably well the causes of the troublesome, inconsistent transmission behavior of television frequencies. It lies with the vagaries of the atmosphere —not with sunspots, aurora borealis, or any of the ionization phenomena. These frequencies are not reflected by layers above the earth's troposphere, as are standard-broadcast radio frequencies. However, the earth's atmosphere acts on television waves much as a glass lens does to visible frequencies. Normally air close to the earth is both warmer and contains more water vapor than at higher altitudes. This blanket of air normally presents to television signals a "lens" of varying dielectric constant, being largest close to the earth and declining at higher altitudes. Work with radar frequencies has shown that the bending or "refractive" power of the air to the shorter waves is greater the higher its specific inductive capacity. Television waves thus "lean forward" slightly, causing them to follow somewhat the earth curvature. Acceptable reception is normally possible up to about 1½ times line-of-sight distances.

But the atmosphere changes. Occasionally the more moist, warmer layers move to higher regions. This means the refractive power of the upper air increases, causing the waves to reach farther around the curved earth.

A CBS television camera shows newscasters in action. The camera, with lenses, camera tube, and amplifiers, is mounted on wheels.

This change in atmospheric effect is a random, unpredictable one. But it occurs too often to permit station spacing on the original basis and hold to FCC's high standard, which is that station interference not exceed one percent of the time. The future allocation program will probably call for stations that share channels to be at least 200 miles apart unless the system known as station synchronization, now under investigation, proves successful, in which case the distance between stations on the same channel may be reduced to 150 miles.

Had nothing else happened, because of this interference problem television would be definitely limited to service considerably less than originally planned. But, fortunately, something did happen. Essentially this was the accumulation during and since the war of a vast amount of know-how in the generation, transmission, and reception of waves still shorter than the present band allotted to television, which are called very high frequencies or vhf. Specifically the band from 475 to 890 megacycles, termed ultra-high frequencies or uhf, are to be opened for settlement by television.

Before the FCC can open the uhf band for occupancy it must make many difficult decisions interrelated and vitally important, remembering that subsequent changes are difficult and frightfully costly. Shall uhf be opened solely to black-and-white television of present standards? Or, shall some be reserved for the still undeveloped color (whose frequency-width requirements are still unknown) and, if so, how much? What about some channels for high-definition black and white? What about mixing vhf and uhf channels in the same city, remembering that, because of the different propagation characteristics, to do so may be tantamount to giving some stations inherent advantages over their competitors? Decisions on these matters by FCC are expected in 1949, which will again allow television expansion in the vhf band and permit utilization of the uhf area.

How these and other important questions will be answered cannot at this moment be stated with finality because they rest with the FCC. However, the considered estimates of some authorities can be set forth.

All stations now granted channels in the vhf band are almost sure to continue to operate on those channels. Also, with the lifting of the freeze, new allocations will be made of the 12 vhf channels to applicants elsewhere throughout the United States, but on some new basis of spacing. The standard on all vhf channels is almost sure to remain at 525 lines per picture.

What will happen to the 475 to 890 uhf region is less clear. However, probably much, if not most, of it will be offered to applicants for 525-line black-and-white video. If all of it were opened for "homesteading" by 6-mc black and white, 69 new channels would be added to the present dozen in vhf. However, it is probable that some portions of the uhf spectrum will be reserved for color. Possibly a small portion will be set aside for experimentation with Stratovision and/or high-definition black and white, although the support for this form of television is now small and is waning because of the general feeling that the next step in television progress from present black and white is inevitably to color. High-definition black and white in this country appears but a remote eventuality.

One avowed policy of the FCC is to make available in any given area (and there are 140 so-called market areas in the United States) not less than 3 nor more than 7 television channels. Obviously, however, in the less populated areas there will be no takers for all those channels, television costs being what they are. To achieve this five-channel allocation in cities that already have television with channels solely in one of the two bands appears impossible. Mixing of the bands appears inevitable in some communities.

The nearly two million receivers already built for operation on the 12 channels within vhf can continue to be used to pick up programs as at present or from future stations employing vhf channels. These sets can be made to operate also on the forthcoming uhf channels by the addition of a conversion unit whose cost probably will be from $25 to $75. Once the FCC settles the matter of the uhf band, black-and-white receivers will be built for operation in both the vhf and uhf regions. This is possible because of electronic-tube developments that permit response to frequencies in the uhf region as well as those in the conventional video band. Such a set would have been impossible five years ago—which, indeed, is why television foundations were originally laid on the basis of the lower frequencies (vhf).

Color is something else again. It has many extremely ardent and vocal enthusiasts. In fact, in 1946 Columbia Broadcasting Company experimented with, publicly demonstrated, and urged the adoption of color television instead of black and white because of its enormously greater appeal to the observer—a fact no one denies. Those who have seen television in color speak in ecstatic terms of it in comparison with the present monochrome. Many feel that color is inevitable as a step in the march of video progress that cannot and should not be blocked. However, in 1946 color video was not so well developed. To have waited for its development instead of proceeding with black and white, which was, by comparison, ready, would have delayed television by several years. Meanwhile manufacturers and telecasters had invested millions in black and white; people were becoming impatient, having long been told that television was just around the corner. Hence the decision by FCC early in 1947 to go ahead with black and white, by-passing color until it reaches a state of development suitable for general use. Meanwhile, of course, the vhf spectrum is now tenanted by black and white, a position from which it is not likely to be dislodged in the foreseeable future. The uhf band not yet opened for settlement is another matter. Color, when it comes, probably will be lodged there.

There are two basic schemes for telecasting pictures in color. Both have been demonstrated. One is a sequential system actively developed primarily by CBS.* Here a scene is viewed by a single camera through rotating filters having a sequence of red, green, and blue. The three pictures, as seen by the camera in succession, are broadcast in rapid succession and are reproduced on a single picture tube, in front of which is a revolving screen, with red, blue, and green filters. The rotation of this color screen is synchronized with the transmission of the three telecast pictures so that, say, in that brief interval when the red image is being telecast the red filter of the receiver is in position and so on. The process is so rapid that the eye sees but one picture, which is the synthesis of all three colors.

The second scheme is simultaneous. The scene, as before, is dissected into three colors—red, blue, and green. Each is telecast continuously and received on separate scopes, with red, blue, and green phosphors respectively. By optical means, these three screens are seen as one, giving to the eye a single, color picture that is the summation of what appears on the three scopes.

*A general description of the system and some components built for it by Westinghouse was given in "Color Television—A Reality," by D. L. Balthis, *Westinghouse* ENGINEER, September, 1946, p. 155.

A Westinghouse console-model television receiver. The 12-inch viewing kinescope is lowered out of sight when it is not in use.

Each system has advantages and limitations. The sequential system would require more than twice the bandwidth of 525-line black and white—possibly about 15 mc instead of 6 mc, although developments may reduce this. It may require a rotating screen at the receiver that must be exactly synchronized with the transmitter. It may be noisy, and may entail maintenance. Also, because the three colors are seen in succession, the time difference, though small, may be enough where action is rapid to produce color break-up or fringing of a rapidly moving detail of a scene. Use of color filters reduces the light efficiency or brightness. The simultaneous system may use a slightly narrower band—perhaps 12 mc. The problem of optically registering the images from three scopes or three different sections of a single scope into a single picture is not a simple one, and it may employ three picture tubes or a three-section fluorescent screen within one tube, either adding to size and cost of the receiver.

Perhaps the final answer lies in neither system. Certainly much development time and large sums of money must be spent before an acceptable and perhaps entirely different system will be achieved. At present color video seems bound to come, but is several years away. When it does come, present black-and-white receivers will in all likelihood be obsoleted (except for reception of black-and-white pictures of lesser quality.)

Television Relaying Systems

Television has another problem: how to hook its stations into a network. The comparative ease of receiving radio signals from stations even half way around the world, or conducting programs over long distances by conventional telephone circuits is simply not available to television. For an inauguration in Washington to be seen by a Philadelphian requires some relay link; the Washington station cannot normally be picked up in Philadelphia directly.

Today there are only three known kinds of links: coaxial cable, microwave transmission, and Stratovision. Thus far the coaxial cable is the most extensively used, although that situation may not continue. The coaxial circuit as its name implies, consists of two conductors, one of which lies at the axis of the second, a surrounding, tubular conductor. Several such circuits may be included in a single cable. The electrical characteristics of this coaxial arrangement are such that frequencies in the video spectrum—60 cycles to 4 megacycles (the video frequencies themselves, no carrier) can be transmitted "appreciable" distances without undue loss. (Video frequencies would be attenuated substantially to zero in a few hundred yards of ordinary telephone cable.) Even so, coaxial cable requires repeaters to re-strengthen the signal. Thus, some 350 to 500 repeater stations would be necessary for a coast-to-coast cable link. Furthermore the requirements placed on each repeater are terrifically stringent. Not only must the repeater amplify the video frequencies without introducing noise, but also it must amplify each of the four million frequencies present in the signal by the same amount and without distorting their phase relationships. That is, the time of transmission of all frequencies between 60 cycles and 4 megacycles must be correct within one hundredth of a microsecond for the entire length of the cable. Obviously, minute errors of any sort in the repeaters are multiplied by the number of repeaters in the link. That telephone engineers have been able to achieve the present degree of distortionless amplification in coaxial links is nothing short of miraculous.

In spite of staggering technical problems, video programs are being transmitted many hundreds of miles and reproduced with high quality. A coast-to-coast coaxial cable for video programs is possible. In fact, the first cross-country telecast will likely be by cable. However, coaxial cables now being laid are not limited to television use. Like a freight train, or more correctly like a pipe line, they can carry many things: a multitude of telephone communications, teletype services, wire-photo signals, or other classes of information. Because a coaxial circuit can carry one television program or several hundred simultaneous telephone conversations, for example, the telephone company could sell the use of its coaxial circuits for other functions should other relay systems be developed for television. In fact the telephone company might welcome the departure of television from its cables.

Another practical relay link is through space with microwaves. Waves up to 7000 megacycles, because of their directional quality, can be used to carry video signals, beamed from one antenna to another at approximately line-of-sight distance away, depending upon antenna elevation and topography. Such indeed is the principle of radar. The proposed microwave link between the two California cities calls for covering the 350 air miles in 9 hops, the longest being 65 miles. Fortunately microwave beam energies required are small, usually less than one watt. The transmission quality and bandwidth by microwaves is somewhat better than by cable. Several successful microwave relay links are now in operation.

The third scheme of relaying is offered by Stratovision. This scheme, in effect, simply raises the transmitter antenna to, say, 25 000 feet, by having it carried in specially fitted airplanes lazily circling above the weather. A program, telecast to it from a ground station, is rebroadcast from the plane. The purpose of the Stratovision system is twofold. First, because of its elevation, a Stratovision plane places strong video signals in receivers within a circle 400 miles across instead of the 60-mile circle diameter maximum reachable by a land station. This means approximately 35 times greater coverage. In fact the FCC has stated that Stratovision is the only system known today by which television can be brought to rural communities out of reach of city stations. Unless Stratovision is adopted, large areas in the West and Southwest have no present hope for television service.

The second function of Stratovision is for relaying. A program originating at one land point can be relayed from one Stratovision plane to another 400 miles away and it in turn to another equally distant. Thus the nation could be spanned by about 8 Stratovision relay stations compared to over 100 microwave repeaters, or the 500 amplification points necessary with a coaxial circuit. And that considers the length of the country only, not its breadth.

That Stratovision is technically feasible has been amply demonstrated. World Series' baseball games, political conventions, and other events have been satisfactorily telecast on an experimental basis to audiences in a 300 000-square-mile area. Aircraft makers see no difficulty in maintaining continuity of service under all weather conditions. The economics of telecasting and relaying greatly favor Stratovision.

Problems of Television

Television has grown so rapidly that many side issues have not taken shape or at least are still in controversy. The industry for all its skyrocketing is still in a state of flux.

Take receivers, for example. They have naturally undergone rapid development and improvement; particularly, as they have entered truly mass production, costs have declined and will decline further. In 1946 a set with a 10-inch screen cost about $400. Today such sets are sold for $250. Prices range now (midsummer 1949) from about $150 for the least expensive set with 7-inch screens to about $1000 for those with the present largest, or 20-inch scopes. Further economies of manufacture undoubtedly will be made, but short of some revolutionary new design of receiver—and none has appeared since sets entered quantity production several years ago—cost reductions will come slowly. The day of a set for $50 seems distant.

Television receivers seem wedded to reproduction of the picture on the end of a kinescope, which is a specialized version of a cathode-ray oscilloscope. Admittedly its efficiency of converting an electric signal to a visible picture is small, not over five percent. However, no better practical device is in sight, although suggestions of other means of modulating light beams have been offered and even demonstrated. Meanwhile, people are viewing distant events in the comfort of their own living rooms on the milk-colored ends of kinescopes, and will so continue indefinitely.

Picture size is another unsettled matter, although it is becoming increasingly evident that people buy the largest size screen they can afford (and have living-room space for). Most receivers use screens 7, 10, 12, 16, and 20 inches in diameter. All give pictures of identical definition when viewed from the proper distance. But there is the catch. The ideal seeing distance is about ten times its height. The best seeing position for the 7-inch screen (about 5 inches high) is limited for best definition to about four feet. For comfortable viewing under normal living-room conditions for more than a few minutes at a time this restriction is a definite handicap. Thus the preference for larger screens, because the acceptable zone of viewing very considerably increases with each larger kinescope size.

Numerous uses for television beyond the field of entertainment have been suggested. The military field has many obvious ones, which the services are aggressively exploring. A practical commercial application called Ultrafax is for the high-speed transmission of large quantities of printed information. Here pages are televised in rapid succession and are photographed as they appear on the receiver screen. The transmission speed is tremendous, equivalent to 20 full-size books per minute.

The application of color video in the surgery classrooms is being seriously considered and has been demonstrated. The advantages of enabling a large class of student surgeons to view a delicate operation in full color are obvious. The system has but one present drawback—a cost that exceeds the purse of all but the wealthiest medical institutions.

Many industrial uses can be named. Numerous places occur where it would be desirable for an operator of a large machine to observe the action at some distant part of that machine. Perhaps television might be useful for studies of hazardous conditions such as atomic-energy piles. Television is, in short, a technically feasible medium for viewing any distant event, and industry has many of these. Doubtless, as always happens when a glamorous new medium appears, it will be proposed for many uses that, while possible, can be served as well or better in other ways and at much less cost. On the other hand, some special functions will undoubtedly be found that rightfully belong to television. It is too early to say what these will be.

The merchandising field offers a particularly promising one. Numerous demonstrations have been made of intra-store television by which programs originating in one part of the store are fed by wire to receivers located in windows and within the store itself, thereby obtaining attention to merchandise and activity that would otherwise go unnoticed by the shoppers.

While the technical and mechanical aspects of television are interesting and important, they are pale by comparison with its sociological effects. Television cannot be dismissed as just another communication medium that eventually will comfortably settle into its niche in our national life without creating a commotion in the established order of things. There are those who pooh-pooh its force, who—having seen a few television programs as presently offered—say that television is not for them. But apparently these are a small minority. Surveys to date, while too early to be absolute, do show some startling conclusions. For example, the appeal of television is not a novelty that wears off. Attention to video programs in the second six months in the average home is almost as great as during the first six. Any fading novelty appears to be to a large extent offset by the steady improvement in program quality. In the metropolitan areas that have had television for some time, reports indicate the average home receiver is in use about three hours daily and that when video programs are available radio sets are silent—even with big-name programs on the air. However, the daytime popularity of television, with the poorer picture seen because of the higher ambient

The three methods of linking television stations are: Stratovision (left), an eight-circuit coaxial cable (right), and microwave relay, of which an artist's version of a new-type relay tower for the New York-Chicago route is shown below. The coaxial cable and relay tower photos are by courtesy A. T. & T.

light, remains to be proved. Radio may always hold a daytime edge. One survey of 1580 television-set owners elicited these startling results: 92.4 percent listen to radio less than before purchasing a television receiver; 80.9 percent go to movies less (several surveys indicate a one-third reduction in movie attendance); 58.9 percent read books less; 48.5 percent read magazines less; 23.9 percent read newspapers less. Television definitely means people stay home more, with all that implies sociologically. It is even enough to be significant for electric-power and other utilities to notice, although to what extent is uncertain.

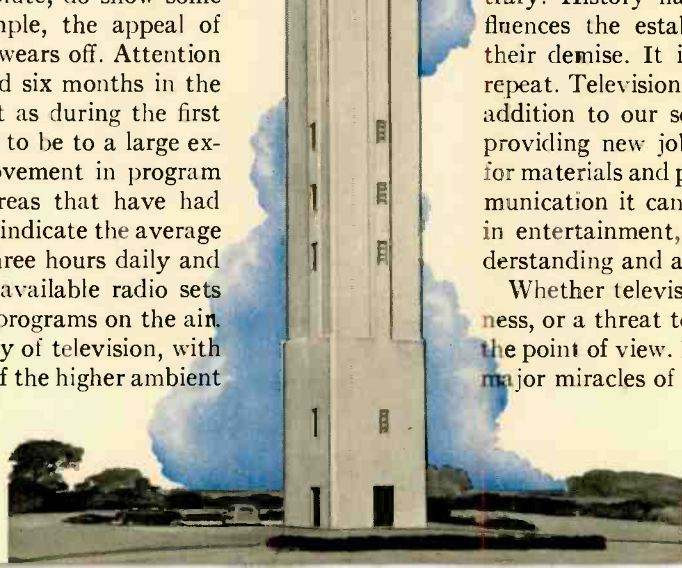
The motion-picture and sports industries will be heavily affected. Some say the movies, for example, will not seriously lose in attendance, pointing to the fact that people fundamentally like to get out of their homes, to join other groups, and will see at a theater more polished presentations than will be available for a long time via the air.

While attendance at theaters may be seriously affected it may be that the business of making motion pictures will be greatly augmented by television. The making of films for television may become an enormous business. One executive has estimated that when television is well established some 5000 hours of pictures on film will be required just for television, and that the present total Hollywood output of feature films and shorts is only 650 hours annually; already, in fact television, in recording its programs on film for shipment by air to other stations, is producing more film than Hollywood. Whether this prediction will hold depends in part on the extent to which television presents shows with live talent or from film especially prepared for telecasting. There are strong advocates for shows with real actors. On the other hand, motion-picture people are counting heavily on the economies and higher polish of filmed presentations.

The effect on sports is yet inconclusive. It does seem clear that people prefer to see a major encounter via television rather than witness a minor event in the flesh—with all that that implies to the minor-league class of any sports field.

Some see in it the doom of the motion-picture theater, of radio, of many sports. However, the phonograph did not ravage the ranks of the musical profession and the radio was not the undoing of the phonograph—as was freely predicted. To the contrary. History has it that every new medium influences the established ones but does not mean their demise. It is reasonable to expect history to repeat. Television should be looked upon as a major addition to our social order, one of great effect in providing new jobs, creating new, enormous needs for materials and products. As a new medium of communication it can create a new order of magnitude in entertainment, education, and international understanding and allied fields.

Whether television is looked on as a spur to business, or a threat to the established order depends on the point of view. In any case, television is one of the major miracles of our time.



Tapping the Underwater Oil Reservoir

When in 1859 Colonel Drake drilled the first oil well in the United States, he had to penetrate to a depth of only 69½ feet. But this task required four months. Nowadays it is not uncommon to drill a 10 000-foot well in a month, sometimes under several feet of water. The difference is attributed to the know-how oilmen have since accumulated and to more powerful drilling rigs. Exemplary of modern rigs is the "Queen Mary" barge.

Just one year ago the Avondale Marine Ways, Incorporated, at Avondale, Louisiana, launched a 174-by 40-foot barge. As vessels go, this barge sets no new record for size. But within its hull is the equipment for the most powerful electric drilling rig in the world. The barge, owned by Creole Petroleum Corporation, is being used for offshore drilling on Lake Maracaibo, Venezuela.

The vessel, officially No. 2142 in Creole's records, was christened the "Queen Mary" by the men who work and live on it. And for good reason, too. Its appointments, relatively speaking, are lavish, featuring modern shower and toilet facilities, a radio room, two top-deck bunkrooms with mattress bunks, desks, and individual lockers, and a galley with refrigerators and hot plates—conveniences more likely to be found on an ocean liner than on a drilling barge.

From the oil-drilling point of view, the Queen Mary is perhaps even more significant. Its record total generator capacity of 1500 kw, more than twice that of the average drill rig, makes it the most powerful rig for offshore operation. Its drilling speed is unexceeded. This barge is indicative of the trend to equipments of higher power to provide faster drilling speeds, a trend necessitated by the greater penetration required to tap new oil reserves. The vessel also marks the increasing acceptance of the idea of mounting the power supply and as much other apparatus as possible on a floating barge.

The principal equipments required for drilling any oil well are: (1) the rotary table, to rotate the bit; (2) the "draw works," a hoist to raise and lower the drill pipe and casing pipe; (3) the derrick, to support the draw works and pipe; and (4) "mud," a mixture of special clay and water to remove the cuttings. Using the electric-barge principle, the derrick, the rotary table, the draw works, the driving motors, and the operator's controls are mounted on a stationary foundation. The movable barge, which contains the mud pumps and the electric supply for the draw-works and table motors, is anchored alongside the platform and linked thereto by necessarily flexible power cables and mud hose.

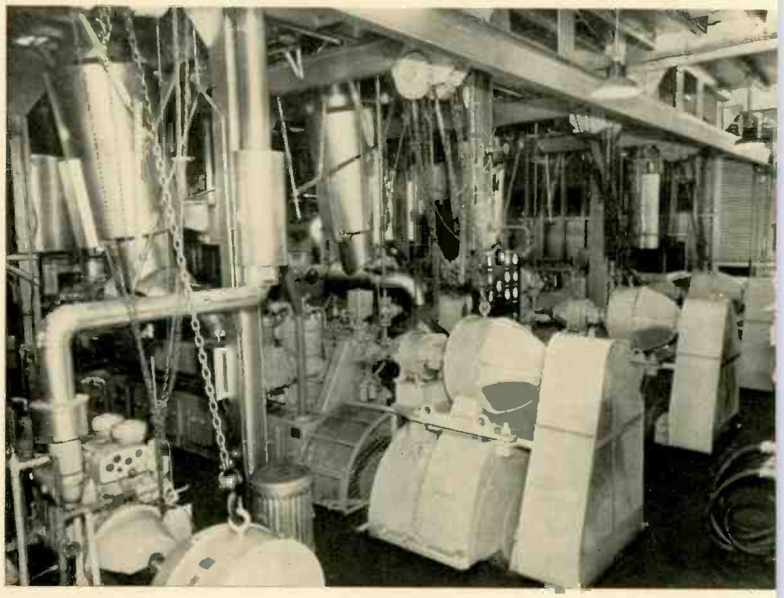
Some offshore rigs necessitate mounting the entire equipment on the foundation to provide close coupling between the supply of motive power and the driven machines. Such mounting is essential where mechanical (rather than electrical) drive is used, because the flexible mechanical connection required between the floating power barge and the stationary derrick floor is impractical.

The electric-barge type of rig has several advantages. First, because flexible connections are easily made, much of the equipment can be mounted on the barge, rather than on the derrick floor. This minimizes the dimensions of the foundation and the weight it must carry, and consequently the investment in caissons and platform, which usually are not recoverable economically. Second, after oil is reached, the power-supply equipment need not be dismantled, but can be quickly and easily moved to another site to drill another well. Also, because the flexible connections are extendable, the electric-barge rig enables greater continuity of operation than the steam-barge rigs, particularly during storms. When these arise, the distance between barge and derrick floor can be increased to prevent collisions; drilling continues as usual.

The Drilling Operation

Except for the foundation, drilling in unprotected waters some distance offshore is the same as drilling on land. The well is sunk by hoisting to the top of the derrick a 30-foot length of hollow drill pipe with the bit, perhaps 12 inches in cutting diameter, attached at the end; the pipe is then rotated and lowered into the ground. After each 30-foot penetration, another section of drill pipe is added over the previous sections, and drilling is continued. When the bit becomes dull, the entire "string" of pipe is removed and the bit replaced.

The bit is always larger in diameter than the drill pipe, thus forming an annular opening around the pipe. Mud is pumped at high pressure down through the pipe to the bottom of the



The engine room of the Queen Mary, showing the three 500-kw main diesel generators, on top of which are mounted exciters and the 75-kw auxiliary generators. The fourth 75-kw auxiliary generator, which is diesel driven, can be seen in the left foreground.

Prepared by L. H. Berkley from information furnished by engineers of Creole Petroleum Corporation, Avondale Marine Ways, Inc., and Westinghouse Electric Corporation.

hole. Here it squirts out the bit, picks up the cuttings, and returns them to the surface, through the annular opening, to the mud pit on the barge. The cuttings are screened out and the mud re-used. Another function of the mud column is to resist the pressure of gas pockets that may be encountered.

When the oil-bearing formation is reached, the drill stem is removed and a string of casing pipe is cemented into the hole. The well is now complete. The equipment on the derrick floor is loaded on the barge, which is towed to another site.

The Electrical Equipment

The electrical equipment on the oil-drilling barge is comprised of two separate systems, one for the main drilling equipment and one for auxiliaries. The drilling operation proper is accomplished by one 800-hp draw-works motor, one 300-hp rotary-table motor, and three 500-hp mud-pump motors. Power for these motors is supplied by three 400-kw, 395-volt, direct-connected d-c diesel generators. The total of 1200 kw is sufficient because all the motors are never used simultaneously at full power. During drilling, for example, the table and one or two pump motors may deliver full power, but the draw-works motor runs either at light load or not at all. During hoisting, the table and mud-pump motors are stopped, but the draw-works motor may operate at full hoisting power.

The electrical control is arranged so as to provide maximum flexibility and to give the driller complete control of all operations from his station on the derrick floor. For example, for drilling, he can use the generators separately to drive the table and mud-pump motors; and for full-power, rapid hoisting of heavy loads, he can use all three generators combined to supply power for the draw-works motor alone. Under such conditions, this motor can develop a peak of 1575 hp. The changes are made simply by pressing buttons.

The control is provided with an emergency stop to cut off all power and other safety features. Instruments indicate to the drill-rig operator the loads on the draw works and bit, and the speed of the bit.

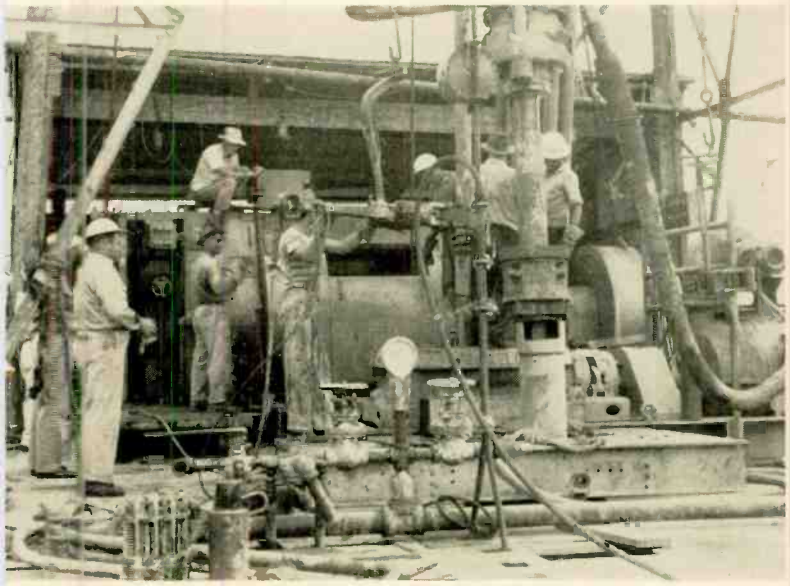
The generators are of the constant-speed, adjustable-varying-voltage type, with three-field excitation. This scheme, similar to that used in elevator control, has steadily gained favor with oilmen since its inception two decades ago. Its merits are: fast but smooth application of power to each motor and inherent protection of generator and engine by automatic limiting of no-load voltage, load current, and motor torque. Furthermore, it eliminates the need for control of engine speed, permitting the diesel to run most efficiently at all times. An adjustable-voltage exciter is mounted on each generator.

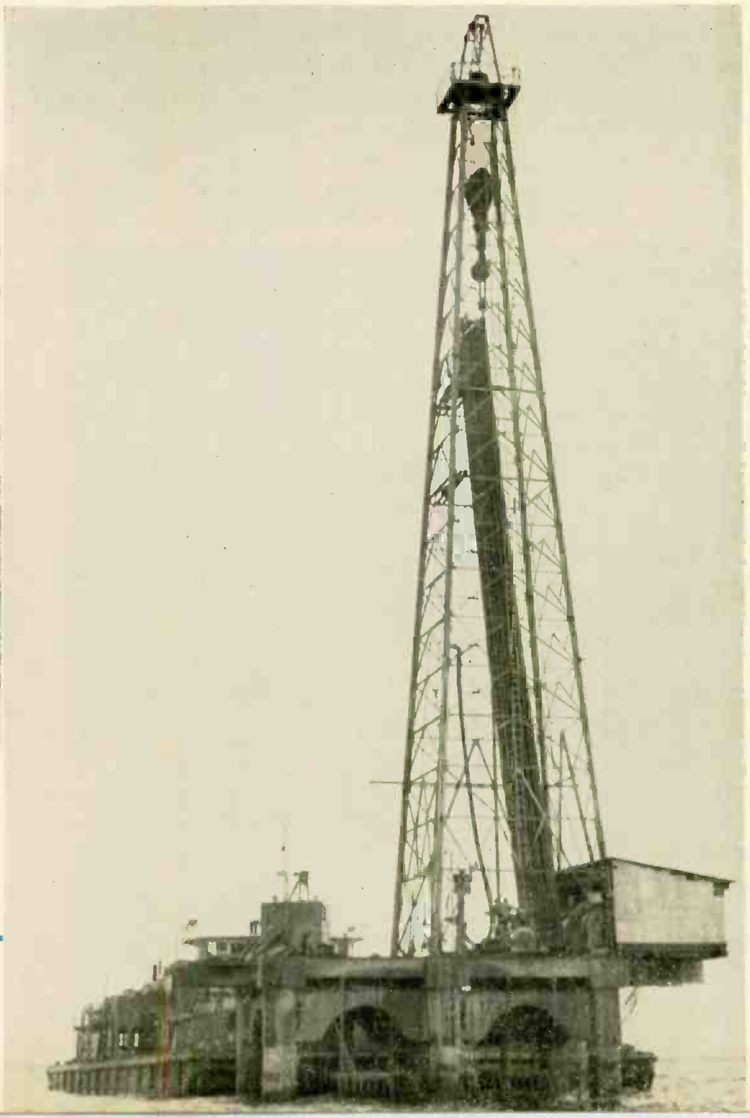
Atop each main motor is an individual blower that provides adequate ventilation regardless of motor speed. Ducts provide safe air, permitting operation in a hazardous atmosphere. The controls are interlocked to prevent starting or running the motor if the blower is not in operation.

Connections between generators on the barge and the draw-works and table motors on the derrick floor are made by single-conductor power cables and multi-conductor control cables. Cables are fitted with marine-type receptacles and plugs, all grouped on a single terminal structure.

Power for auxiliary equipment is supplied by four 75-kw, 125-volt, constant-voltage d-c generators, three of which are mounted atop and vee-belt driven from the main diesels; the fourth is separately driven by a small diesel and provides power when the main engines are shut down. This 300-kw total auxiliary power is used for constant-field excitation of main motors, ventilating blowers, winches, draw-works brake, mud-mixing pump, whirley crane, water distillation and circulation, lighting, refrigeration, fuel pumping, and other uses.

When placed in service last October, the Queen Mary distinguished itself in another significant manner by striking oil on its trial run.





The caissons supporting the derrick floor (right) are 5 to 6 feet in diameter and up to 200 feet long to resist waves often 20 feet high. The barge is in rear. The Venezuelan crew (above); the table motor and blower are at right.

Thermostats for Electric Appliances

Wherever temperature must be maintained, some form of thermostat will do the trick. This device, because of its extreme versatility, is used in many varieties of household appliances and other equipments. And because of this adaptability, thermostats have evolved like the earth's inhabitants. Both started in one simple form; but as conditions and requirements altered, both progressed and evolved into numerous mutations.

P. R. Lee, *Appliance Engineering Department, Westinghouse Electric Corporation, Mansfield, Ohio*

The vast utility of most of our modern electric home appliances is due to the fully automatic thermostat. It silently, but vigilantly, governs the appliance within definite bounds of temperature. Truly it is the brain of the device. Without it, rayons and silks would scorch and stick under the flatiron; milk would freeze or sour in the refrigerator; houses would be too hot or too cold—modern living would come to a comparative standstill.

Modern thermostats can be classified in at least two ways: (1) by type of contact separation; and (2), by the type of thermally responsive element, the prime mover. There are two basic types of contact separation—creep and snap action—and three of prime movers—solid, liquid, and gas.

Creep-Type Contacts

Thermostats in which contacts open and close with a slow movement, Fig. 1, are classified as "creep" thermostats. The contacts travel at a very slow rate, usually between 0.00003 and 0.00025 inch per second. The prime movers move slowly and their motion is usually transmitted to the contacts by a system of levers.

The bimetal creep thermostat used in the flatiron does not cause radio interference.

The separation of creep-type contacts is very small, about 0.0005 to 0.005 inch. Because of this small separation and because the contact pressure is low, the hot arc blast that results during current interruption is concentrated. Hence, the interrupting capacity is low compared to contacts that move more rapidly and have a greater separation.

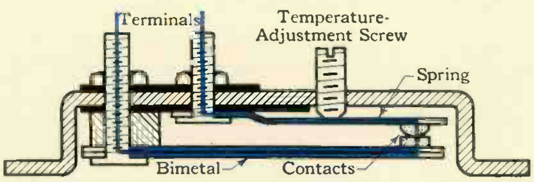
Creep contacts used on 115-volt a-c circuits do not actually interrupt the currents of five amperes or more. The contacts separate so slowly that, before the opening is sufficient to disrupt the circuit, the current, as it passes through zero, extinguishes itself. The usual a-c limit for creep contacts at 115 volts is 15 amperes (more by special design).

When creep contacts are used on direct current, the arc may hang on long enough to damage the contacts and may even cause failure to open the circuit. For this reason, creep-type thermostats are never used on d-c circuits unless either or both the voltage and current are low. The d-c limits are 0.05 ampere at 115 volts and 10 amperes at 6 volts.

Creep-type thermostats inherently have a low temperature differential (i.e., they maintain temperature within narrow limits) because the energy created in the bimetal is used continuously and is not stored, and because the contact separation is small. Also, because of the small contact separation, creep thermostats are not recommended where vibration is present, as is the case with most motor-operated appliances. Mechanical jarring of the thermostat as it approaches operating temperature causes the contacts to open and close frequently. This is called "fluttering" or "buzzing" and, of course, causes annoying radio interference. However, proper design can reduce buzzing although the contacts may tend to open and close rapidly once or twice.

Temperature differential can be widened and fluttering reduced by increasing the thermal inertia of the prime mover (or by reducing the heating rate of parts close to the prime mover), by spring loading the bimetal, by introducing frictional resistance between the prime mover and the contacts, or by combinations of these. Adding thermal inertia prolongs the increase in prime-mover temperature for a short time after

Fig. 1—Schematic diagram of a bimetal thermostat with creep-type contacts.



the contacts have opened; this continues separation and prevents reclosing. The same is true on cooling. Thus, thermal inertia increases temperature differential and eliminates radio interference by giving high contact pressure in the closed position and wide separation in the open position.

In the scheme of spring loading the bimetal, Fig. 2, the contacts are held together by a spring, which gives high contact pressure. The bimetal must exert sufficient pressure to counteract the spring loading before it can separate the contacts.

In the frictional-resistance system, the bimetal must first develop sufficient pressure to overcome static friction, after which there is a sudden movement of parts; this movement is repeated until the contacts are fully opened. In this manner, a sizable contact separation can be developed, but in actual practice it is variable and the temperature is not uniform.

The actual minimum and maximum temperatures obtained with creep-type thermostats may be comparatively erratic; that is, they vary, cycle after cycle. This effect is usually more pronounced at the upper limit, probably due to a minute welding of the contacts if they close on the peak of the a-c wave. Hence, the prime mover must store sufficient energy to break this weld. This prolongs the heating and results in a higher maximum temperature than when there is no weld. Size, shape, and composition of contacts, contact pressure, and the manner of separation are factors that determine erraticness. Erratic operation can be minimized by good design.

Because of the extremely slow movement of contacts, it is impossible to interrupt two or more contacts simultaneously. Hence, only single-pole, single-throw, creep-type thermostats can be made. Creep-type thermostats are characterized by simplicity (fewer parts), low cost, and long life. Life is limited by the contacts, but one million cycles is not unusual. These characteristics make creep-type thermostats popular in the appliance field.

Snap-Action Contacts

Snap-action contacts, Fig. 3, move abruptly. In all types the prime mover stores enough energy to overcome pressure on the contacts. Snap action is created by several means: the permanent magnet, the mercury switch, and the spring toggle or over-center toggle, which is the most common. On most electric appliances, contact separation varies from 0.003 to 0.500 inch but the usual range is from 0.010 to 0.040 inch. Because the contacts move rapidly, several circuits can be opened and closed simultaneously. Thermostats can be built for multiple-pole, double-throw operation and with several sets of contacts per pole.

Snap-action contacts, like creep contacts, do not interrupt alternating current, but they do interrupt direct current. The direct current and voltage that can be handled increases with the number of contact gaps and the separation. The speed at which the contacts separate, which varies from 0.005 to 30 inches per second, is important on d-c circuits, but not on a-c circuits because the latter are self-interrupting.

High interrupting capacity is an outstanding feature of

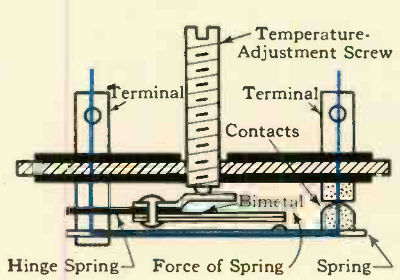


Fig. 2—Spring loading the bimetal of a creep-type thermostat increases temperature differential, reduces buzzing.

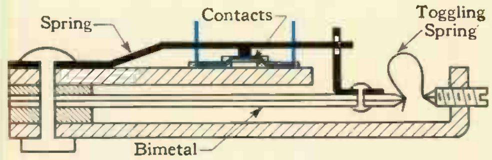


Fig. 3—A bimetal thermostat with snap-action contacts.

snap-action controls. Because the separation is wider than with the creep-type, the bimetal does not flutter, contact surfaces are cooler, and, as a result, less material is lost during arcing and contacts last longer. Maximum current capacities are normally 8 amperes at 115 volts direct current (160 times the wattage of creep types) and 30 amperes at 220 volts alternating current (4 times the wattage of creep types). Higher ratings are possible with special designs.

Uniform temperature differential is one outstanding characteristic of snap-action controls. The minimum and maximum temperatures are uniform, cycle to cycle. These thermostats are never erratic like some creep types. Each "on" and "off" temperature is a duplicate of the former. Radio interference is nonexistent unless the frequency of operation is high, over 60 cycles per hour. In most electric appliances, the frequency is from 10 to 40 per hour.

Thermostat life may or may not be long, depending on design. Life is sometimes limited by fatigue, rather than by contacts, as is the case with creep-type thermostats. If high localized stresses are present in the over-center toggle mechanism, fatigue cracking appears early. The adjustable bimetal disc type is particularly poor in this respect. If improperly designed, the life is only 10 000 cycles, but with care it can be extended to 75 000 cycles. However many other snap-action types will last 500 000 cycles, which in most cases far exceeds normal service requirements.

Solid-Expansion Thermostats

Solid-expansion thermostats utilize the difference in expansion between two dissimilar metals or alloys for actuating a

This roaster employs a bimetal creep thermostat.

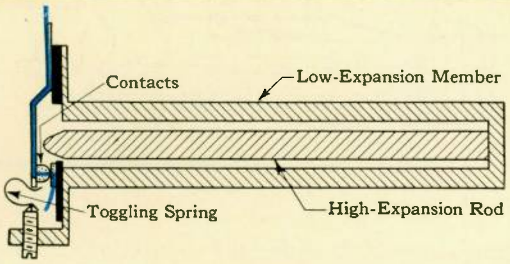


Fig. 4—An early form of solid-expansion thermostat.

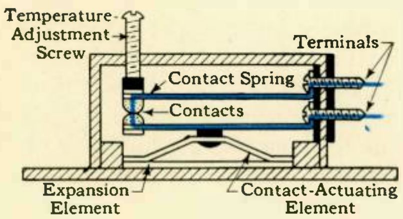


Fig. 5—This thermostat used single-alloy members to move the contacts.

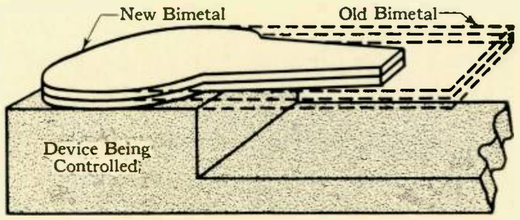


Fig. 6—Modern bimetals have a large area in contact with the device being controlled and a small area acting as prime mover.

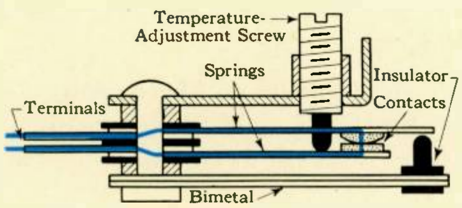


Fig. 7—Schematic diagram of a modern bimetal creep thermostat.

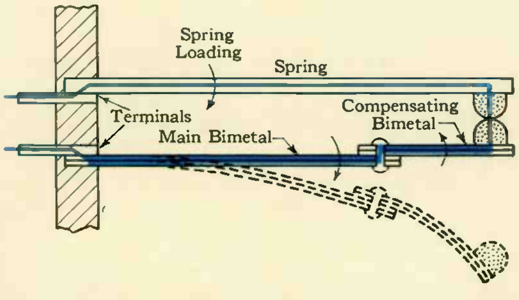


Fig. 8—This compensator is used to give a wide temperature differential. The compensating bimetal, which exerts an upward pressure with increasing temperature, has a higher resistance than the main bimetal, which exerts a downward pressure that tends to open the circuit. When the temperature increases beyond the thermostat setting, the main bimetal, because it is larger, prevails and opens the circuit. Both bimetals start to cool. The compensating bimetal, because of its higher resistance, is at a higher temperature. It cools faster, giving a large contact separation and hence a wide temperature differential. When temperature falls to the point where the contacts close, the compensating bimetal heats rapidly, thereby producing a high contact pressure.

contact mechanism. One of the first types employs a single-alloy expanding rod (Fig. 4) 6 to 12 inches long. The rod actuates a very sensitive spring toggle for snap action. This type is reliable but costly, and its interrupting capacity is small. It is used only infrequently in the appliance field and is in general limited to industrial ovens and furnaces.

A new, smaller type, Fig. 5, utilizing a single-alloy, low-expansion spring member mounted on a single-alloy, high-expansion rigid member, was introduced about 1933. As the lower member is heated, it lengthens, lowering the center of the upper member, a flexible spring on which creep-type contacts are mounted. When the temperature is high enough the contacts separate. Because of the smallness of the movement and the absence of lever systems to multiply motion, temperature stability is not as good as with bimetallic types. However, this type has excellent response to changes in load temperatures. This characteristic minimizes the temperature overtravel (in excess of the setting) that often occurs on the first cycle.

The common bimetal thermostat is the best-known form of the solid prime-mover type. At least 85 percent of all thermostats used in electric appliances are bimetallic. They are reliable and low in cost.

The bimetal alloys used depend on the factors of temperature, stress, and corrosion, among others. The compositions of some of the most common alloys are given in table I.

To prevent bimetal corrosion, special alloys are used, but usually these do not possess high temperature-deflection characteristics. Where larger deflections are needed, more active bimetals are electroplated for corrosion protection.

Sometimes a trimetal is used. The center component is employed for several reasons: to reduce the heating rate (by using an alloy of low ohmic resistivity) and to permit operation at higher temperature or stresses (by using an alloy with high-temperature, high-stress characteristics or an alloy to which a stronger bond can be made).

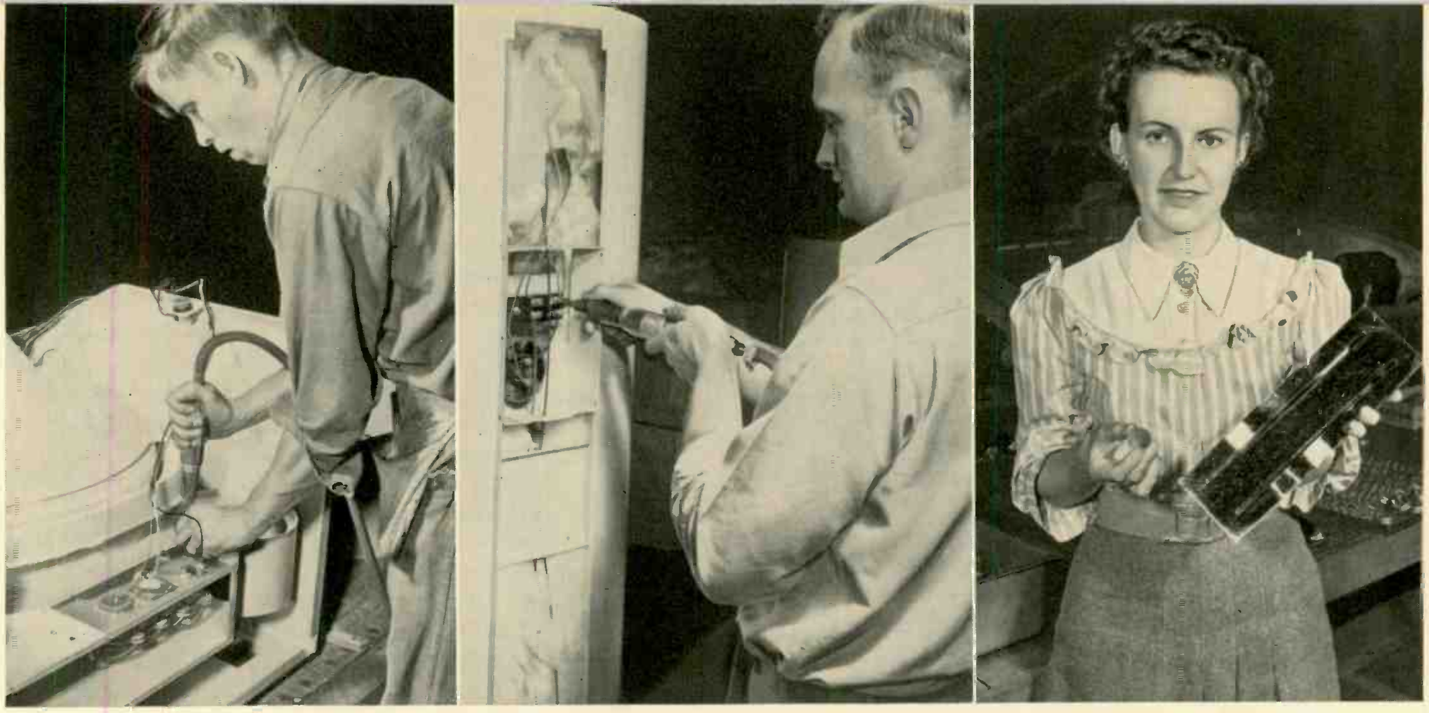
Bimetal Creep-Type Thermostats

One of the earliest forms of bimetal creep thermostats consisted of a cantilever-supported bimetal directly over a cantilever-supported spring, Fig. 1. The free ends were joined by electrical contacts. As the bimetal was heated it deflected away from the spring, separating the contacts. Temperature setting was adjusted by changing the position of the spring member. This thermostat had a very narrow temperature differential and interfered with radio reception. Thermal response was poor because the bimetal conducted current and hence could not be placed in good thermal contact with the object to be controlled. Cost, however, was low.

In time, such thermostats were improved by spring loading the bimetal, which eliminated radio interference. More recent improvements made have been along the lines of reducing thermal inertia of the bimetal to improve the response to

TABLE I—COMPOSITION OF COMMON BIMETALS

High-Expansion Component	Low-Expansion Component
22% Nickel 3% Chromium 75% Iron	36% Nickel 64% Iron
100% Brass	36% Nickel 64% Iron
22% Nickel 3% Chromium 75% Iron	42% Nickel 58% Iron
22% Nickel 8% Chromium	45% Nickel 55% Iron



(Left) The electric dryer uses two bimetal disc thermostats. (Center) The Tri-Snap bimetal thermostat is used on the water heater. (Right) Contrast in size of a bimetal disc thermostat and a Tri-Snap.

temperature changes. Today, bimetals have a large area in contact with the device being controlled and a small unsupported area to act as prime mover, Fig. 6.

Modern thermostats are smaller than the type shown in Fig. 1 and have fewer parts. They cost little and perform exceedingly well. Most small electric appliances, flatirons, steam irons, waffle irons, sandwich grills, and roasters employ bimetal thermostats. The schematic diagram of a modern thermostat for such devices is shown in Fig. 7.

Compensators are easily incorporated either to govern overheating on the first cycle or to increase the temperature differential, Fig. 8. They usually consist of a small piece of bimetal deflecting in an opposite direction to the main bimetal. Automatic room-temperature compensators, used on thermal timers, consist of an auxiliary bimetal that moves the contacts when room temperature changes, thus maintaining proper relative position between contacts and bimetal.

Bimetal Snap-Action (Spring Toggle) Thermostats

This type has an over-center spring toggle, Fig. 3, added to the bimetal structure. Usually the bimetal is cantilever supported and restrained from motion by pressure applied on the free end by the toggle spring. When the bimetal develops sufficient pressure on heating just to exceed the external spring pressure, the bimetal and the spring begin to move together and snap over center to the opposite position, picking up the movable contact and opening the electrical circuit.

As the bimetal and spring move, the pressures caused by both are reduced. However, the reduction in transverse pressure exerted by the bimetal must be less than the reduction in transverse pressure exerted by the spring toggle, so that the bimetal remains stronger than the spring toggle. The contact structure by itself may be of either the creep type or snap-action type, Fig. 9, but a snap-action bimetal generally gives sufficiently fast operation. In either case, to insure positive snap action at the contacts, the bimetal should pick up the contact during its travel and not at the start.

Parts of the bimetallic snap-action thermostat are usually operated at low stress concentrations, which practically eliminates fatigue. Its disadvantages are the multiplicity of parts and the possibility that the assembly may fall apart when subjected to shock, as in transportation. The friction in the moving toggle may vary, changing the characteristic.

Bimetal Snap-Action (Disc) Thermostats

The first automatic flatiron built in this country had the snap-action bimetal-disc thermostat, Fig. 10, generally now limited to motor-protective devices. Essentially the prime mover consists of a dish-shaped bimetallic disc in which the high-expansion component is on the concave side of the dish. As it is heated, stresses in the bimetal increase, building up sufficient pressure to overcome the pressure induced by "dishing." At that point, the disc snaps over center. The reverse happens on cooling. Movable contacts attached to the bimetal disc engage stationary contacts on a separate base structure. These contacts open and close as the disc snaps.

Many variations have been created for different applications. Some have three insulated contacts attached to the disc that bridge six stationary contacts on a base structure. In other instances, two movable contacts on the disc engage two stationary contacts; current passes through the bimetal.

Since the bimetal disc is the spring toggle, this thermostat has few parts and is the simplest of all snap-acting types. The action can be made very powerful and the over-center toggling pressure very high, so that contact separation is rapid and positive, which adapts the disc well to direct-current and multi-pole operation. The larger the diameter of the disc, the greater the contact pressure and contact separation.

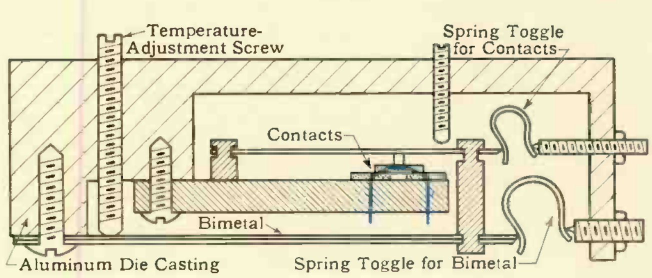
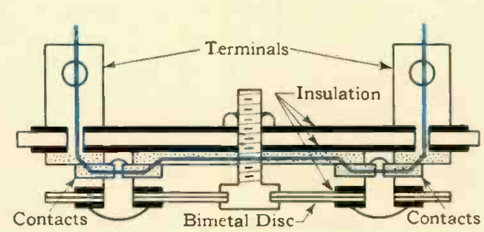


Fig. 9—A thermostat with both snap-action bimetal and contacts. ←

Fig. 10—The bimetal-disc thermostat is now limited mostly to motor-protective devices. →



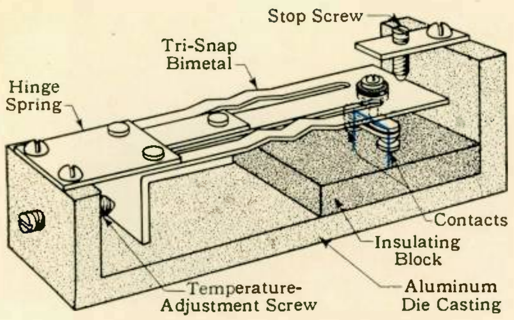


Fig. 11—Schematic diagram of a Tri-Snap thermostat.

Hence, the range of capacities is wide. Other advantages are compactness and low cost.

However, because a large amount of energy is stored for the snap action, temperature differential is wide, particularly with adjustable thermostats. The wide differential is one reason why the disc type is no longer used in flatirons.

Short life, shorter than any other type of thermostat, is another disadvantage. It is due to bimetal fatigue as a result of high concentrated stresses. Cracks usually develop first along the grain structure and then spread. Operating temperatures change, the bimetal gradually loses its snap action and ultimately creeps, contacts erode, and failure may result.

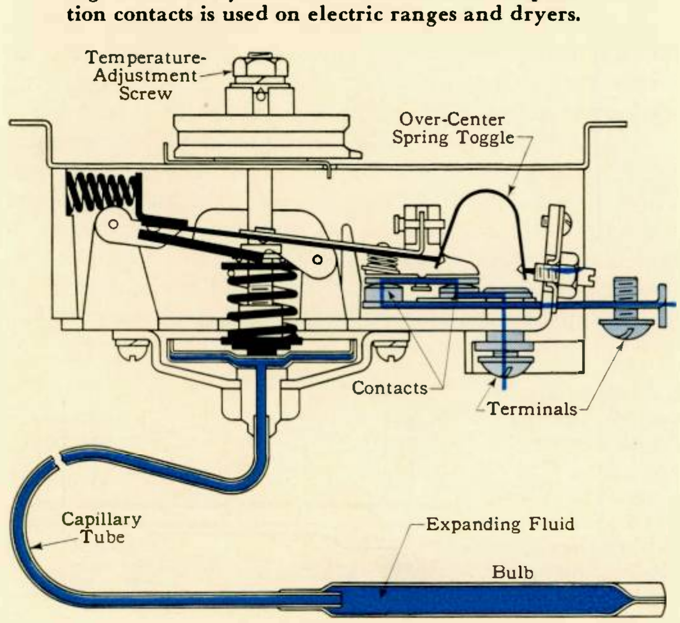
Bimetal Snap-Action (Tri-Snap) Thermostats

In an effort to take advantage of the good qualities of the disc thermostat and yet overcome its deficiencies, Westinghouse developed the Tri-Snap control, Fig. 11. It is similar to the disc type, but it is rectangular rather than round and has two longitudinal slots to provide three sections or "legs." The two outer legs are crimped to shorten them slightly with respect to the center leg. A portion of the center leg is restricted in motion. Movable contacts are mounted either directly on the bimetal or are picked up after snap action has started. The bimetal is usually cantilever supported with the restricted area close to the fixed end. This design increases life and reduces differential tenfold. Cost is low and snap action positive. This thermostat is compact and has few parts.

Hydraulic Fluid Thermostats

Hydraulic fluid thermostats, Fig. 12, utilize fluids as the prime mover. The fluid is hermetically sealed inside a tube, having at one end a flexible bellows or diaphragm and at the other end a bulb immersed in the medium to be controlled.

Fig. 12—The hydraulic thermostat with snap-action contacts is used on electric ranges and dryers.



The tube is thick-walled and of small internal diameter to minimize its volume of fluid. As temperature increases the fluid expands and mechanically advances the flexible end to drive a contact mechanism. Temperatures of liquid mediums can be controlled more reliably because the prime mover can be almost directly immersed in the liquid. This cannot be done with bimetal thermostats unless the contacts and prime mover are sealed. Also, the bulb containing the expanding fluid can be formed to match the contour of any metal surface, thereby obtaining good thermal contact.

Remote control is another feature. The bulb can be located almost any distance from the contact mechanism and the capillary connection can be made as long as desired, but any change in its temperature affects the operating temperature. Also, the length offers some resistance to the flow of fluid. Hence, when the main bulb is heated rapidly, motion is not immediately transferred to the contact structure, but is slightly delayed. The ability to isolate the prime mover from the contacts is advantageous if the atmosphere is corrosive or humid (to keep the contacts away), if space is at a premium (the bulb need be the only member in the medium), or if the thermostat is adjustable (the control knob can be located where it will remain cool). Fluid thermostats are costly.

The system is essentially the same whether the expanding medium is liquid or gas. Liquids are more commonly used because greater temperature ranges are permissible, and because they are practically incompressible, tremendous pressures can be used in the switching mechanism. Fluids having high temperature coefficients of expansion, such as chlorinated diphenol, provide maximum motion per degree change.

Hydraulic thermostats are also made with creep and snap-action contacts. The creep type was used on electric roasters until about 1931, when it was superseded by bimetal types.

The snap-action type has found wide usage on major electrical appliances, such as ranges and dryers. On ranges it is advantageous in that it can be used year after year without redesign, although the electric range is completely modified. The flexible tubing can be bent to any shape to conform to any location of bulb and control knob. The same thermostat can be used regardless of whether the control knobs are on the left rear or on the right front of the range. On electric dryers this type is ideally suited because of the presence of both moisture and lint. Due to lack of crevices, sharp corners, and projections on the bulb itself, lint cannot accumulate on the thermostat mechanism and cause improper operation.

TABLE II—CHARACTERISTICS OF THERMOSTATS

Prime Mover	Solid (Bimetal)			Hydraulic	
Operation	Creep	Snap Bimetal, Creep Contacts	Snap Bimetal, Snap Contacts	Creep Contacts	Snap Contacts
Temperature differential-deg. F	1	40	100	2	10
Erraticness	Poor	Excellent	Excellent	Fair	Excellent
Radio interference	Yes	No	No	Yes	No
Interrupting current at 115 volts a-c	15	25	25	15	25
Contact wear	High	Low	Low	High	Low
Fatigue life in cycles	1 000 000	1 000 000	75 000	1 000 000	1 000 000
Overall size	Small	Medium	Small	Large	Large
Cost	Low	Medium	Low	Medium	High
Typical application	Flatirons	Water heaters	Motor protection	Electric roasters	Electric ranges

What's NEW!

The lower frequency also reduces the rate of current rise during welding because the rate of rise of a 12-cycle wave is less than that of a 60-cycle wave. As a result, the current densities in the early stages of the welding cycle are reduced, which results in less "spitting" and burning, and less electrode wear. The electrode keeps its shape longer, thus strengthening the weld.

The new controls convert three phase, 60 cycles to single phase, 12 cycles by controlling the firing sequence of 6 ignitron tubes. Heat control is accomplished by phase shifting, which enables the operator to set the welding current accurately.

A Subway Car Named PCC

The principles of operation of good equipment find their way around. Often they can be applied to other types of equipment with great advantage. This is ably demonstrated by incorporation of the fundamentals of the modern, high-speed surface car known as PCC into a new multiple-unit car for combined subway and elevated use.

These new cars, 130 of which will be built by the St. Louis Car Company, will have basically the same type electrical equipment as the standard PCC car. However, several major changes were necessary in applying the PCC's principles to this type of service. First, the electrical design had to be adapted for multiple-unit operation. Also, for rapid-transit service with heavier loads a larger accelerator was necessary. Single-handle controls, as compared to the PCC's foot-pedal control, are to be used for acceleration and dynamic braking. And finally, the equipment was rearranged for third-rail power supply, instead of the conventional overhead trolley.

Each of these cars will be powered by four 55-hp. motors. The handle control will provide a selection of three extremely smooth acceleration rates with a maximum of 2.9 miles per hour per second with full load. Normal service braking is provided by a selection of dynamic braking rates. A drum-type friction brake on each motor-shaft extension provides a holding brake, which also acts as a supplementary brake in emergencies.

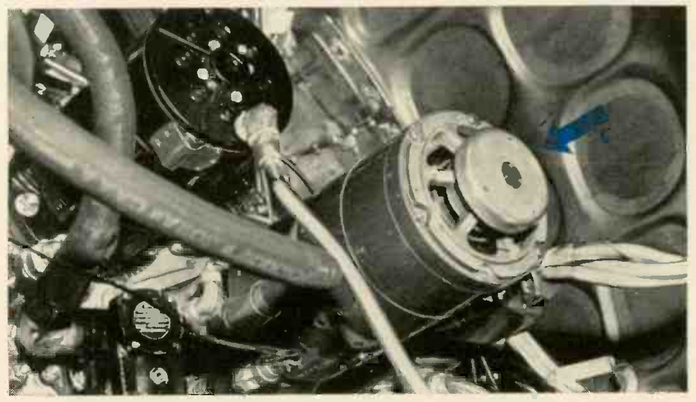
These new multiple-unit cars will be designed for use in two-car units, but can be used in trains of up to ten cars. The two-car unit will have a seating capacity of 99 persons.

This will mark the first time that all-electric, PCC-type equipment has been adopted for rapid-transit service. It will provide modern, high-speed, smooth-operating transportation for Chicago. Since PCC surface cars are already in widespread use in Chicago, a further advantage is offered, because many of the parts of the two equipments are interchangeable. Maintenance is thus facilitated.

Hold That Jiggle Down!

Difficult to predict in design is the resonant vibration frequency of a multi-component machine. The case in point is the airplane, which consists of thousands of subassemblies, each a complete unit with a resonant frequency all its own.

In one instance, when a Westinghouse aircraft generator was hung on a particular airplane engine, the plane vibrated with a



frequency corresponding to the resonant frequency of the generator, which consequently vibrated with an amplitude in excess of tolerance. The situation was clearly not the fault of the manufacturer of the airplane, the engine, or the generator, but it called for an immediate remedy. Because the generator could not be changed sufficiently to alter the resonant frequency appreciably (and still meet dimensional and other requirements), the vibration was reduced by a tuned vibration damper.

Dampers have been used in many ground vehicles and aircraft but this type is unique in construction and operation. Essentially, it consists of two disc-shaped pieces of steel, one bolted on the generator housing and coupled to the other through a neoprene sandwich. Stresses are reduced partly by changes in the resonant point and partly by energy absorption in the neoprene. Neoprene is employed instead of a metal because its spring characteristics are the same in all radial directions and because it provides greater damping.

Ignitrons and Sugar

Typical of new jobs being found for ignitron rectifiers is the sugar-mill tandem, which crushes the juice from sugar cane. A tandem consists of a set of crushers and three roll mills, each supplied by a conveyor fed by the preceding unit. The speed of the entire tandem must be adjustable over a range of 1½ to 1 to allow for a varying supply of cane. The speeds of individual mills must be controllable to insure proper coordination.

Tandems are customarily driven either by steam engines or by wound-rotor motors fed by an adjustable-frequency turbine generator. But the flexibility required is more readily provided by a new system consisting of an ignitron and d-c motors. The speeds of the rolls are changed simultaneously by adjusting the field of a single exciter whose output supplies power to all the motor fields, and individually by separate rheostats in each motor field. The entire tandem is reversed by reversing the voltage of the common exciter. For starting, the ignitron voltage is raised gradually from zero, thus eliminating starting resistance and giving smoother acceleration with low inrush current.

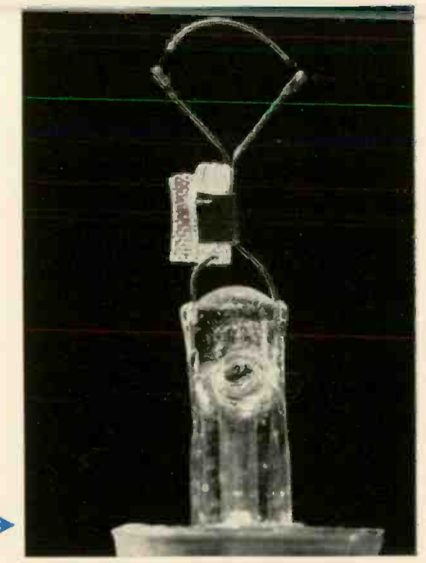
The combination of the ignitron rectifier and d-c motors gives better speed regulation and efficiency than previous systems. As compared to the wound-rotor motor drive, the ignitron scheme requires less maintenance and presents a load of higher power factor. Also, special generators are eliminated, reducing the initial investment. Two ignitron systems are now in operation on sugar-mill tandems in Mexico.

What's NEW!

A New Fiberglas Series Cutout

A cutout device installed in 30-volt street-car and subway-car lamps prevents the headaches maintenance men would face if they had to track down a burned-out lamp in these 600-volt series circuits. This cutout, by re-establishing the circuit, permits all but the burned-out lamp to remain lighted instead of going out like a series string of Christmas-tree bulbs.

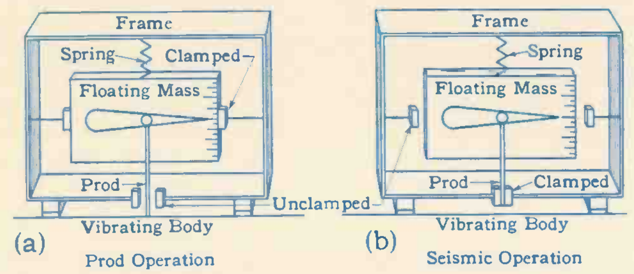
Various materials have been used as cutouts in these gas-filled lamps but a new one of Fiberglas has proved more dependable and accurate. Inserted between the lead-in wires of the lamp, the Fiberglas cutout maintains the critical spacing between these wires. A strap of nickel holds it firmly against the wires. When one of the 20 lamps burns out, the circuit is broken momentarily, and the full 600 volts is impressed across the lead-in wires of the lamp. The insulation immediately breaks down, with the gas in its interstices acting as a conductor. The two wires thus fuse together and maintain the circuit. This type of cutout will operate at 200 volts in the lamp and at 500 volts in open air without breakdown. The use of Fiberglas in a cutout offers the prime advantage of giving a higher and more sharply defined breakdown point and thus more reliable service.



For Charting Miniature Industrial 'Quakes

Every industrial vibration is in effect a minute earthquake—and hence can be measured as such. Real earthquakes are recorded by seismographs; industrial vibrations by an instrument, the Vibrograph, that works on a similar principle. The frequency range of the Vibrograph has recently been extended by a seismic-pendulum support developed in conjunction with The Barry Corporation, Cambridge, Mass.

The Vibrograph provides a continuous magnified record of a machine or building vibration. Vibration can be measured by

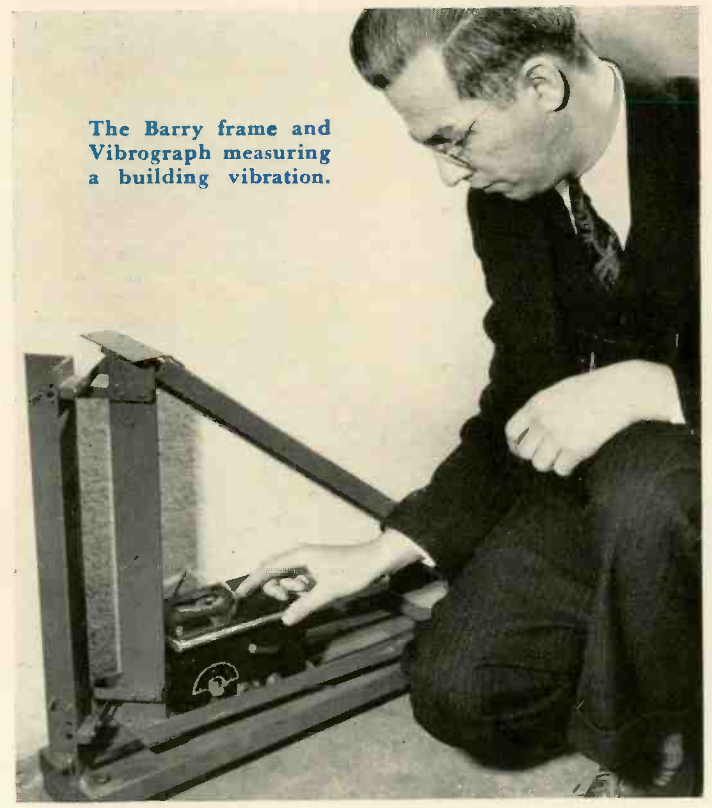


means of a prod (a). The internal mass and scale are clamped to the Vibrograph housing and the prod is placed against the test member. The stylus follows and traces the vibration on a moving transparent plastic tape, while a second stylus traces a timing wave. The tape is examined afterward with a low-power microscope or by projection on a screen.

The housing of the Vibrograph must, of course, vibrate as little as possible, else the wave traced will be in error. This vibration is minimized by the new support, which consists of a triangular arm, weighted at the end and supported by frictionless elastic hinges from a vertical column. The assembly forms a seismic pendulum that tends to damp vibrations transmitted from the floor to the Vibrograph housing. Hence, the Vibrograph tends to remain stationary in space while the prod and stylus move to trace the vibration.

The Barry frame extends the range of the Vibrograph so that it can now record vibrations from 120 to 15 000 cycles per minute, (the lower limit without the auxiliary frame is 600) and amplitudes from 1/10 000 to 1/16 of an inch. Vibrations beyond these limits can be recorded, but with reduced accuracy. Error for amplitudes greater than 1/1000 inch is less than five percent.

The Vibrograph can also record when it is mounted on the vibrating machine. It records by seismic operation (b), so called because the entire housing of the instrument vibrates. The internal mass and the prod and stylus are clamped to the housing, which vibrates with the vibration being recorded. Because of the weakness of the supporting springs, the floating mass and scale are practically motionless in space as the stylus traces the vibration. When operated in this fashion the Vibrograph cannot employ the Barry frame and hence its lower frequency limit is 600 cycles per minute.



The Barry frame and Vibrograph measuring a building vibration.

What's NEW!

New Cutout Door Gives Higher Capacity

Flexibility and simplicity are two sought-after features in industrial equipment, particularly in the electric-power industry. Here growing demands must be met with as few changes as possible, while attempting to keep systems and equipment as simple as is practical. This extends from the largest to the smallest of equipment and even to parts of equipment.

A new HC (high-capacity) distribution cutout illustrates this point. The complete porcelain-enclosed unit, with an interrupting capacity of 8000 amperes at 2500 volts, or 5000 amperes at 5000 volts, can be obtained as a unit for new installations. On the other hand the cutout door alone, containing the fuse link, can be installed on existing type-EA cutouts where short-circuit currents have grown beyond the rating of the existing cutout.

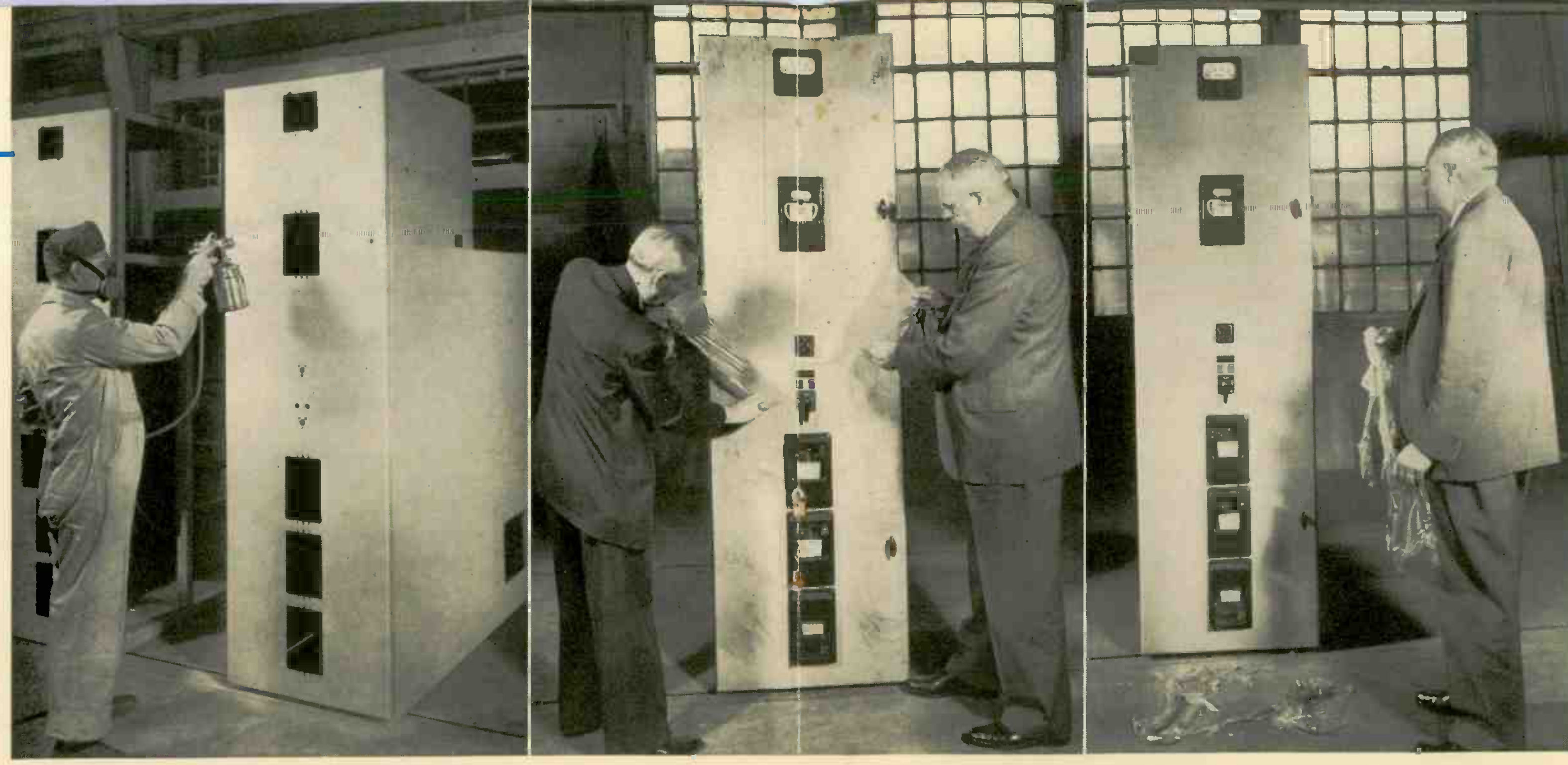
This versatile HC cutout unit is rated at 5 kv, 50 amperes, and will accept any standard universal-type fuse link up to its capacity. It is applicable to any 2400-volt delta, 4160-volt wye, 4800-volt delta, or 8300-volt grounded-wye system.

Spotting Time for Spot Welds

To most engineers, a hundredth of a second is not a very long period of time. But the welding engineer knows that a few of them can spell the difference between a good and a bad spot weld. (A spot weld is normally made in about one-half second.) Therefore, to insure good, consistent welds, the calibration (for time) of a resistance-welding control should be checked when the setting is made and then periodically to assure its constancy.

A new weld-time meter measures the duration of a spot weld directly. It is portable and uses no external source of electric power other than that obtained from three clip-lead connections in the welding transformer primary circuit. When a weld is made, the hands on the clock-type face start and stop with the welding current. The operator reads the duration of welding time in hundredths of a second or in cycles. The accuracy, plus or minus 1/120 second, or ½ cycle, is maintained whether welding current is supplied during all or during only a small portion of each 60-cycle wave.

The clock-type meter is energized by an electronic circuit, power for which is supplied through the three connections. Impulses from the welding transformer start conduction through a thyratron, whose output drives a small d-c motor that moves the hands of the clock.



In the eyes of engineers, an indoor switchgear unit is a thing of beauty that should be kept so forever. But between the painting and the energizing comes much handling that spoils this objective. With this end in mind, switchgear panels are now being coated with a transparent plastic. (Left) The material is sprayed onto the panel after final painting, prior to the addition of the many components that comprise the finished switchgear. The smudges of dirt and grease that inevitably appear during assembly are deposited on the plastic. The coating is left on the switchgear during shipment and installation, after which it is peeled off (center), and the clean factory finish is revealed (right). Touch-up painting, necessitated by blemishes inflicted on the outside surfaces of the switchgear during the process of installation, is no longer required.

New Eyes for Blind Navigation

To pilots of commercial river and harbor craft and ocean-going vessels, marine radar has become an all-directional, all-seeing eye that can reach to almost any desired distance and through almost any atmospheric conditions. Since the end of the war, radar has piled up an impressive service record, justifying the investment in equipment in as short a period as a single trip.

A new marine radar, type MU-1, has a number of improvements that past experience has indicated to be beneficial. One is a built-in performance-checking scheme, which assures that the equipment is functioning properly. When on a calm sea, with no land, ships, or other targets within range, the scope presentation is the same as would exist if the system were not operating correctly, i.e., the screen is essentially blank. Therefore, a means of checking the complete set is important.

During normal operation, radar pulses issuing from the antenna feed horn hit the reflector, which reflects them to a sector of the surrounding area. When a switch on the console control panel is turned to "Test," a narrow vertical slot is opened in the antenna reflector. The pulses pass through this slot and enter a resonant cavity, which delays and returns them to the horn. The pulses pass through the receiver to the screen, where they appear as a radial section if the equipment is functioning properly. If not, the screen remains blank. Thus, both the sending and receiving circuits, including the antenna, feed horn, and wave guide, are completely checked.

Rough sea, heavy rain, dust, or snow storms may cause the scope to be cluttered by what is commonly called "sea return." This may cloud the screen and hinder detection of nearby targets. To avoid this undesirable effect as much as possible, the MU-1 employs a three-position coarse adjustment and a continuously variable fine adjustment on the sea suppressor. Once the controls are set for given sea conditions, a constant target intensity above sea return is provided without further adjustment. The sea suppressor reduces the sensitivity to nearby weak objects, thereby eliminating reflections from waves, rain, and snow, but not from ships and buoys.

Other features of the radar are: a plastic radome housing that protects the antenna from physical damage and prevents variation in antenna speed caused by wind loading; six range scales (1, 2, 4, 8, 20, and 40 miles); four fixed range rings on each scale; a large flat-face screen that reduces the possibility of error due to parallax; and a variable range marker used to measure accurately distances to any target, or to determine the position of the ship from a known target. Optional features include a motor-generator set to supply alternating current if this is not available, a beacon receiver for determining the position of the ship from a radar beacon, and a true-bearing azimuth stabilizer that facilitates navigation by charts.

The Conversion of Spot Welders

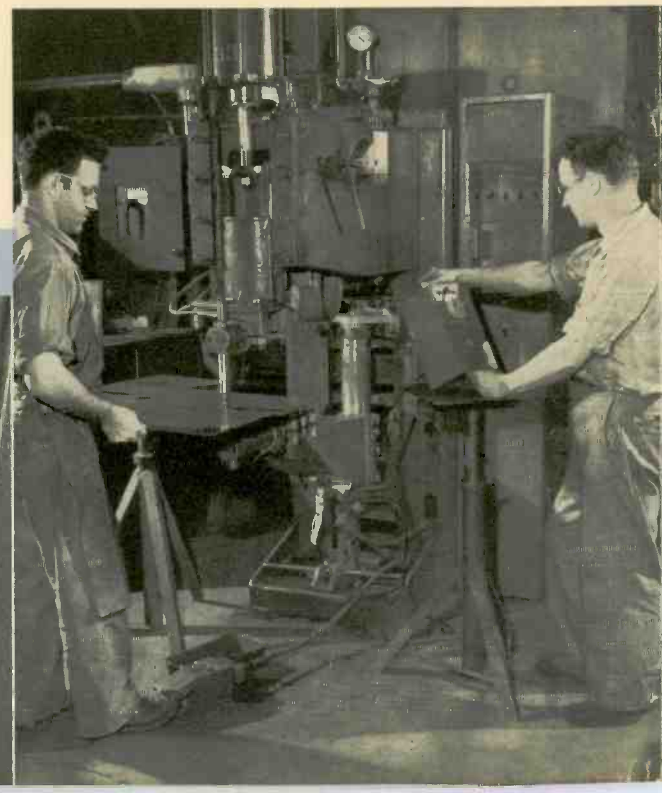
Most spot welders operate on an input of single phase, 60 cycles and deliver an output of the same characteristics for welding. But a new spot-welder control draws three phase, 60 cycles and converts it to single phase, 12 cycles.

The standard, 60-cycle spot welder consists essentially of a timing switch and a single-phase step-down transformer to give a high current capacity. A spot weld is formed when the two electrodes press the two pieces of work together. Currents, often as high as 50 000 amperes, pass through the pieces, causing them to melt and fuse, i.e., weld.

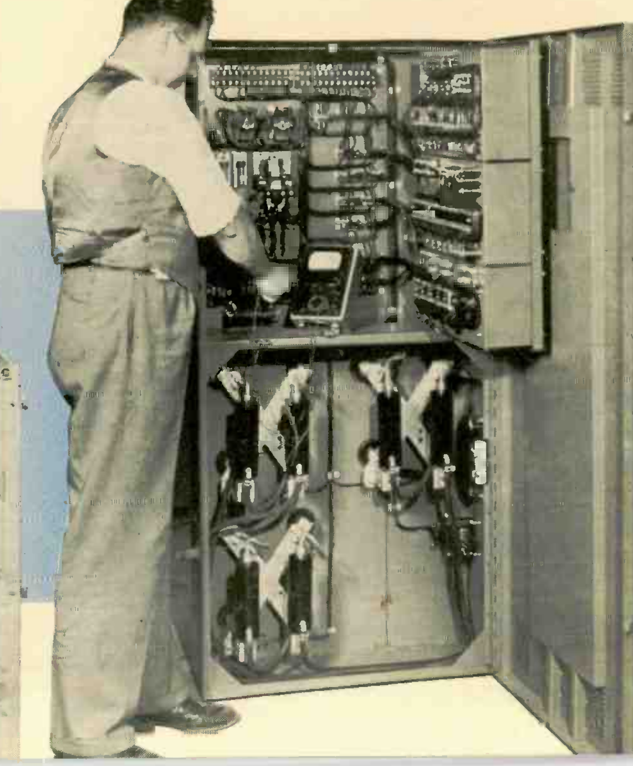
Modern welding machines make as many as 300 spot welds per minute. Each time a weld is made, a tremendous surge of current is drawn from the line, which under certain conditions causes light flicker. The new three-phase welding control reduces this surge and furthermore distributes it among three phases so that the demand per phase is reduced still further. Tests indicate that the kva demand per phase using a three-phase control is approximately one third the demand using a single-phase control.

The 12-cycle characteristic also offers advantages. The impedance to the flow of current through the metal electrode arms increases as the work enters the throat of the welder. This effect is much more pronounced when single phase, 60 cycles is used than when three phase, 12 cycles is used. Thus, the three-phase system permits more consistent welding because the welding current is more stable.

This new type-HC distribution cutout is rated 5 kv at 50 amperes. The door alone, shown open, can be used with older type-EA cutouts.

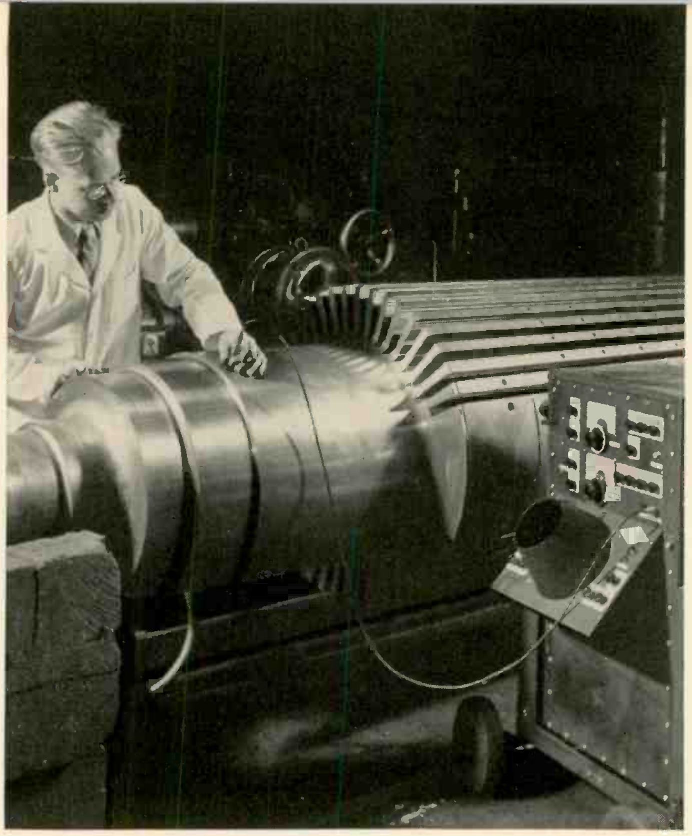


The weld-time meter (below) being used (right) to check the timing calibration of a spot-welding control. It is connected by attaching three leads to the transformer.



A three-phase, low-frequency welding control being shop tested (right). The MU-1 radar console installed (left) and with the front cover opened (below).

Nondestructive Flaw Detection



D. M. Kelman

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If the makers of the famed Liberty Bell could have used modern methods of testing, the old bell might be ringing yet. Unfortunately, the only sure form of testing then known was by destructive means. Now materials can be checked for flaws by such methods as x-ray, magnetic, and ultrasonic. This will undoubtedly lead to the production of better materials, and will permit the application of existing materials at higher operating stresses.

Accurate testing of materials for flaws and defects has long been an enigma to design and research engineers. They can either test a material to destruction—which may prove only the quality of the particular sample—or they can apply a large enough safety factor to the material to eliminate possibility of failure. In some cases these procedures are satisfactory, but often they are not. Destructive testing of a large turbogenerator rotor, for example, would damage the article beyond use besides being costly, laborious, and time-consuming. Often the designer wishes to allow a large "ignorance," or safety, factor by employing heavier sections or by obtaining higher strength materials, but this may not be possible or practical. Obviously in these cases it is more desirable to test materials by some nondestructive method. Several are now available, each with specific uses and limitations, the choice depending upon the purpose of the test.

Materials are tested by three separate groups of people for distinctly different reasons. The research scientist tests them to determine inherent properties, often without regard to prospective use. The production engineer, on the other hand, wants to know whether processing techniques have been successful in developing the desired properties. Both these tests are concerned with production of the material, and tell the design engineer only what he can expect from a homogenous, flawless test piece. Because no piece of material is perfect, and in some cases damaging flaws may be present, he must allow his large safety, or ignorance, factors or use some conclusive means of testing without destruction. In recent years greater emphasis has been placed on nondestructive tests to determine the soundness or freedom from defects of various types of structures and materials.

Many nondestructive flaw-detection tests are now applied, most of which can be grouped under four general classes: radiographic, magnetic, fluorescent penetrant, and ultrasonic.

Radiographic Testing

Radiographic techniques of flaw detection can be applied to almost any material, metallic or nonmetallic. Of these methods, x-ray radiography is the oldest and most widely used. The casting industry has long used it for the detection of porosity, gas pockets, and shrinkage cracks. In recent years the soundness of welds has also been tested by this method. In applying this technique, x-rays are passed through the material and impinge upon a photographic plate. The intensity of x-ray impingement is affected by the density of the material. Thus any defects, such as porosity, permit passage of more x-rays than a uniformly sound section of material and therefore cause a dark area on the film, outlining the defect.

X-ray inspection is limited by the thickness of the section that can be penetrated, the sensitivity of the test, the time consumed in performing the test, and the cost. With high-voltage x-ray equipment, sections of steel up to about nine inches thick can be examined. In most commercial equipment the practical limit is three or four inches. Furthermore, most commercial tests cannot be relied upon to disclose defects whose thicknesses are less than about two percent of the thickness of the material. Under laboratory conditions this can be reduced to about one-half percent, which is helpful for many applications. But even this sensitivity is not sufficient to detect fine surface cracks.

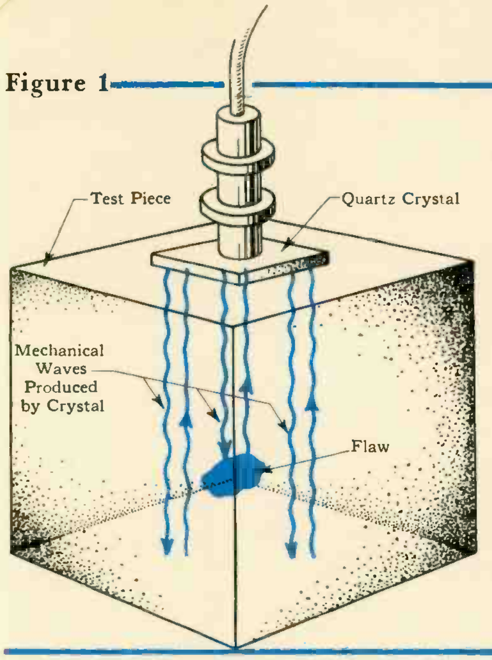
Another nondestructive testing technique, similar in principle and application to the use of x-rays, is gamma-ray radiography. Here the source of rays is a radioactive material such as radium or a radioactive isotope. This method has some advantages over x-rays but has two drawbacks, long exposure time and slightly reduced sensitivity.

Magnetic Method

The second class of nondestructive testing, used for the past several years, involves the application of magnetic fields. The magnetic-particle test, known under the trade name of Magnaflux testing, is the most common. This detects surface defects such as cracks, laps, seams, and inclusions. In ferromagnetic materials it locates discontinuities open to the surface but too fine to be seen with the naked eye, and also some defects slightly below the surface.

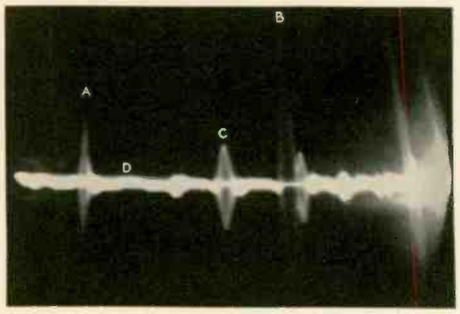
In this test, a magnetic field is set up in the object being tested. Fine magnetic powder is applied and adheres to the surface. Since a surface defect interrupts the magnetic field, blowing lightly on the powder causes it to collect at these defects, thus permitting them to be easily seen. There are many variations in the method of providing the magnetic

Figure 1



A mechanical wave is induced in the material by a quartz crystal vibrating against the surface. The vibration is caused by a pulsating high-frequency potential applied to the face of the crystal. Frequency is adjustable between 0.5 and 10 mc, giving wavelengths in steel from 0.5 inch at 0.5 mc to 0.025 inch at 10 mc. Waves reflect from surfaces they hit.

Figure 2



On this Reflectoscope's screen, *D* is a superimposed square wave calibrated to represent distance in the material. *A* represents the initial input pulse on the crystal, indicating the location of the surface to which the crystal is applied. *B* represents the location of the wave reflected from the opposite side of the material, and *C* is the indication of reflection of the wave from a defect. The initial pulse *A* covers a portion of the screen representing a distance varying from about 0.5 inch at 5 mc, to 2 or more inches at 0.5 mc. Therefore it is not practical to detect defects less than 0.5 to 2 inches from the surface, depending upon the frequency used.

field and of applying the magnetic powder, but all use the same general principle.

Other magnetic-testing techniques utilize various factors that affect the magnetic properties of a material. By detection of changes in these properties with magnetic-analysis equipment, materials of varying composition or heat-treatment are separated. This magnetic-analysis equipment is also used to detect surface defects that cause variations in the magnetic field through a bar. In most apparatus of this type, the material is passed through a coil, and the resulting field is compared to that of a standard sample.

Fluorescent-Penetrant Method

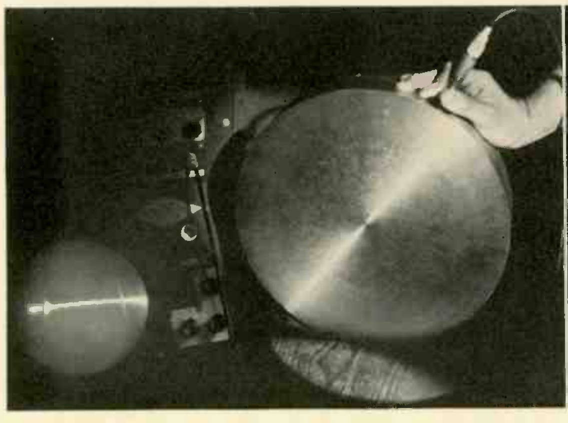
Fluorescent-penetrant inspection serves a purpose with nonmagnetic materials similar to Magnaflux testing with magnetic materials. A fluorescent liquid penetrant, applied to the surface, enters discontinuities. After soaking, excess penetrant is washed or wiped away. When the surface is viewed under ultraviolet radiation, or "black light," discontinuities are readily visible. Seepage of the penetrant is often aided by application of an absorbent-powder film to the surface. This test can be used on either magnetic or nonmagnetic materials but reveals only defects open to the surface.

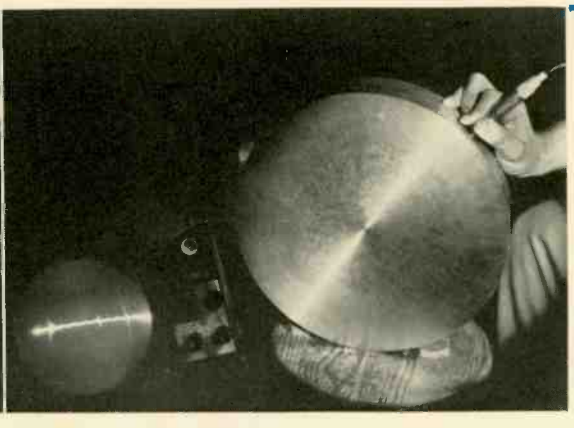
Ultrasonic Testing

The fourth class of nondestructive techniques—now just beginning to find its place in the testing field—involves ultrasonic waves or vibrations. Here, too, there are several different methods of application, each with a valuable and definite place, but with certain limitations. In the most common method, a high-frequency mechanical wave is transmitted through the material, reflects from the opposite side or from any discontinuities in the path of the wave, and returns to the source. Time of travel is measured and, by comparison of the elapsed time for portions of the returning waves, discontinuities are detected. In operation this technique is similar to sonar or radar, differing mainly in the wavelengths used and the medium of transfer. One of the most common instruments in this country is the *Supersonic Reflectoscope* produced by Sperry Products, Inc. In Europe the most popular instrument is the Supersonic Flaw Detector made by Henry Hughes and Son, Ltd. The principle of application of the Reflectoscope is illustrated in Fig. 1.

The potential is applied in pulses of a few microseconds duration. The pulses of mechanical energy pass through the material, and because of their nature reflect or echo from the opposite side of the object if no discontinuities intercept their path. If a discontinuity is present, as in Fig. 1, a portion of the wave is reflected from it and returns to the crystal sooner than the portion that travels a greater distance. Between pulses the crystal is quiet and acts as a receiver, converting the returning mechanical wave into a high-frequency electrical potential. This potential is amplified by electronic circuits and projected on the screen of a cathode-ray tube, Fig. 2, where location of the defect can be examined and measured.

The Reflectoscope on page 1 is being used to test a large





Figs. 3 and 4

(Far left) Half waves are calibrated as one inch in the disc material. Only surface pulses appear so there are no defects present.

(Left) Another pulse has appeared, 5½ inches from the back reflection, indicating a defect at this point.

turbogenerator rotor shaft. In this case the wave is being transmitted diametrically through the shaft. It could also be transmitted longitudinally, since distances up to 30 feet can be penetrated readily in forged steel. However, the sensitivity of the test decreases as the distance from crystal to discontinuity is increased.

This instrument is also used to test turbine discs, as in Fig. 3. The crystal, applied to the edge, causes the wave to pass diametrically through the disc. The pulse on the left side of the screen represents the pulse on the crystal, and, therefore, that surface of the disc to which the pulse is being applied. The pulse on the right side of the screen represents the reflection from the opposite side of the disc. This disc is free of defects in line with the crystal.

The same disc with the crystal applied at a slightly different position is shown in Fig. 4. Here another pulse has appeared between the front and back surface indications. This extra pulse denotes a discontinuity in the material in line with the position of the crystal, and 5½ inches from the back surface. By moving the crystal around the periphery, the entire disc can be examined and the position and size of defects determined accurately.

The ultrasonic technique has several other methods of application. One variation requires two crystals, located at opposite surfaces, one acting as a transmitter, the other as a receiver. Here the total energy transmitted is measured rather than the amount reflected. Density of the material affects transmission of the waves as in the use of x-rays. Any defects cut down the total amount of mechanical wave passing through the material and therefore cause a diminution of the pulse on the receiving crystal. By noting the location of these diminutions, the position of discontinuities can be plotted. Many different methods of applying the crystals are merely variations of this basic principle.

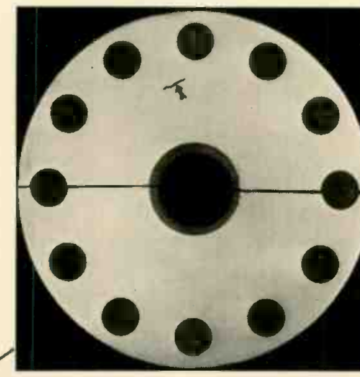
Other interesting and valuable applications for the Reflectoscope have been found. A sketch of the end of a generator rotor is shown in Fig. 6. A crack was detected on the flange end of this rotor by means of Magnaflux. The distance that this crack penetrated into the rotor would determine whether or not it could be removed. The crack was traced through the rotor for a distance of 16 inches at the location represented in the sketch, which unfortunately showed that the rotor was not acceptable. To check the findings, and to determine the cause of the crack, the rotor was sectioned at the points shown by Figs. 5 and 7; these sections were deeply etched in hot acid to bring out the structure of the section. Another etch, taken just beyond that of Fig. 7, showed that the defect had run out. Thus, it was confirmed that the Reflectoscope had given a true indication and a defective forging was prevented from being placed in service.

The layout of the top surface of a large cast-steel thrust collar appears in Fig. 8. A defect was noted in the bore of this collar while it was being machined. It was necessary to learn the extent of this crack to determine whether the thrust collar could be salvaged. The Reflectoscope showed that the large defect extended 14¼ inches in depth and was 16½ inches wide at its maximum point. Several others that could not be seen on the surface at any point were also located. Since these defects were at areas of low stress, engineers decided that they could be burned out and the casting repaired by welding. A projection of the original outline of the large defect and the outline of the material removed during the first burning is shown in Fig. 9. Clearly all of the defective material had not been removed from the thrust collar.

The manufacturer, on burning out the defect, had welded over the edge of the crack at the point shown on this outline and the crack could not be detected visually. More material was removed. When this was done the defect again appeared and still more was removed. The outline, after final burning, is shown in Fig. 10. Here again the Reflectoscope had given a very accurate indication of the extent of the defect. In this case, a casting that might otherwise have been rejected was salvaged, saving considerable manufacturing time and expense in this process.

Another instrument that makes use of ultrasonic mechanical waves is the *Sonigage*, developed by the General Motors Corporation. Several other firms have been licensed to manufacture this instrument under various trade names. The instrument used at Westinghouse is made by Sperry Products, Inc., under the name of Reflectogage. This instrument was developed primarily for measuring thickness where only one side of the object is available; for example, in measuring the wall thickness of hollow propeller blades.

In the application of the Reflectogage a mechanical wave of continually varying frequency is transmitted through the material by means of a piezoelectric quartz crystal. When a thin material is set in vibration by a mechanical wave, the opposite faces are set in motion. By continually varying the frequency, the wavelength of the vibrations generated in the material is continually changed, since the wavelength in any given material is inversely proportional to the frequency. Each time the half wavelength reaches a value such that the thickness of the



The defect (indicated by arrow) at this point was about one inch long and over three inches below the surface of the flange.

Fig. 5

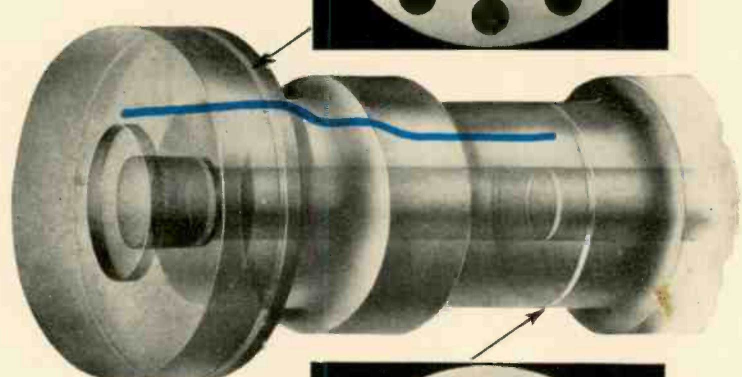


Fig. 6

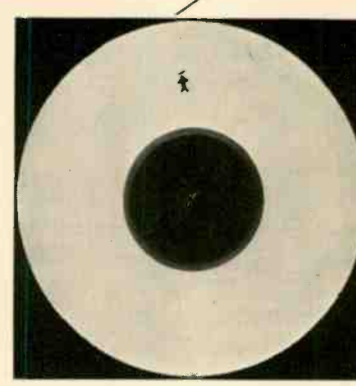
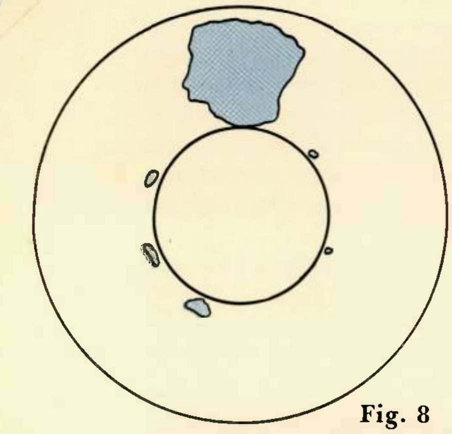
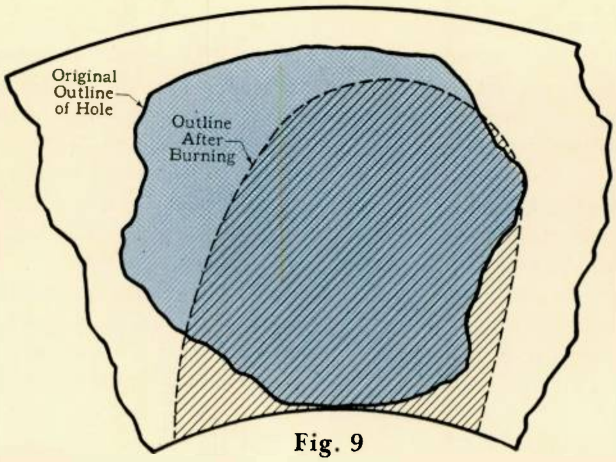
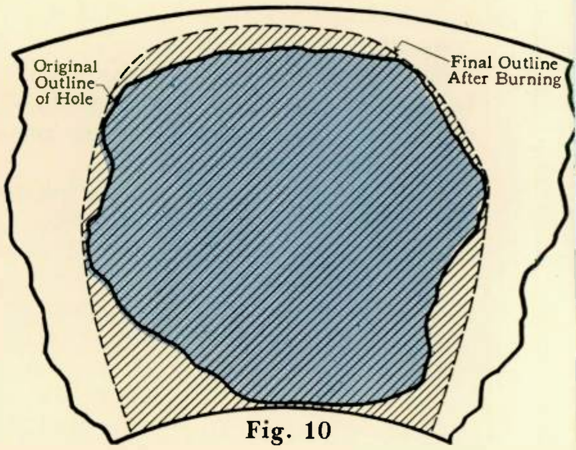


Fig. 7

The section at this point showed that the defect was still present, but had diminished in length to about one-sixteenth inch.







Several defects were found in this cast-steel thrust collar (left). The center drawing shows the defect and the first area burned out.

All the defect was not eliminated so more material was removed. The drawing at the right shows the final outline after all burning.

material becomes an integral multiple of it, a sharp increase in the amplitude of the mechanical vibration occurs. This condition, known as resonance, causes an increase in vacuum-tube plate potential, and, through the electronic circuits incorporated in the equipment, causes a peak to appear on the screen of the instrument at the location representing the frequency at which resonance occurs. Because the relationship between the velocity of sound (which is constant for any given material), the wavelength, and the frequency of vibration is fixed, the thickness of the material can be determined by calculating the wavelength at the frequency indicated by the peak on the screen.

Although the Reflectogage was developed primarily for the measurement of thickness, Westinghouse engineers use it for detecting defects or discontinuities in materials. This is possible because, in effect, a defect decreases the effective thickness of the object.

This instrument is also used to check the bonds in brazed joints by measuring the thickness at the location of the bond. Thus, in checking the bond between two one-eighth inch strips, if there is an indication at one-fourth inch, the bond is good. If, however, the indication is at one-eighth inch, the bond is not satisfactory.

A defective piece detected by the Reflectogage appears in Fig. 11. These were coil-retaining wedges from turbogenerators. The material in these wedges was a special wartime substitution utilized at the request of the customer when the material customarily used was not available. Although these generators were intended for short-life wartime service, some are still in use. When a few of these installations were dismantled some wedges were found to be cracked. Since there were other installations having the same type of wedges, it was necessary to determine whether any of these wedges had cracked. Only the top surface is available for inspection, since the other surfaces are covered. These installations were the main generators of ships. Because it is a very expensive operation to tie up a ship and remove the generator for examination, a rapid method of inspection that could be performed on shipboard was desirable. With the Reflectogage, engineers were able to detect very readily the presence of cracks in these wedges.

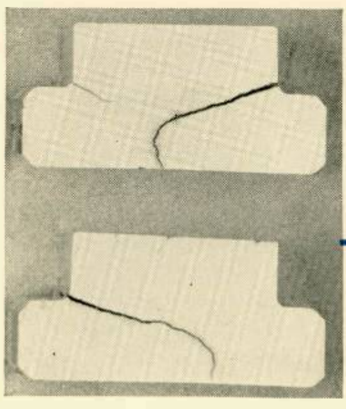


Fig. 11

Defective coil-retaining wedges detected by the Reflectogage. Cracks shown were not visible on the surface available for inspection.

The crystal was applied to the top surface, which was along the outside diameter of the rotor, and the thickness of the wedges measured. If an indication corresponding to the known thickness was obtained, the wedge was not defective. If, however, any other thickness measurement was obtained, it was obviously caused by some defect in the material. In this manner it was possible to determine the quality of the wedges in a minimum length of time with a minimum of dismantling costs.

Summarizing, nondestructive tests for the detection of flaws may be grouped into four classes:

1—*Radiographic tests*, which will detect internal flaws in sections up to nine inches thick.

2—*Magnetic tests*, used for the detection of surface defects and those up to one-eighth inch below the surface in magnetic materials.

3—*Fluorescent-penetrant tests*, for detection of defects open to the surface in nonmagnetic as well as magnetic materials.

4—*Ultrasonic tests*, for the detection of defects located from 0.025 inch to 30 feet below the surface.

Of these tests, all may be applied to both metallic and nonmetallic materials except the magnetic tests, which are restricted to magnetic materials.

Each method has limitations, and there are places where none are applicable. Frequently, however, they aid a design engineer considerably in lowering his safety, or ignorance, factors so that he may use to greater advantage and with greater safety the materials provided by metallurgists. As already noted, no one has ever made a "perfect" piece of metal. All materials are more or less imperfect and it follows that these methods, which reveal more of the true nature and extent of imperfection, permit the safer application of commercially available materials.

These methods further permit utilization of objects that might otherwise be rejected, as in the case of the thrust collar, and prevent usage of others that might be put into service without knowledge of any defect, as in the case of the generator rotor with the internal flaw.

Radiation Hazards—Atomic-Age Problem

If our senses gave warning of all hazards, the work of the industrial hygiene engineer would be much simpler. But they don't. Radiations from radioactive materials are unseen, unheard, and unfelt, and are thus extremely dangerous. Large-scale activity in the atomic-energy field has necessitated more rigid protection measures for personnel. Only by careful observance of these precautions can the radiation danger to personnel be eliminated.

H. W. SPEICHER, *Industrial Hygiene Engineer, Westinghouse Electric Corporation, East Pittsburgh, Pennsylvania*

LONG before the first deadly mushroom spread across the sky, near Alamogordo, New Mexico, atomic-bomb scientists were faced with serious operational problems and tremendous responsibilities. Among the more difficult of these was the question of health hazards from radiation. Although not strictly a new problem, it was one that never before had required such widespread precautions. Similar difficulties now confront industry, as the peacetime uses of radioactive materials become more widespread. The problem is one that requires painstaking care, minute precautions, and constant watchfulness, but it certainly is not impossible of solution. As a matter of fact it may someday be classified in the same category as protection against such potentially dangerous things as electricity, flammable liquids, or toxic materials, all of which are now handled with a great deal of respect but little fear of the danger involved.

Radiation from radioactive elements and compounds is admittedly dangerous. Some of this energy, a result of atomic disintegrations, is very penetrating, and materials that receive such radiations undergo a structural change. This is especially true of living matter.

Fundamental Concepts and Units of Radiation

A fundamental postulate relating to the action of these radiations in matter states: Only energy that is absorbed can be effective in producing a reaction. For example, gamma rays, which are somewhat similar to x-rays but more penetrating, pass entirely through the body except for the few stopped by collision with atoms in the body tissue. These collisions cause the radiation to be absorbed. The first result of the radiation's impact on a cell is the production of secondary radiation in the form of fast-moving electrons. These electrons, in turn, ionize atoms in their paths. The ionized atom is temporarily in an abnormal condition, and while in this state enters readily into new combinations. The ionization of the individual atom lasts only briefly, but if enough atoms are ionized simultaneously, a large enough percentage of the cell constituents may undergo transformation to produce a structural change. In this manner collisions cause destruction of tissue and injury to internal organs.

Radiations are emitted either as light quanta in the form of x-rays and gamma rays; as charged particles like alpha particles, electrons (beta rays), and positrons; or as neutral particles like fast or slow neutrons. These radiations are similar in that they produce ionization in living matter or tissue that they penetrate.

X- and gamma rays have long been measured in terms of roentgens, or in smaller units one thousandth as large called milliroentgens (mr). The roentgen is defined as the quantity of x- or gamma radiation such that the associated corpuscular emission per 0.001293 gram of air produces, in air, ions carrying one esu of electricity of either sign. This quantity really refers with physical exactness to the "quantity of ionization" produced in air by secondary electrons resulting from the photoelectric effect, the Compton effect, and pair production. The photoelectric effect is the interaction of a gamma- or x-ray photon with the atom as a whole, resulting in the emission of an atomic electron. In the Compton effect the gamma- or x-ray photon collides with an atomic electron, which is ejected from the atom. Pair production is the conversion of the x- or gamma-ray photon into two electrons, one positive and the other negative.

When tissue ionization is produced by any primary radiation other than photons of gamma or x-rays, the quantity is not expressed in roentgens. Radiation doses received from beta rays, protons, alpha rays, and neutrons are measured in reps (roentgen equivalent physical units). The rep is that amount of ionizing radiation that causes one gram of air or tissue to absorb 83 ergs of energy. Therefore one rep equals 83 ergs per gram of tissue. This amount of energy is also equal to 10^8 beta rays having an average energy of 0.52 mev (million electron volts).

The intensity of transmitted x-rays through a lead glass window being measured by a beta-gamma meter. A wrist film holder and a pencil electrometer (in coat pocket) give an indication of radiation exposure.

Another useful unit is the rem (roentgen equivalent man or mammal), which is the amount of radiation that produces the same biological damage as one roentgen of gamma or x-rays. The roentgen is defined only in terms of x- or gamma radiation, i.e., for photon energy; since all types of radiation are dealt with in atomic-energy plants, other units became necessary and the rem and the rep were established.

Permissible Levels of Radiation

In 1936 the American Advisory Committee on X-rays and Radium set the maximum permissible level of radiation at 100 mr per day for x- and gamma radiation. Recent chronic experiments have indicated that this level definitely should be considered as a maximum permissible level of radiation exposure. A person exposed continuously to this rate will experience a certain amount of biological and genetic changes, but animal experiments and limited observations on man do not indicate that this level of radiation will produce pathological changes. The Chalk River atomic-energy project in Canada recently chose half the American permissible dose, or 50 mr per day, as their maximum permissible radiation level. An American scientist, as a result of animal experiments, suggested in November, 1946 that the maximum permissible dose for women who intend to be exposed to radiation for many years should be limited to 0.02 roentgen (20 mr) per eight-hour day. He also indicated that the total accumulated lifetime exposure should not exceed 100 roentgens for females and 1000 roentgens for males.

Animal experimentation and mathematical calculations indicate that there might be a small but significant shortening of the expected life of persons exposed to the present tolerance doses of radiation. When populations of laboratory animals are exposed daily, throughout their lives, to varying amounts of external whole-body radiation, they show a marked reduction in their average lengths of life.* This reduction is proportional to the dosage over a considerable range. There are, of course, marked differences in the efficiency with which different radiations produce an effect on length of life, neutrons being most effective and gamma rays least. If this animal work can be extrapolated to a long-lived species, like man, on the

*"Influence of Radiation Exposure on Length of Life of Laboratory Animals," R. D. Boche. Paper read in Chicago at the 49th Annual Meeting of the American Roentgen Ray Society, September 10, 1948.

A "hot" radioactive material being pulled into a lead coffin. Radiation measurements are made during this operation to prevent overexposure of personnel. (Courtesy of Oak Ridge National Lab.)

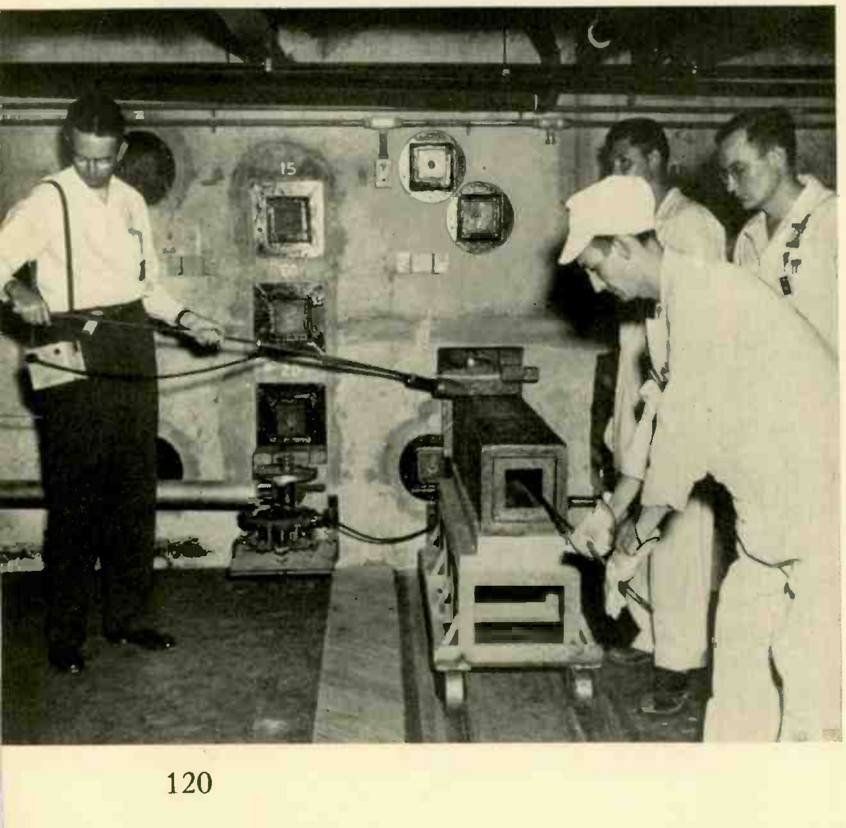


TABLE I—MAXIMUM PERMISSIBLE RADIATION EXPOSURES (PLUTONIUM PROJECTS)

Type of Radiation	mr/day	mrep/day	mrem/day
X-Ray	100	100	100
Gamma	100	100	100
Beta		100	100
Fast Neutron		20	100
Thermal Neutron		50	100
Alpha (Internal effects only)		10	100

assumption that the percentage reductions are similar, then the reduction of life expectancy in years would be appreciable. This comparison indicates that a person's life might be shortened as many as three years if his exposure started at age 30 and continued at 0.1 roentgen per day, five days per week for the rest of his life.

From the beginning of the Plutonium Projects, health physicists have been conservative and applied a safety factor of ten. They have considered 100 mr per day as a maximum permissible dose of x- or gamma radiation, but the permissible operating dose has been taken as about 10 mr per day. Maximum permissible doses for all types of radiation are shown in table I. A recent analysis of radiation-exposure records kept by the Health Physics Personnel Monitoring Section of the Oak Ridge National Laboratory indicates that no employee is averaging more than 10 mr per day from radioactive materials.

Some radiations are much more damaging than others due to the variation in specific ionization (the amount of ionization in one centimeter of material). In fact, the maximum permissible doses vary approximately inversely as the cube root of the specific ionization in air. An alpha-radiating substance will probably produce no damage on the hands, but inside the body it is about ten times as hazardous as an equivalent amount of a beta- or gamma-emitting substance. When any radioactive material is swallowed or inhaled, the alpha, beta, or gamma radiation is emitted within the body. This emission can result in serious injury to the more sensitive parts of the body, such as the blood-forming tissues. Even though the internally deposited quantities are minute, they are in contact with live tissue and therefore their destructive activity is a maximum, since the distance from radioactive material to tissue is a minimum or zero.

However, all life on this planet is subjected to continuous bombardment by cosmic rays from outer space, where nature's atomic machines are operating, and to bombardment from natural radioactive substances (of which there are approximately 50 radioactive isotopes) in the earth's surface and in the human body. These natural radioactive isotopes are accumulated through the air we breathe and the food we eat, and are continually blasting our living body cells during their period of existence. This radiation is about one fiftieth of the permissible operating dose of 10 mr per day, thus its effect is not permanently damaging.

Radiation damage is not measured by the fact that it destroys some of our body cells, but by the harm that results when the cells are destroyed at a greater rate than they are repaired; when sufficient radiation is received to disturb normal body function and development; or when heredity effects on our children and grandchildren become readily perceptible.

Radiation Safeguards

Since exposure to radiation should not exceed certain limits various safeguards are necessary. The best protection is to plan carefully the work with radioactive materials, and to make proper use of shielding, remote control devices, and adequately ventilated hoods. However, two characteristics of radiation injury combine to make protection against it difficult. First, the amount of energy necessary to injure or kill biological tissues is very small; thus our physical senses do not perform the same protective role that they do in guarding us from heat burn, mechanical injury, or injury from ultraviolet radiation. As yet, our senses have not been developed sufficiently to warn us of the presence of ionizing radiation in the air, or the presence of radioactive materials in the body.

Secondly, the damaging effects of radiation often are not evident for some time, and irreparable damage may occur from single or repeated exposures before obvious signs occur.

In planning the best radiation protection, three fundamental factors must be considered. The first is distance. Man should stay as far away from radioactive sources as is practical. One of the best methods is to use long-handled tongs, levers, periscopes, and control rods for manipulating active sources or beakers containing radioactive solutions.

An important rule to remember when using distance as protection against gamma and x-rays is that radiation intensity varies inversely as the square of the distance from the radiating source; thus if a certain intensity exists at one yard from a source, the intensity at two yards is only one fourth as great.

The second fundamental factor is shielding, which is accomplished by placing an absorbent material between the person and the radioactive source (see table II). Shielding is used where more convenient or economical than distance. Because of their great density, lead and concrete are commonly used as protection against gamma or x-rays. Absorption of this photon radiation behaves in general according to the familiar exponential equation $I = I_0 e^{-\mu x}$, where I is the transmitted intensity after passing through x thickness of absorbing material, I_0 is the initial intensity, and μ is the linear-absorption coefficient. Reduction of these radiations by materials is thus an exponential type of absorption.

Contrary to what might be expected, lead is not a satisfactory neutron shield. Instead, water and paraffin are two of the best shields because they contain large percentages of light hydrogen atoms, which are much better absorbers of neutron energy than heavier atoms.

Beta radiation is usually less penetrating than x-rays, gamma rays, or neutrons. Usually a sheet of Micarta, aluminum, Lucite, or glass is adequate protection.

Alpha radiation is much less penetrating than beta radiation. While the most energetic alpha particles are completely absorbed in a few centimeters of air or by a sheet of paper, beta particles describe paths in air several hundred centimeters in length, and traverse layers of aluminum up to a few millimeters thick. However, in passing through successive layers of absorbent material, the total number of particles and the energy of each particle decreases progressively.

The penetration of these radiations is dependent upon their energy. The greater the initial energy, the deeper the penetration into matter. A combination of shielding and distance is usually the best means of radiation protection.

The third fundamental factor for protection against overexposure is time. The time factor is applied in many cases by dividing the radiation exposure over an extended period, or among a number of persons. For example, one person may work with a radioactive material until his maximum permissible dose is received; the time involved may be a matter of seconds, minutes, or hours per day, since exposure is directly proportional to both the intensity of the source and time of exposure. If the operation must be continued for a lengthy period, a change of personnel is made when each person has received his maximum daily permissible dose.

The preceding factors apply to external exposure. Special attention must be paid to applications where radioactive dusts or gases can be inhaled or ingested.

When it is possible for radioactive material to be suspended in the air as a dust or gas, it should be confined in a drybox, a completely sealed box equipped with window lights and rubber gauntlets. Work is performed manually inside the box by inserting the hands in these gloves.

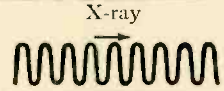
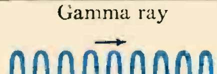
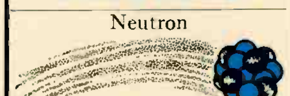
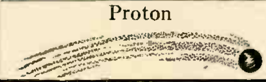
Working areas where radioactive materials are used should be kept scrupulously clean at all times. The handling of radioactive isotopes is comparable to that of pathogenic bacteria—air containing them should not be breathed, food containing them should not be ingested, and all contact with the skin should be avoided. Radioactive solutions should not be pipetted by mouth, and smoking in areas containing radioactive substances should be prohibited. The hands should always be thoroughly washed and checked for contamination before eating, smoking, or leaving the working areas.

Contaminated waste materials must be handled with extreme care. Liquid wastes should be collected in storage tanks and not discharged to the sewer system, for this would create a radiation hazard to plumbers and other persons who could contact this material without warning. Solid wastes must be buried in a properly located and guarded burial ground, or in a cave in a desert region.

The industrial hygiene problems involved in controlling health hazards due to radioactive materials are extremely important and require many more protective personnel than are now needed to control the usual accident hazards of industry. For instance, where two or three safety engineers are now necessary for an industrial population of 5000 persons, 100 to 150 trained personnel are required for safeguarding the same group of workers using radioactive materials.

The problems of radiation protection are obviously involved and complex, but individual and collective security of personnel exposed to radioactivity can be maintained if the problem is fully understood and the proper precautions taken.

TABLE II—RADIATION AND ITS SHIELDING

Type of Radiation	Typical Sources	Common Shielding Materials
X-ray 	X-ray equipment; in hospitals, shoe stores, and in industrial locations	Lead, concrete, leaded glass
Gamma ray 	Radium, other radioactive materials	Lead, concrete, leaded glass
Neutron 	Cyclotrons, atomic piles	Water, paraffin, cadmium
Beta 	Radioactive materials	Micarta, Lucite, glass, aluminum and other metals
Alpha 	Radioactive materials, cyclotrons	Paper, Micarta, metal foil
Positron 	Radioactive materials, high-voltage x-rays	Micarta, Lucite, glass, aluminum and other metals
Proton 	Cyclotrons	Paper, glass, metal

Stories of RESEARCH

What Makes a Weld

WHAT makes one weld stronger than another? Why is it that some metals are much more difficult to weld than others? Exactly what effect do voltage, current, time, and rate of change of temperature have upon the resulting weld? How does the presence of a gas affect the welding process? These and many more questions are being constantly explored by Westinghouse research engineers in a new welding laboratory. As a result of their experiments and those of others, welding is slowly becoming a more precise science.

In tackling problems such as these the first step is to determine the nature of the welding reaction and the factors that contribute to it. These factors are then measured and their effects evaluated. In resistance welding, for example, these parameters include the current applied, the time involved, the force with which the electrodes are held, the design of the electrode, its acceleration, and the nature of the material being welded. Investigating any of these parameters naturally provides valuable information, but simultaneously recording all, or several, would give a much better overall picture of the operation.

New tools are required to measure each of these variables. A device to record the exact position of the electrodes at all times during the welding period is one example. This device must meet several exacting requirements: it must record chronologically the displacement of the electrode simultaneously with the measurement of other factors; it must be extremely sensitive with respect to both velocity and very small displacements; and the transducer, i.e., the device that converts the mechanical motion to electrical variations, must be located in the strong magnetic field of the welding current and yet be unaffected by it.

Of the several types of transducers the only one found that answers all the requirements effectively is the differential transformer. This device consists of three coaxially wound coils, one primary and two secondaries, with a movable magnetic core that varies the coupling between the coils. The two secondaries are identical and are connected so that their voltages are 180 degrees out of phase when the core is centered in the transformer. Thus the net secondary output voltage is zero when the core is centered. Any movement of the core upsets this balance. One voltage becomes greater than the other and a net voltage is registered, its magnitude being proportional to the amount of displacement. The signal from the device can be passed through the proper filters and amplifiers and fed into a recording oscillograph, thus making a continual record of the motion of the electrode. This gives a graphic record of the exact electrode position at any given time in the welding reaction and thus provides a further insight as to precisely what is occurring.

The exact means by which metal transfers from electrode to metal surface in arc welding is another welding reaction being studied in the new research laboratory. In the ideal transfer reaction extremely small metallic particles pass from the electrode to surface. Unfortunately this type of reaction does not take place in every instance. As the electrode is consumed larger globules of the metal melt from the end and fall to the surface of the metal, temporarily short-circuiting the gap and resulting in a less uniform weld. When the arc voltage is raised the welding arc must be longer; thus there is more chance for loss of essential alloying elements through oxidation. Raising the current is another method that helps eliminate these temporary short-circuits, but the final and complete answer for better electrode-to-metal transfer has yet to be found.

These are merely samples of the work now going on and being planned at the new welding research laboratory. The problems yet to be investigated are numerous. The important fact is that through this research may come knowledge that will lead to better methods of welding, a wider field for welding, and better tools and material for the welder.

Toward Better Air Cleaning

Here J. S. Lagarias of the Westinghouse Research Laboratories inspects one of the collectors of an experimental electrostatic precipitator designed by H. E. Dyche, Jr. These models are built on the same principle as their larger commercial version, the Precipitron. The object of experimentation with these portable units is to study the exact effectiveness of the electrostatic dust collector in precipitating and retaining different types of dust particles. Laboratory tests with this unit determine how much dirt can be collected before particles begin to overload the collector, what adhesives can be used on the collecting surfaces to increase efficiency, and also show the distribution and structure of the deposit. This experimentation is aimed at improving the performance of the already remarkably efficient Precipitron.

Porosity Plus

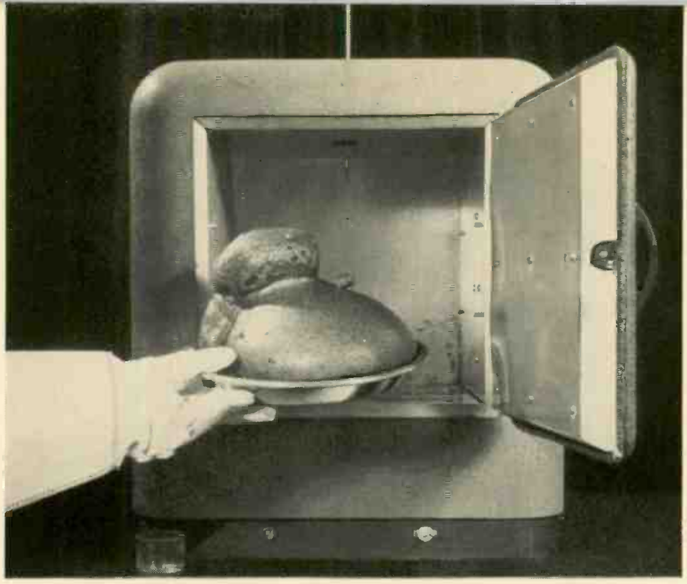
SCIENTISTS at the Westinghouse Research Laboratories recently held a seance. Or so it would have appeared to the casual visitor. For perched on nothingness—seemingly hanging in air in a glass tank—was a dark brown solid wrapped in cellophane. A visitor with a suspicious nature might have looked surreptitiously for hidden wires—but none were there. The material was actually floating on a gas—Freon 113, a common refrigerant. Even with this explanation the phenomenon might still seem implausible—a solid floating on a gas? But this was no sleight-of-hand trick, it was a demonstration of the amazing lightness of a new foamed phenolic resin developed by Westinghouse scientists. Weighing less than 0.6 pound per cubic foot, its density is really in the realm of gases rather than solids. It is only about five times as heavy as air. As a further comparison, balsa wood is about twelve times as heavy as the foamed resin, and charcoal over twenty. Even the fluffy meringue on pie is about fifteen times as heavy.

The phenolic resin ingredients are mixed, preparatory to baking.

If the visitor had stayed to watch Robert Sterling, the material's chief developer, prepare a sample of the substance he would have been in for an even more startling demonstration. Sterling places a small aluminum container, its bottom barely covered with the dark liquid resin, in a high-temperature oven. After a few minutes, at 180 degrees C, a large piece of porous material—over a hundred times the volume of the liquid—is removed from the oven. Under the high temperature the phenolic resin changes into solids and gases, and the pressure of the gases causes the tremendous expansion. When the maximum expansion is reached further heating results in permanent hardening.

The potentialities of this new foamed resin stir the imagination. The most obvious one would be as a low-temperature insulation. Dead-air space is one of the best thermal insulating mediums known to man, and the thousands of tiny air pockets in this resin would make it an excellent insulating material. Its thermal conductivity compares favorably with other top-grade insulating materials, but in its extremely low density it is in a class by itself. And it would have even greater advantages. Most insulating materials present difficulties in shipping because of their relative fragility and their large space consumption. The new foamed resin would have neither of these limitations; shipped as a liquid, one gallon of the resin could be expanded "in place" at the installation site to a slab two inches thick and ten by ten feet square.

Application of this foamed resin could be extended to almost any low-temperature insulation requirement. It could conceivably be used in refrigerators, refrigerated railway cars, beverage coolers, or as insulating material for ships or prefabricated houses. In some of these uses rigidity requirements might necessitate a heavier density to provide greater strength. But even at double the weight, which would probably not be required, this material would still be lighter than other insulating materials. Density can



After baking, the foamed resin has expanded 100 times in volume.

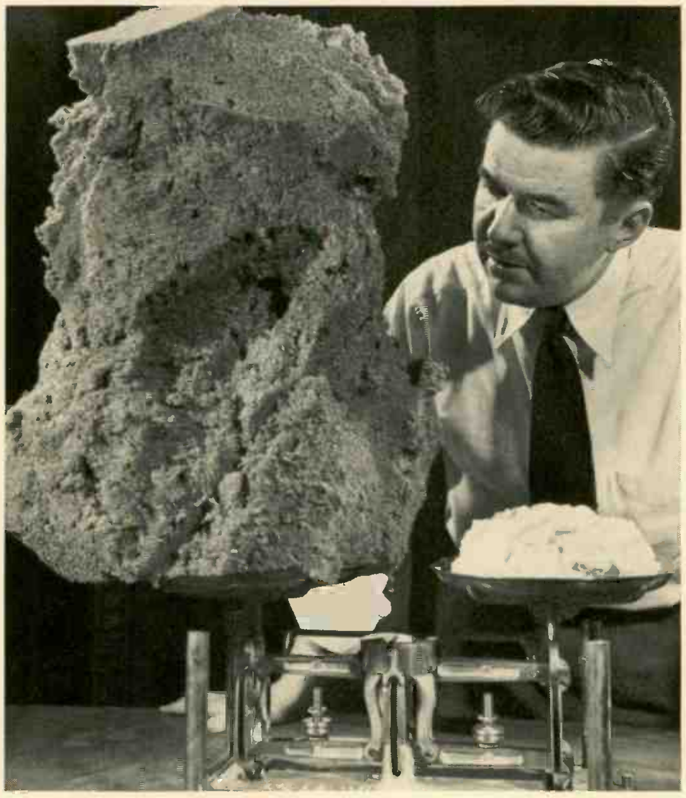
be changed by varying temperature conditions and the composition of the resin.

At first glance this light, fluffy material would seem to be too fragile for many insulating uses. But its very lightness seems to provide one of the reasons why it is not easily damaged. Because of this extremely light weight it has a very low inertia and therefore does not damage easily under shock or acceleration.

Other properties of this foamed resin make it particularly suitable for insulation. It is resistant to moisture absorption and settling. As it foams into a closed area it "wets" the sides of the container and bonds with them. Furthermore it spreads itself uniformly and completely within the area since it is still liquid during expansion.

Insulation is but one possibility for this new resin. Research men are certain that such a material—one of the lightest solids known to man—will have many other uses. As yet it is still in experimental stages—among other things research men are determining its properties at various densities. But when it reaches the commercial stage, its possibilities may surpass even the expectations of its chief developer, Robert Sterling. They seem limited only by the imagination.

Even fluffy meringue is far heavier than the new foamed resin.



Lightning Strokes Prefer Tall Structures

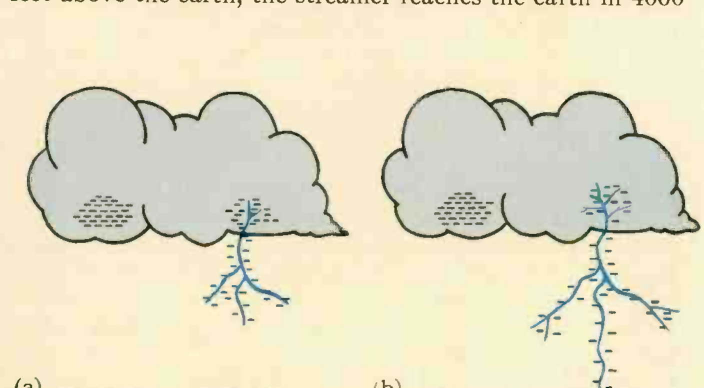
The lightning rod, oldest of electric devices, was in use almost a couple of centuries before its principles were understood. Now not only its action but also the mechanism of lightning—the birth, growth, and decline of a lightning stroke—can be set forth in the simplest terms. The requirements of a good lightning shield and the extent of protection it provides can be rather exactly predicted.

Edward Beck, *Manager, Lightning Arrester Engineering, Westinghouse Electric Corporation, East Pittsburgh, Pa.*

The attraction for lightning possessed by tall structures that extend above their surroundings is well known. In fact it was observed more than two thousand years ago. That smaller objects within a certain volume adjacent to such a structure are unlikely to be struck is also well known. The protection of one object by another has become known as shielding. What is the explanation of this phenomenon and over what region will a shielding structure protect?

The explanation is made manifest by the accepted theory of the formation of a lightning stroke between cloud and earth.[1] As a result of certain processes that occur during thunderstorms, electric charges are accumulated in clouds or parts of clouds. These charges have their counterparts in equal and opposite charges in the earth beneath. As the charges grow, the potential between cloud and earth increases. This potential is not distributed uniformly. In the formation of strokes to open country or to moderately high objects of, say, 600 feet or less, the potential gradient is most intense in the vicinity of the charged volume in the cloud. When the gradient, which is expressed in volts per centimeter or inch, exceeds the dielectric strength of the short length of air across which it appears, the intervening air breaks down and a streamer starts from the cloud toward the earth. This streamer, or pilot leader as it is sometimes called, carries charge with it. Thus the potential gradient ahead of its tip is high and further breakdown of the air ahead of it occurs. The leader proceeds toward the earth in jerks, at the same time charging the embryo stroke channel. The current in the streamer is not high, probably below a hundred amperes. Its average velocity of propagation is relatively slow, about one half a foot per microsecond, i. e., a hundred miles per second. (The velocity of propagation of electricity in a wire is almost one thousand feet per microsecond.) From a cloud two thousand feet above the earth, the streamer reaches the earth in 4000

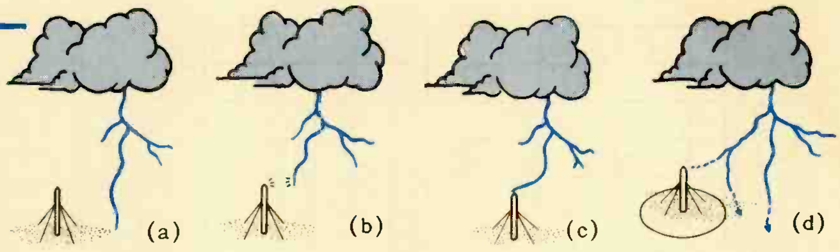
Figure 1



A lightning discharge in "slow motion." In (a) the charge centers in the cloud are shown. The pilot streamer and stepped leader start earthward. The outward branching of streamers to earth lowers the charge into the space beneath the cloud. In (b) the process begun in (a) is almost completed and the pilot streamer is about to strike earth. The heavy return streamer is indicated in (c), the negatively charged space beneath the cloud now being discharged to earth. One charged cloud center is fully discharged in (d) and streamers between charged centers within the cloud start to develop. As the cloud charge centers neutralize in (e) a dart leader is propagated to ground along the original channel. Finally in (f) a return streamer is created, discharging to earth the negatively charged space under the cloud, completing the stroke.

Figure 2

The effect of a mast on a lightning stroke. In (a) the stroke leader is sufficient distance from the mast as to be unaffected by it, whereas in (b) the leader approaches the top of the mast. A strong field appears between mast and leader, causing the top of the leader to be drawn to the mast, in (c). In (d) appears the shielded area. Strokes always terminate either to the mast or outside this area.



microseconds or four thousandths of a second, the equivalent of one-quarter cycle of 60-cycle current.

When the tip of the leader comes close to the earth the electric field becomes intense and eventually a short upward streamer rises from the earth to meet the descending pilot leader. As they meet, contact is finally made with the earth, or some object connected with the earth.

Establishment of this contact is like closing a switch between the two opposite charges, one charge residing partly in the stroke channel and partly still in the cloud, and the other charge in the earth. It is now that the high currents associated with lightning flow. A high impulse current first flows to neutralize the charge in the stroke channel. This may then turn into a moderate current of longer duration than the first peak to exhaust whatever charge remains in the cloud. The process of stroke formation is illustrated stepwise in Fig. 1 and a generalized curve of stroke current in Fig. 3.

As the potential in the charge center, from which the stroke started, falls, other adjacent charge centers in the same cloud may discharge into it and down the same channel, thereby producing successive current peaks. Such strokes are called multiple or repetitive strokes. They occur frequently, and sometimes the rapidly repeating flashes can be seen with the unaided eye.

Consideration of the formation of lightning strokes makes it apparent why tall projections from the earth's surface are struck more often and why there is, around such a projection, a region seldom struck. In Fig. 2 (a) is shown a pilot leader approaching the earth at some distance from a high conducting projection, such as a tower. The leader is not cognizant of the tower, and contacts the ground. Fig. 2(b), the leader's path is close enough to the top of the tower that the electric field between the tower and the leader's tip becomes sufficiently intense to draw a streamer from the tower toward the leader. Contact is made as in Fig. 2(c), and the stroke current passes through the tower. In this wise the tall tower draws to itself leaders that without the tower would have gone to earth in its vicinity.

It is now also apparent that because of the attraction of the tower for leaders that pass within its reach, there is a region, Fig. 2(d), surrounding the tower where strokes are highly improbable. Either a leader contacts the ground at some distance from the tower or approaches sufficiently close to the tower to contact it.

Strictly speaking, an object is not protected absolutely from all strokes unless it is surrounded by a conducting and grounded shield. However, the probability of an object being struck can be reduced to a small figure by proper arrangement of masts, rods, or wires. A shield configuration is considered good if it will allow only one stroke in a thousand to reach the protected object. This is called 0.1 percent exposure. Roughly speaking, for a single mast or rod, the exposure is 0.1 percent within a cone whose apex is at the top of the mast and whose surface makes an angle of 30 degrees with the vertical. As a rule of thumb the cone of protection has a base whose diameter is equal to the height of the mast.

The exact exposure for a given configuration depends on several factors, such as the height of the cloud above the earth, the height of the shielding mast or rod, and probably on the charge at the tip of the leader. The parameters of various degrees of protection have been established by theory, observation, and laboratory tests on models.[2]

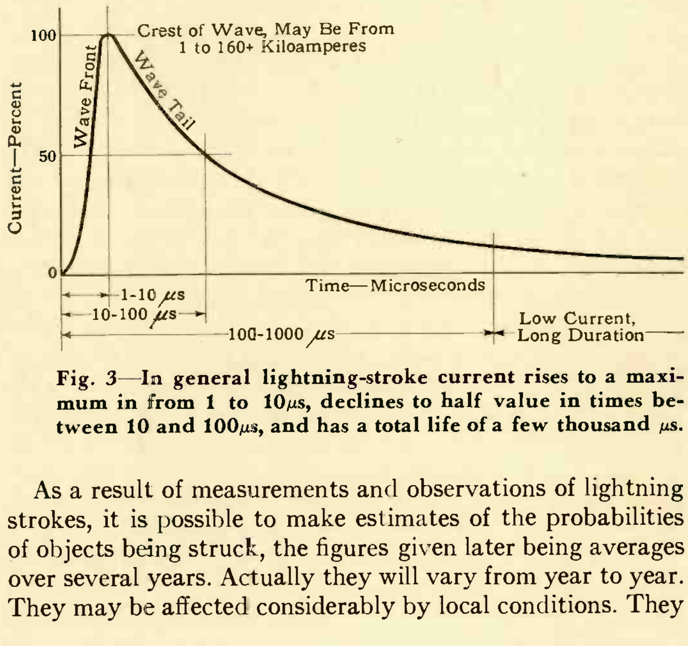
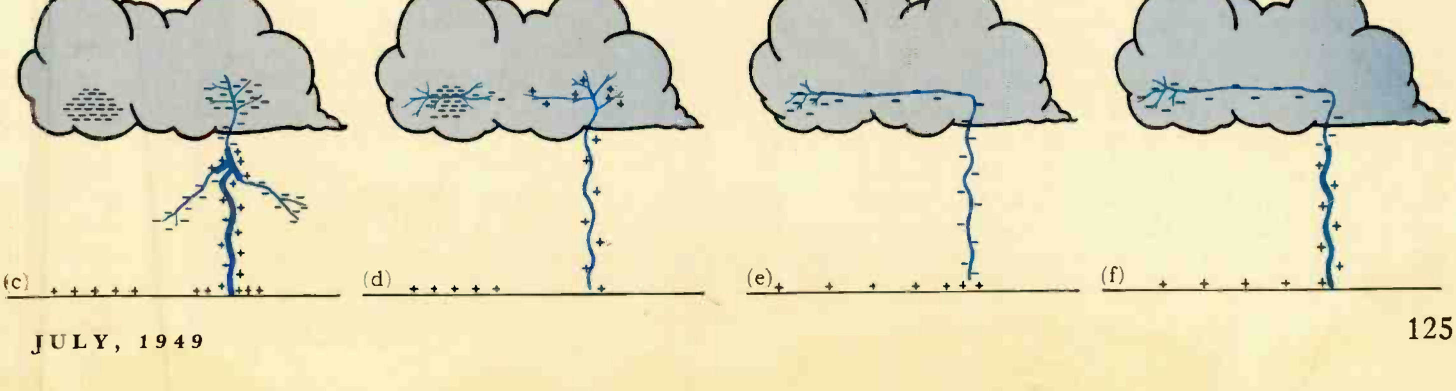


Fig. 3—In general lightning-stroke current rises to a maximum in from 1 to 10μs, declines to half value in times between 10 and 100μs, and has a total life of a few thousand μs.

As a result of measurements and observations of lightning strokes, it is possible to make estimates of the probabilities of objects being struck, the figures given later being averages over several years. Actually they will vary from year to year. They may be affected considerably by local conditions. They



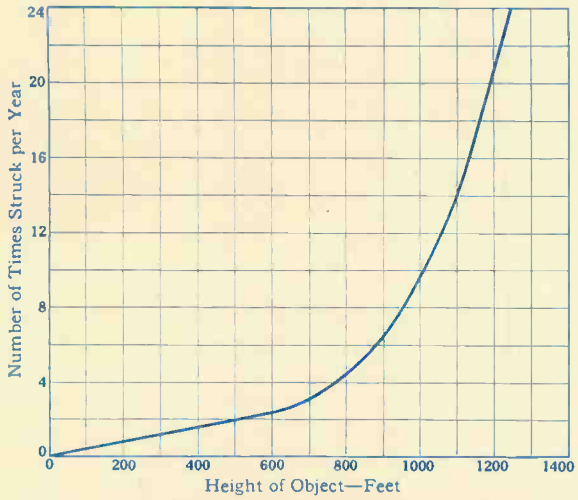


Fig. 4—The number of times per year that isolated objects of various heights are struck in level terrain in a region of 30 storms per year.

are based on a storm frequency or isokeraunic level of 30 thunderstorm days per year. The isokeraunic level varies throughout the country.

Isokeraunic maps have been published by the U. S. Weather Bureau.[1,5] These maps average, over a considerable period of years, the observed number of days on which thunder was noted. Although they do not give direct information on the number or severity of strokes that occur, they are useful in estimating the probabilities of objects being struck, because it may be assumed that these probabilities vary with the isokeraunic level.

The frequency with which isolated masts or towers are struck varies directly with their height above ground or surrounding objects, up to heights of about 600 feet[3], Fig. 4. Above that height the probabilities increase faster, because, in the case of a very high structure, the field at its tip becomes so intense as the charge in the cloud and the earth are built up that the pilot streamer starts upward from the structure instead of downward from the cloud. This promotes strokes to such high structures even more actively.

Masts up to about 600 feet in height, in an isokeraunic level of 30, are likely to be struck once a year for every 275 feet of height. Thus, an isolated mast or chimney 150 feet high, located in level terrain in the region of New York City where the level is 30, is likely to be struck about once in two years. If located near Jacksonville, Florida, where the isokeraunic level is about 80, it would probably be struck about one and a half times per year or three times in two years.

Some estimate, also, can be made of the probable frequency with which buildings of known roof area and elevation may be struck, assuming they are located in level terrain and isolated from structures of comparable or greater height, although the data available is not as definite as for masts. By weighing the data for masts, the statistical data on strokes to transmission systems or overhead ground wires, and the probabilities of strokes to open country, it seems reasonable to conclude that a building 100 feet square and 30 feet high will be struck on the average about once in 10 or 15 years. Within certain limits, the chances of being struck vary with its height but not in the same ratio as its area. For example, a tall building is considered as a mast. Thus a building 200 by 100 feet and 60 feet high may be struck four times as often or once in two and a half to four years. It should be remembered that nearby structures or adjacent hills may reduce the exposure. On the other hand, a building on a hill top or a hill side may have an increased exposure.

As the familiar lightning rod amply demonstrates, buildings can be shielded from lightning. To protect a building effectively, three requirements must be met. The shield must be so placed as to intercept strokes; the shield must be a good conductor connected to earth and adequately insulated from conducting bodies that are to be protected; and the termination of the conductor in the earth must make good contact with the earth.

Considering these requirements, not all buildings need additional protection. Whether or not they do depends on the construction. An all-metal building or one with a well-grounded, substantial metal roof is not damaged if struck, because the lightning current has a good conducting path to ground. Tall, steel-reinforced buildings are struck frequently without the occupants being aware of it, except perhaps for the crash of the thunder. Such a building or any substantial metal enclosure, for example, an automobile, is a safe refuge during a thunderstorm when it is separated from ground by only the distance between the tire rim and earth. A wood or masonry building, however, may be damaged if struck by lightning, and protection is necessary if damage is to be prevented. In the case of a wood or masonry building with a metal roof, the owner should avoid the mistake made by the farmer who equipped his barn with a copper roof but failed to ground it. The outcome of this was unpleasant.

Power-station or substation structures, although often of steel, are frequently provided with direct-stroke protection. This is not done to protect the structure, but to avoid risk of severe direct strokes into the line conductors adjacent to the apparatus in the station.

For any particular building, the probabilities of being struck may be low, but considering a number of buildings, such as several substations on a power system or a group of farm buildings, the chances that some building may be struck is appreciable. Whether to shield or not is usually a question of economics and sometimes of sentiment. It may be considered more economical to run the risk of damage. In others the risk to human or animal life may make protection mandatory, or the sentimental attachment to such things as old trees or buildings may make it desirable.

Buildings can be shielded in various ways. Suppose, for example, a building 100 feet square and 30 feet high, with a probability of receiving a direct stroke once every 10 years. Based on the data given in reference no. 2, exposure of 0.1 percent for the building can be obtained with a single mast in the center of the roof, projecting 55 feet above the roof. The mast, rising 85 feet above ground, may be struck 0.31 times a year or once every three years, but the building itself would be struck only once in 3200 years. Other configurations can be used to obtain the same exposure, such as a greater number of short masts or rods properly disposed around the building, or one or more horizontal overhead grounded wires.

There is evidence that the shielded area between two masts or rods is greater than the sum of the shielded area of each.[4] Walter concludes that two masts of equal height may be separated by a distance equal to five times the height of one of the masts and still provide effective shielding in the band between them. The Wagner, McCann, and Lear data indicates that even wider spacings give effective protection under certain conditions of heights of shield and shielded objects. The increase in shielding afforded by several masts, or rods, is considerable and possibly has not been realized generally.

The conducting connection of the shield to the earth must

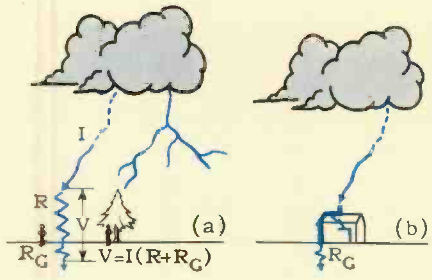


Fig. 5—Lightning stroke to a tree (a) and the equivalent circuit, and a stroke to a house (b).

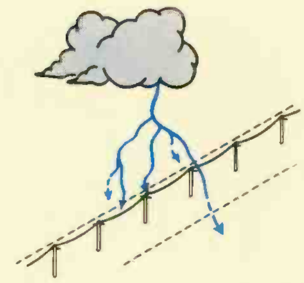


Fig. 6—A horizontal conductor, supported above earth on poles, gives a zone of protection against lightning

be good, to prevent secondary flashes from the struck shield because of voltage drops produced by impedance to the lightning current. Suppose the tall structure in question is a poorly conducting masonry chimney or a tree, as in Fig. 5(a). The tree attracts the pilot leader; it is a good lightning interceptor but an unreliable shield. When the tree is struck, lightning current flows in a high resistance, as indicated in the equivalent circuit. If the lightning current is large, high voltages occur. Hence a man standing under the tree may be the recipient of a side flash. For this reason, trees, particularly isolated ones, are dangerous things under which to take shelter during a thunderstorm. The same applies to masonry chimneys not provided with well-grounded lightning rods. Under a chimney, one not only runs the risk of being a spark terminal but also of being struck by falling bricks knocked loose by the effects of the energy produced in accordance with Ohm's law. Like most tall chimneys, valuable trees such as those planted by George Washington at Mount Vernon are protected by wires run up the trunks to provide a good conducting path should the tree be struck.

Similar unhappy results may occur with poorly grounded lightning rods or masts. Lightning current flowing in a high contact resistance between the grounding electrode and earth creates a voltage drop, so that the shielding conductor may be raised many thousand volts above true earth potential. In Fig. 5(b) is shown a house with a lightning rod. The resistance of

A demonstration with man-made lightning shows that an automobile is safe refuge in a storm. Note the arc from metal tire rim to ground.

the earth connection is high. If the rod is struck, a spark may jump from the rod to some nearby grounded object in the house, such as a water or gas pipe or to the electric wiring. This occasionally happens, as manifested by flashes in rooms, the stripping of shingles from roofs, or plaster from walls, or similar occurrences. Poorly grounded lightning rods may be a hazard rather than a safeguard. One of the principal reasons why lightning rods were in disrepute for some years is that in many cases little attention was given to careful grounding. Lightning rods can be very effective if the teachings of Benjamin Franklin, augmented by the later experimental data that was denied him, are observed.

Methods and instruments for measuring the resistance of the ground termination are available, and it is wise to use them because the resistance of a ground cannot be determined by looking at it. How low should the resistance be? The lower the better; one ohm is better than many. In some soils it is easy to secure low ground resistance, in others it may be extremely difficult[5].

In the case of long, circuitous conductors the rapid rate of rise of lightning current may produce voltage as a result of inductance. The inductance of a straight wire of usual cross section is about 0.4 microhenry per foot. A lightning current rising at the rate of 10 000 amperes per microsecond—a high but not improbable value—will produce 4000 volts per foot of wire as long as the current is rising at the aforementioned rate. In a 50-foot length of wire this amounts to 200 000 volts, sufficient to bridge a foot or so of air to an adjacent grounded conductor. Lightning conductors should therefore be as straight and direct as possible.

Side flashes and consequential damage as a result of bad grounds or long leads are not inevitable, because lightning currents vary in intensity. Many strokes contact trees or masonry or poorly grounded lightning rods without causing damage. However, the purpose of protection is to insure against the widest range of practical possibilities.

The opinion is sometimes advanced that lightning has a penchant for jumping from conductors at sharp bends, because of the "inertia." This is erroneous. If it jumps from a sharp bend to some other object it is probable that the path from the bend along the lightning conductor to ground is long, and therefore has appreciable inductance, or there is resistance somewhere in the path, so that a high voltage exists momentarily, sufficient to spark to something in the vicinity of the bend. The clearance to other objects is probably least at the bend, for that may well be the reason for making the bend. Lightning current is an electric current, and doubtless many of the reported miraculous occurrences could be explained by the application of the laws of electro-physics if all evidence and facts could be ascertained. That is usually difficult to achieve because lightning damage has much in common with an automobile accident, as far as evidence and recollection are concerned.

The considerations pertaining to tall structures and their shielding influence apply also to overhead wires. Suppose a

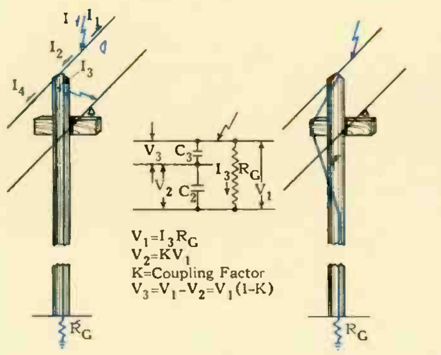


Fig. 7—The overhead ground wire and its equivalent circuit. It indicates the effect of ground resistance, voltage in line wire produced by coupling, potential between line and ground wires, possibilities of flashovers, and means of increasing clearance to avoid flashovers.

horizontal conductor be supported on poles, Fig. 6. The wire, like the mast, will attract leaders that approach within its sphere of influence. Since such a wire may extend for miles, the probabilities of its being struck become appreciable. Statistical data indicates that transmission systems, meaning the line conductors or their overhead ground wires if present, are struck on the average of once per mile per year, if located in isokeraunic levels of 30. If the wire has no direct metallic connection to the earth, the lightning current will produce very high voltage, and flashover to ground will probably occur. If the wire is grounded at intervals and well, high voltage is prevented. The wire acts like a continuous lightning rod.

Such a grounded wire also provides a protected zone paralleling the conductor. Another wire within this "tent like" volume is not likely to be struck directly. This is the principle of the overhead ground wire widely used over transmission lines.[6] The shielding angle to assure 0.1-percent exposure is 30 to 45 degrees, depending upon the height above ground. The matter of secondary flashes from a struck ground wire system to the line conductors is an important consideration.

A simple arrangement on a wood pole of one line conductor with an overhead ground wire is suggested in Fig. 7. In (a) the down lead that connects the ground wire to earth is attached to the pole. It is assumed that the ground resistance is high. When the ground wire is struck, currents are as indicated. The current in the down lead and into the earth causes a voltage drop in the ground connection, thereby raising the potential of the ground-wire system above true ground. The line conductor is held at a potential, which is near ground, by its capacity to ground. It picks up voltage from the struck ground wire by coupling. The coupling factor may be 30 to 40 percent. The difference in potential between the ground wire and the line conductor may thus become high, and if the clearance between the down conductor and the line is small, or if the pole is metal and the insulator is small, a flashover occurs from the ground-wire system to the line conductor. This is just as bad as a direct hit on the line conductor with a flash to ground, because either may cause a short circuit. Furthermore, a backflash from the ground wire to the line injects current and high voltage into the line, which may unnecessarily endanger other insulation. Ground resistance and clearances are important considerations in the design and construction of lines with overhead ground wires. Sometimes special measures are necessary to obtain reasonable ground resistances, and sometimes it may also be necessary to offset the down leads so that adequate clearances are secured, as in the right hand view of Fig. 7.

The foregoing is an elementary description of the factors that enter into the arrangement of a simple combination of line and overhead ground wires. The design of lightning-proof transmission lines is not as simple as discussed here,[7] but the basic principles upon which modern power-line design rests are those mentioned.

Overhead ground wires can be used effectively for the shielding of buildings and other structures. In fact, for some types of buildings they are more economical than a multiplicity of rods.

Whether or not a transmission system has overhead groundwire protection, it is subjected to lightning voltages if located in regions where there is lightning. If it is without ground wires, it may be struck directly or it may experience voltages by induction from nearby strokes. If it has ground wires, it may still pick up voltage from the ground wire by coupling, or from a backflash from the ground wire. Such voltages will be impressed on apparatus connected to the system. To safeguard it against lightning damage it is necessary to provide some means of limiting the voltages that can appear at the apparatus to values that the apparatus insulation can withstand. This is the function of the arrester.

REFERENCES

1. "Lightning Phenomena," by Wagner and McCann, *Electrical Engineering*, August, September, and October, 1941.

2. "Shielding of Substations," by Wagner, McCann, and Lear, Trans. AIEE, Vol. 61, 1942, p. 96.

3. "The Measurement of Lightning Currents in Direct Strokes," by McCann, Trans. AIEE, Vol. 63, 1944, p. 1157.

4. "Ueber Blitzschutz durch Fernblitzableiter" (Concerning Lightning Protection by Means of Remote Lightning Diverters), by B. Walter, Zeitschrift fuer techische Physik, Vol. 14, 1933, p. 118.

5. "Code for Protection Against Lightning," U. S. Bureau of Standards Handbook H-40.

6. "Shielding of Transmission Lines," by Wagner, McCann, and MacLane, Trans. AIEE, Vol. 60, 1941, p. 313.

7. "Transmission Line Design and Performance," by Harder and Clayton, AIEE paper 49-111, not yet published.

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Personality Profiles

P. R. Lee is the kind of individual who makes a thorough investigation of everything he puts his hand to. As a result, he knows thermostats inside and out—and also his family background.

Lee, an amateur genealogist, has traced his family back through 3½ centuries. Not all of his findings are creditable, he admits, for he has uncovered "some scoundrels" in the Lee family tree. Because he is of Norwegian descent, Lee's genealogy is particularly difficult to trace. Oddly, in Norway, a man acquires the name of the land he buys, or of his wife if she is the oldest daughter.

Lee, normally an enthusiastic, animated conversationalist, becomes more so when discussing genealogy or thermostats. The latter has been his principal field of endeavor since he graduated in 1927 from the University of Minnesota with a degree in electrical engineering. Lee joined Westinghouse immediately after leaving college. For 2½ years he worked on electric appliances and cooking equipments, which gave him a strong appreciation of the importance of thermostats in modern living. In 1930, he joined the thermostat section, first as a sales engineer and later as a designer. In 1946, he became manager of thermostat engineering.

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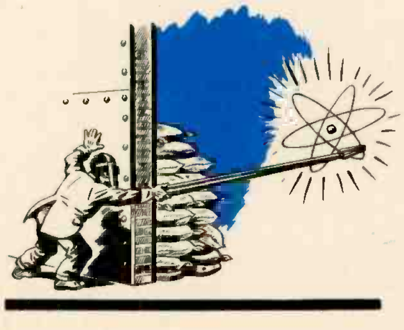
H. W. Speicher is a member of that small corps of men who constantly labor behind the scenes to make their industries healthy places to work—the industrial hygiene engineers. Like all good engineers he is



constantly looking ahead to foresee the health hazards that will come into being with new industries. Realizing that, while atomic energy is as yet in its infancy, radiation may before long present a widespread hazard to industrial workers, he has prepared himself for that eventuality by considerable study of the problems involved, including a year's training in the Health Physics Department at Oak Ridge. But Speicher's prime interest has not always been industrial hygiene. For the first eight years after his graduation from Juniata College with a B.S. in Chemistry, he taught this subject and physics in a Pennsylvania high school. During this period he acquired an M.A. in Physics at Ohio State. In 1938 he joined Westinghouse as an assistant hygiene engineer. In the ensuing eleven years Speicher has built up a fund of information on the various problems encountered in the relatively new field of industrial hygiene; recently he was appointed the head of the Industrial Hygiene Laboratory. Despite this interest, he still presides over a regular class at the Westinghouse Technical Night School.

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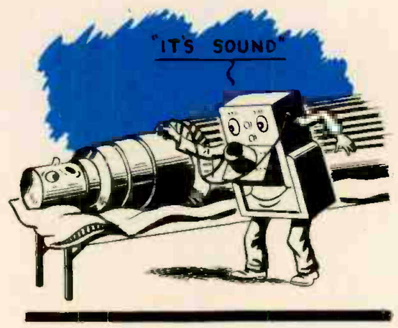
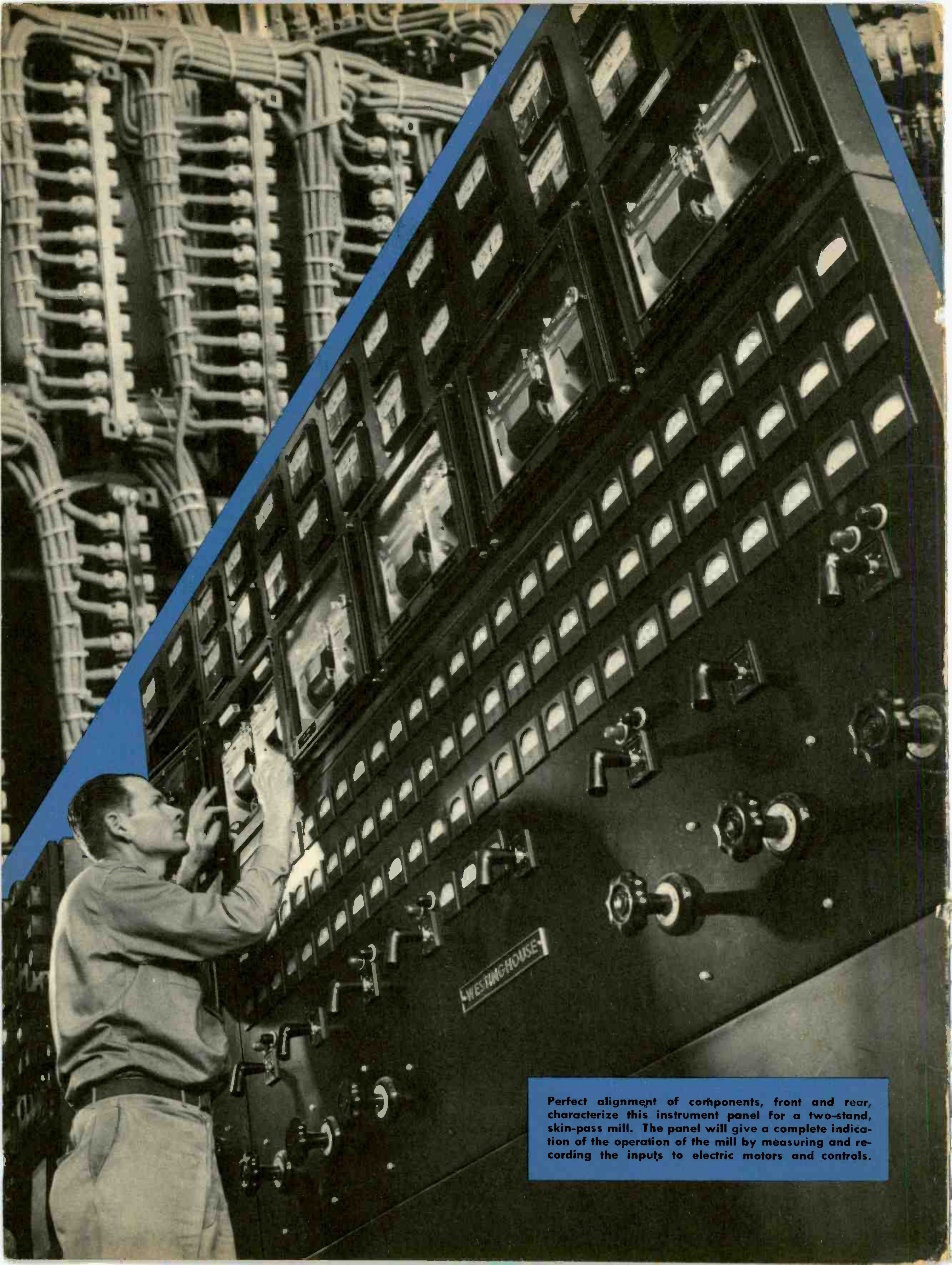


Most metallurgists have at one time or another been bothered by the fact that they had no good way of testing large castings for flaws. *Donald M. Kelman* did something about it by developing new applications for ultrasonic testing. Kelman became a metallurgical engineer by virtue of a B.S. in M.E. from the Polytechnic Institute of Brooklyn in 1940 and postgraduate work in metallurgy at the same institution and at the University of Pittsburgh. His education plus eight years of industrial experience as a metallurgist have given him an excellent background for his present position in the Materials Engineering Department, where he spends most of his time on forging and allied problems. Kelman was one of the first to develop applications for ultrasonic flaw-testing techniques. He has found many interesting uses for this equipment, and has even used it—with some success—on the human body, where it detects bone or other solids.

• • •

As to *Edward Beck*, the author of the lightning-protection article, we'll be hanged if we'll give the guy any more space on this page. To date he has appeared in so many issues that we've about lost track. There were: February and November, 1942; November, 1943; March and November, 1944; and May, 1949.

So for those of you who don't know about Beck (and you must be new readers), we refer you to our last issue for details on his interesting career.



Perfect alignment of components, front and rear, characterize this instrument panel for a two-stand, skin-pass mill. The panel will give a complete indication of the operation of the mill by measuring and recording the inputs to electric motors and controls.