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VOL. 7 NO. 4

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A Nonarmored Submarine Telegraph Cable

C. S. LAWTON and L. H. HUTCHINS, JR.

AT THREE-THIRTY o'clock on the morning of October 3, 1951, the cable ship *Lord Kelvin* completed the final splice between an armored and an unarmored deep-sea cable. Two hours later, a radio message was received that #2 HM-CN, the cable circuit into which had been spliced a new type of ocean cable, was restored to service. This message signalled the successful conclusion of a development program begun three years before by The Western Union Telegraph Company and the Simplex Wire and Cable Company. It proved that, in favorable weather, a light unsheathed cable can be joined to the end of a cable having conventional steel-wire sheathing which has been raised from the depths, and then be lowered to the floor of the ocean more than one thousand fathoms below. Time alone now can prove whether or not such an unconventional cable can endure in an environment which has been a friendly one for the thousands of miles of cable already there.

The idea of omitting the steel armor wires of deep-sea cables has been in the minds of ocean-cable engineers for a good many years. Necessarily, a cable must be of such construction mechanically that it can be laid on the ocean bottom in sound condition. But once there, a cable lying in the silt of which the ocean floor is composed at depths of the order of one thousand fathoms is subject, under normal conditions, to virtually no physical disturbance, and hence may be presumed to require no extraordinary mechanical protection. It is only the physical stresses imposed on cable during the laying and repairing processes which have made it necessary to include a heavy, expensive steel sheathing in the construction of deep-sea cables. Therefore, engineers have reasoned, cable companies pay a sizeable proportion of their deep-water-cable costs solely to put cables on the bottom, not to keep them there. One logical approach, then, to the ever-present problem of reducing cable costs is quite conceivably to be found in the omission of the sheathing. Unfortunately, however, the lack of appropriate materials hitherto has made it impossible to reconcile essential physical and electrical requirements in such a way as to construct a practical, economical cable.

A submarine telegraph cable for deep-water service must have several diverse properties, as follows:

1. It must have sufficient tensile strength to support the dead weight in sea water of the length of cable between the ocean bottom and the laying ship, plus the live load caused by the vertical movement of the ship on the ocean swell, at depths that vary from ½ or less to 2½ nautical miles, and sometimes more, as the laying operation proceeds. The necessary relation between the strength of the cable and its weight in sea water is expressed as the "cable modulus", which is defined as the ratio of the breaking strength of the cable to the weight in sea water of a nautical mile of the cable. The value of this modulus thus represents the length of cable in nautical miles which, when suspended vertically in sea water, is self-supporting. The required minimum value for modulus will vary with the maximum depth in which a cable is laid. The safety factor will be given by dividing the modulus by the depth.

2. It must possess sufficient radial compressive strength to transfer the load represented by the weight of cable below the ship onto the drum and sheave over which it is payed out, without mechanical failure or permanent distortion of its component parts. That property which is the measure of ability to resist such forces is commonly called, when applied to a single material, the modulus of compression. For a composite structure like an armored cable, however, the usual definition of modulus is not applicable, and consequently such an attribute has never been quantitatively

A paper presented before the Winter General Meeting of the American Institute of Electrical Engineers in New York, N. Y., January 1953.

assigned thereto. For the relatively simple structure of a nonarmored cable, the value of modulus possessed by the outer covering is of great importance, and must be considered, since the entire tensile load is being carried by the central member of the cable.

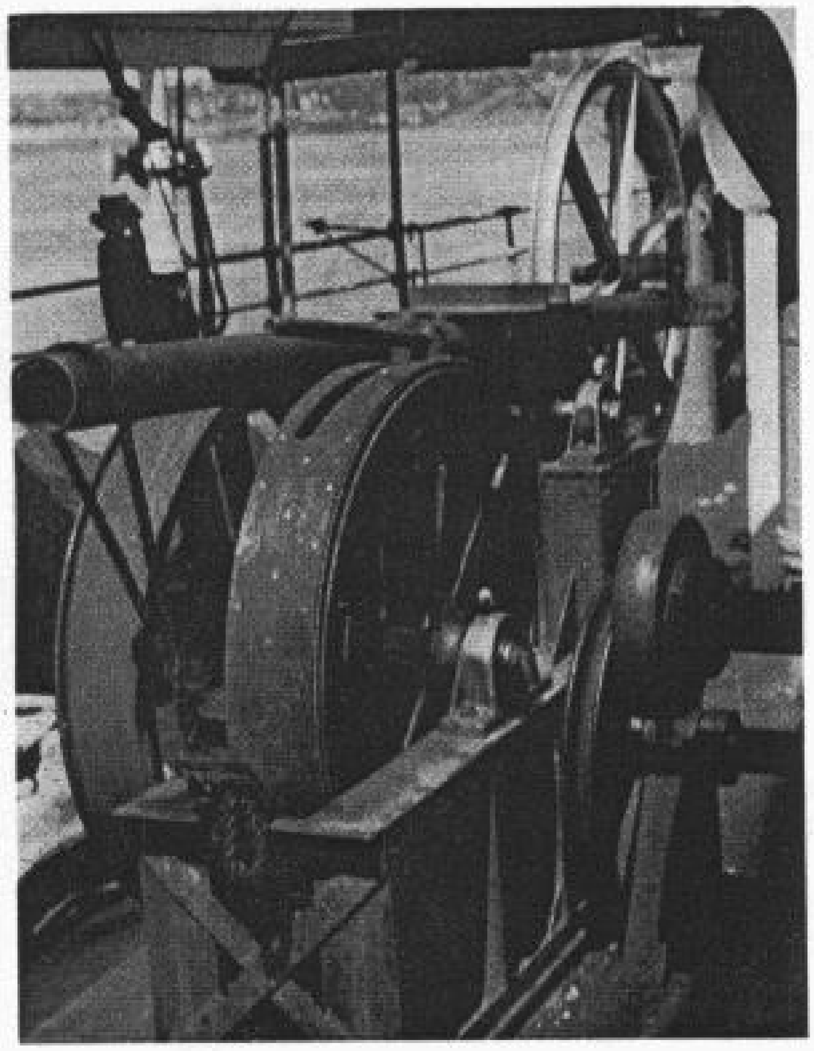
3. It must be of such construction mechanically that sudden changes of tension thereon do not produce distortions such as kinking and knuckling. The former is evidenced by the formation of small loops along the cable as a result of severe twisting about itself, and the latter by the ejection of the conductor from the insulating envelope as a result of the formation of a sharp bend in the conductor. Both of these phenomena result in cable failure; a bad kink will usually cause the conductor to part when tension is regained, and a knuckle ruptures the insulation immediately to produce a fault to ground.

4. It must provide all the electrical properties to its operation as a transmission line for telegraphic communication. The "speed of signalling" of a telegraph cable, i.e., the maximum rate at which character impulses can be transmitted with sufficient intelligibility, depends primarily upon the capacitance of the insulation and the resistance of the conductor. It is the product of these two parameters that is known as the "time constant" of an electrical circuit, and, in earlier days, when applied to cables, was called the "KR Law", which stated simply that the signalling speed was inversely proportional to the product of d-c resistance and inductive capacitance. So propounded, it neglected skin effect, inductance, and conductance, which, at the frequencies of transmission then employed, was a good enough approximation; and, as a matter of fact, still is. Therefore, any appreciable length of cable spliced into an existing line must possess a unit RC value no greater than that of the line, if it is not to slow down the cable circuit as a whole; i.e., produce a decrease in the signalling speed employed.

   The insulating material of a cable also possesses an electrical parameter that has no effect on signalling speed unless its value is so small as to cause the conductance, ordinarily insignificant, to become large—dielectric resistance. It is, nonetheless, a very important property, for it is used as a measure of insulation quality throughout the life of a cable. The first warning of deterioration and impending failure of the dielectric is usually given by abnormal behavior of the galvanometer in the measurement of electrification current. Such a condition can be discovered, moreover, long before it affects transmission.

5. Once laid, it must be inert in the sea water in which it is immersed. The insulating material surrounding the conductor must deteriorate neither physically nor electrically at a rate rapid enough to interfere with successful operation within a period of time that, in the ocean-cable art, is counted in decades. In deep water, a cable life of more than fifty years is not uncommon. Physical instability, insofar as it has no direct effect on the electrical characteristics and does not act to change them, can be tolerated, but only to a limited extent. For example, if a cable loses its mechanical virtues so rapidly that it cannot be raised to the surface within a reasonable time after being laid, repairs are difficult to make and a fault could result in expensive replacement. Electrical instability can, on the other hand, under no condition be tolerated, for so long as it exists the cable is an operational liability. If resistance and/or capacitance increase with time, compensatory changes must be made in terminal networks and amplifiers, which can become expensive. When they become impossible, replacement of the cable is the only alternative which will ensure continuance of reliable communication.

It is apparent from a study of these requirements that the omission of the steel wires from the outside of a deep-water cable presents some interesting mechanical problems. First, it is these wires that give the cable its effective tensile strength, for they are of high-carbon, relatively low-elongation steel. The conductor, the only other metallic member, is of soft-drawn, high-elongation copper, and therefore contributes substantially nothing thereto. Hence the task of supporting the weight of the cable in suspension falls entirely on the steel. Second, since these wires constitute a helical sheath that completely encloses the core (which is the term applied to the insulated conductor), they serve efficiently as a protective barrier against radial forces. Hence they furnish the cable with the radial compres-



Paying-out gear; brake drum on right, cable drum on left, dynamometer sheave in background

sive strength essential to its laying. The sheathing also poses a minor electrical problem, for, being metallic, the wires help to conduct the earth-return currents and thereby influence the form of the sea-return path. Thus not only circuit resistance, but inductance as well, is affected by their presence. A cable without this steel armor, then, must be so designed that all these problems are solved with practicality and economy; and it was the commercial production of two recently-developed materials that made it possible to do so.

One obvious means of eliminating the outer sheathing wires is to combine as many of their functions as possible with that of the central conductor, and thereby cause the conducting member to serve also as the strength member. The complete cable need only consist, then, of an inner metallic material and an outer insulating material, provided both of them, individually and cooperatively, possess the characteristics imposed by the demands of the service.

With the entire responsibility for supplying the tensile strength of the cable falling on the conductor, the mechanical arrangement of the elements thereof must be given careful consideration. The simplest structure is of course a single solid wire, but unfortunately it is not a practical one. The possibility of flaws, although remote, to be sure, with the present high development of the art of drawing and heat treatment, must nevertheless be considered. Also, since joints between coil lengths of bare wire could not be made by welding or brazing, because the high temperatures necessary would change the physical characteristics, and a mechanical-type joint cannot be insulated by an extrusion machine, an excessive number of finished-cable splices would be necessary.

With a solid wire ruled out by reason of mechanical limitations, it becomes necessary to design a conductor made up of several strand elements, and so disposed that the tensile strength of the total area of conducting material is most efficiently realized, with respect to its weight. The most common method of stranding is to spiral six wires, or strands, around a central one, all being of equal diameter. Such a construction, however, is very liable to place a disproportionately large share of the total load on the center strand, by reason of its position within the structure, and result in a reduction of ultimate strength by as much as two-sevenths of the available total. A stretched or ruptured center strand would cost one-seventh, and a brazed surrounding strand another seventh, assuming they occurred at the same cross-section, which is quite possible. Adequate spacing of brazes in the individual strands during fabrication would have to be specified, else the conductor could be further weakened to the point of inutility.

Suppose, instead, the conductor is arranged as an annulus of n strands of uniform cross-section in a single layer. With this configuration, each strand is subjected to the same forces as every other strand, and the minimum strength developed can be no less than $(n\text{-}1)/n$ fractional part of the possible total, and this at a point where a single-strand joint occurs. The final detail of the mechanical design then becomes the determination of a practical value for n, not a difficult decision to make. An annulus of ten wires was decided on, on the basis of:

1. Feasibility of manufacture, in that appropriate machines were available for the stranding operation.
2. Adequacy of numbers, for it was essential that a sufficient number of strands be present to cause a reasonable reduction of the total available tensile strength at points of strand brazes.
3. Ease of splicing, because there would not be so many strands that complete-conductor (or finished-cable) splices would be exceptionally difficult to make.

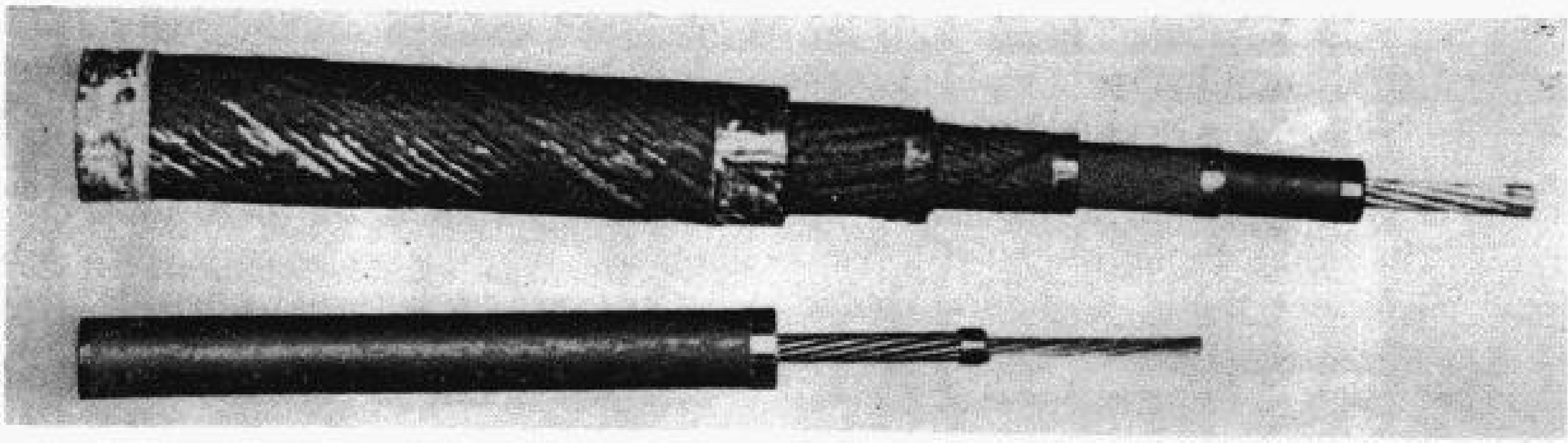
With a fundamental configuration decided on, the next step in the design of the nonarmored cable was to make a complete electromechanical analysis of all the parameters of the conductor and dielectric affecting the performance of the cable. Once those were established, it was only necessary to decide on the values of speed and modulus that were considered essential for the cable to possess.

A speed constant was selected comparable to that of existing transatlantic telegraph cables 0.7 ohm-mfd per nautical mile of cable length. In the selection of the value of modulus, however, present practice could not be used as a criterion. The modulus of armored cables usually runs above 7 nautical miles, not because they are designed to be laid in such extreme depths, but because the armor wires, being exposed to the ravages of the salt water, corrode in the course of time and consequently lose their strength. Therefore, if a ship is to be able to raise the cable to the surface several years after it is laid, within its normal life span, in order to repair a fault, allowance must be made for this diminution in modulus by making it larger than necessary when new. A nonarmored cable, on the other hand, has its strength member within the insulating sheath, completely protected from the action of the sea. Hence no loss in modulus need be designed for, and the initial value can be as small as is adequate to provide for a reasonable factor of safety during laying and/or recovery. Since deep-sea cables are rarely laid in depths exceeding 2½ nautical miles in the north Atlantic, that value appeared to be a safe maximum to use for the dead weight. More or less arbitrarily, a figure of two for the combined live weight and safety factor was selected, producing a value of five for the modulus.

The one remaining problem, now, in the complete design of the unarmored cable is the determination of the proper materials for the conductor and dielectric. The material selected for the conductor was cadmium-copper, 1 percent by weight cadmium and 99 percent copper, having a tensile strength of 90,000 pounds per square inch, a conductivity of 80 percent IACS, and a specific gravity of 8.89 based on pure water. Not only does cadmium-copper (also called cadmium-bronze) possess a remarkable combination of strength and conductivity, but it also possesses another extremely useful property — high fatigue resistance — which imparts to it exceptional torsional strength, or the ability to withstand considerable twisting and bending without failure.

The essential properties of the insulating material are its specific gravity and dielectric constant. Actually, not much choice is presented in the selection of a suitable insulator, for only one material, polyethylene, is currently available that makes it possible to construct a cable that is at once technically and economically practical. With a specific gravity of 0.925 and a dielectric constant of 2.28, polyethylene meets all other physical and electrical requirements. It has good compressive strength, good abrasion resistance in heavier walls, fair resistance to cold flow compared with other types of submarine insulations, and an exceptionally low rate of water absorption. It possesses an amazingly high resistance constant, high dielectric strength to both d-c and a-c voltages, and low a-c conductance or loss factor, not in themselves of first order importance, but very useful attributes.

To test the new design under service conditions, Western Union decided to construct about 20 miles for insertion in a working cable. Although the cable was designed for transatlantic use, one of their coastwise links was chosen for the test



Comparison of armored and nonarmored cable

because of its easy accessibility, and because a landline fall-back facility was readily available in case of trouble. The first nonarmored cable was manufactured in May of 1950, and had the following construction and constants:

1. 17 nautical miles—type D-485/600 bronze and polyethylene nonarmored deep-sea ocean telegraph cable.
2. Conductor No. 6 AWG (approx.)—ten No. 16 AWG (0.051 inch) Hitenso BB-961 hard cadmium-bronze wires around a polyethylene thread of 0.128-inch diameter, 3.00-inch left-hand lay (preformed and postformed).
3. Wall, 0.180 inch = 0.580 inch insulating diameter polyethylene.
4. Cable modulus = 5.05 nautical miles.
5. Speed constant = 0.69 ohm-mfd per nautical mile of cable length.

The accompanying photograph illustrates the physical comparison between the new cable and a conventional transatlantic-type armored cable embodying standard practices.

TABLE I

	Armored		
	Coast-wise	Trans-atlantic	Non-armored
Diameter, inches	0.90	1.04	0.58
Weight in sea water, lbs. per NM	1,950	2,690	360
Breaking strength, lbs.	17,250	20,400	1,800

Three fundamental problems arose in connection with the proposal to repair breaks in existing cable lines by the insertion of a nonarmored type of cable, as shown by Table I which gives a comparison between typical conventional armored deep-sea telegraph cables and the nonarmored design. The problems were:

1. Handling nonarmored cable with ship's machinery designed for conventional types is like trying to play a trout with gear designed for tuna. The pull necessary to revolve the cable drum with driving gears de-clutched and brakes lifted is 600 or 700 pounds and the usual ship's dynamometer is completely insensitive to tensions below 1,500 pounds. Repair ships like *Lord Kelvin* are equipped to pay out cable over the bow, but the danger of such light cable fouling the ship's propellers (twin screws are standard in cable ships for maneuverability) obviously made it impractical to pay out the nonarmored cable over the bow.
2. The new cable, having a breaking strength far below that of steel-armored cables, does not possess sufficient tensile strength to support, in a depth of water for which it is designed, the weight of such a length of armored cable. Hence, how may this light, relatively weak cable be spliced to the heavier one, and the combination successfully lowered to the ocean floor?
3. The new cable, having a specific gravity in sea water considerably below that of old cable, will sink far more slowly. Hence, at what laying speed will it be necessary for the ship to run, in order not to trail the cable too far behind it?

As a solution of the first problem, a light, easily-portable paying-out machine was constructed and installed aft, together with a more sensitive brake and dynamometer. A paying-out drum of 39 inches diameter, equipped with a fleeting knife, was used. It could have been even smaller. The width of tread was 6 inches, which was ample. A duplicate of this steel casting was mounted on the same shaft to serve as a brake drum, fitted with an external steel band having a molded segmented lining. Water cooling was avoided by the simple expedient of using a brake of ample area to dissipate the heat generated. The brake lining provided a frictional coefficient that remained substantially constant at all speeds, including the static condition. A lever arm was provided for loading the brake with weights. The frictional drag of the cable coming up from the ship's tank through bell-mouths and around roller leads was found to be enough to ensure tightness of the turns on the paying-out drum, and although means were provided for putting additional drag on the cable leading onto the drum, they were not used. From the drum, the cable passed through a dynamometer of conventional cable-ship type, but constructed to a much smaller scale, so as to be correspondingly more sensitive. Leaving the dynamometer, the cable left the ship by way of a stern sheave, also of 39 inches diameter, mounted directly abaft the paying-out gear and overhanging the after rail.

Coming to the second problem, consideration was given to buoying the first splice, but this would have meant leaving slack in the cable when the buoy subsequently was removed and the bight of cable was dropped. While not serious for an experimental job, this would be unacceptable as a regular practice, both transmission-wise and economically. Therefore, it was decided to interpose between the steel-armored and the nonarmored cables two intermediate designs that would make the transition less abrupt by providing a tapering of strength and weight along the section. The first of these was constructed as follows:

1. One-half nautical mile (3,004 feet) — type D-485/600-24/13 cadmium-copper and aluminum-armored deep-sea cable.
   Over finished nonarmored cable apply:
   One 70-pound cutched jute serve, applied wet;
   24 No. 13 BWG (0.095 inch) type 56S-H aluminum-alloy wires (preformed);
   One 17/3 impregnated jute serve.
   Over-all diameter = 0.990 inch.

and then spliced to the second:

2. One and one-half nautical miles (9,131 feet)—type D-250/430/600 copper, steel, and polyethylene nonarmored transition cable.
   Conductor No. 6 AWG (approx.)—One strand, 0.117-inch non-tinned copper; ten strands, 0.051-inch improved plow steel; around, 3.00-inch left-hand lay (preformed and postformed).
   0.180-inch wall = 0.580-inch diameter polyethylene

which was in turn joined to the 485/600 nonarmored cable at the factory prior to shipment. Table II gives a comparison of the four types involved in this experiment.

TABLE II

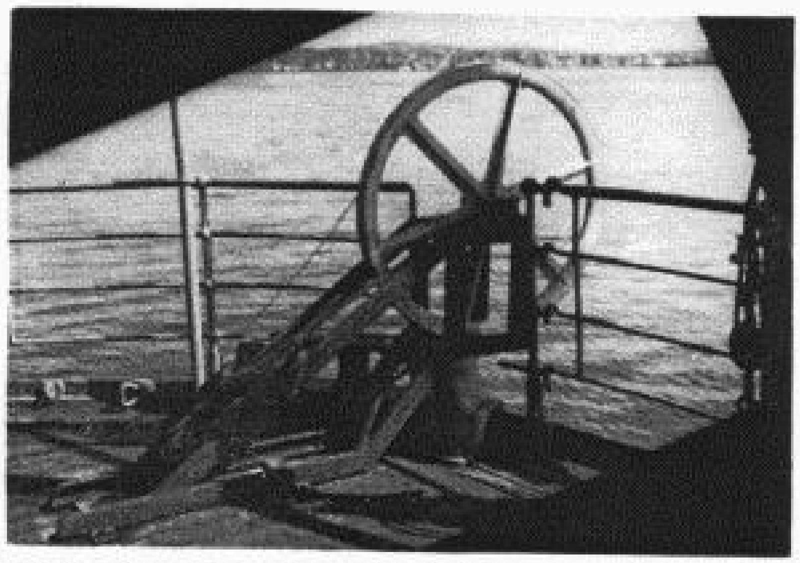
Cable	Breaking Strength	Weight in Sea Water	Modulus
	Lbs.	Lbs./NM	NM
Steel-armored	17,250	1,950	8.8
Aluminum-armored	10,000	1,150	8.7
Copper and Steel	5,000	560	8.9
Cadmium-Bronze	1,820	360	5.0

The moduli between cables become 5.2, 4.3, and 3.2 nautical miles in passing from steel-armored cable through the transitions to the nonarmored cable, which proved to be satisfactory for the initial installation in 1200 fathoms of water.

The solution of the third problem involved first the calculation of the rate at which this new cable would sink into the sea, and second the determination of the relationship between the angle of inclination of the cable with the water surface and the speed of the laying ship. In both cases, only theoretical studies were made, for the equipment necessary for performing the proper experiments was not available. Moreover, precise results were not needed, but merely an idea of the order of magnitudes involved. These calculations showed that pay-out could probably be made at a speed not too much slower than normal, with a reasonable laying angle prevailing.

Echo sounding showed the average depth along the proposed route to be about 1250 fathoms. Sampling indicated soft mud bottom.

In order to make possible the paying-out of the transition pieces over the ship's bow and the nonarmored cable over the stern, special preparations had to be made. These consisted of leading the end of the first transition piece up from the ship's tank, through the after paying-out gear and dynamometer, thence over the stern sheave, and forward around the starboard side of the ship outside everything (even the ship's rigging) and in again through the bow sheave frame. Via this route, both transition pieces and a short length of non-armored cable were transferred to the ship's forward well deck, where they were coiled down. The next step was to reverse the coil in order to bring the end of the first transition piece to top, ready for splicing to the cable in circuit. Meantime, the bight of nonarmored cable was secured along the outside of the ship with rope yarn lashings which could be cut away quickly.



Stern sheave on starboard quarter over which cable was paid out from cable ship

The working cable was hooked, cut, and raised on a grapnel on the east end of the proposed insertion, tested through to Canso, Nova Scotia, suitably prepared for splicing, and temporarily buoyed off. No attempt was made to recover the cable lying on the bottom over the distance within which it was to be replaced, the ship proceeding directly to cut and raise the cable to the westward near the position for splicing on and commencing the pay-out.

The suspended end was brought inboard over the center bow sheave and the starboard picking-up gear and led to the splicing area. After testing through to Hammel, Long Island, the first ship splice (steel-armored to aluminum-armored cable) was made in the conventional manner, by overlapping the steel sheathing with the aluminum sheathing.

The pay-out was begun under a tension of 23 cwts, with the first splice passing over the bow without incident. As more of the aluminum cable went out, tension was gradually decreased so that by the time the splice to the second transition piece went over the bow, the tension was only 16 cwts. From there on, the tension was tapered off until the splice to the regular nonarmored cable went over. As the cable in suspension gradually became lighter, the angle at which it entered the water diminished, bringing the point of entry farther and farther aft along the ship's starboard side. In order to reach the very low tensions required, it was necessary to keep the paying-out drum in gear and drive it with the engine rather than depend upon the brake. Adjustment of tension near the tail end of the aluminum piece was a matter of judgment, as the dynamometer came to rest against its bottom stop before the splice was reached.

As the last of the regular nonarmored cable coiled forward left the deck, the ship was stopped and the cable was held on a manila stopper. The nonarmored cable was lifted off the paying-out drum and dynamometer, and as the stopper rope was eased away the bight passed through the bow-sheave frame. The lashings along the side were cut one by one as tension came on them until, with the cable suspended freely from the stern sheave, the manila stopper rope was cut away and the pay-out was resumed from aft.

Tension was maintained in the region of 420 pounds, which was about 7 percent less than the vertically-suspended weight at a depth of 1250 fathoms in order to avoid residual cable tension on the bottom. A paying-out speed of 4 knots was found to be about the practical limit because the cable was emerging from a small after tank, and the particular lead employed tended to produce some slight whipping. At this speed, the cable entered the water at an angle of approximately 10 degrees with the horizontal. The buoyed east end was reached with about a mile and a half of cable remaining in the tank. The buoy had been set to the westward by the current, so that in picking up the moorings the ship had to move eastward, thus making it necessary to continue paying-out the nonarmored cable. By the time the end of the steel-armored cable had been raised to the bow on the buoy moorings, all but 200 fathoms of the nonarmored cable had been paid out over the stern.

With the cable held on a stopper, the surplus was cut off and the end was then transferred to the bow around the outside of the ship for final testing and splicing. The final splice was made by first serving the last few fathoms of nonarmored cable with cutched jute, then carrying the steel sheathing wires of the armored cable well beyond the core joint. The splice so made was then served over with tarred hemp spun yarn in conventional fashion, the bight was lowered over the bow on manila rope and the latter cut away, thus releasing the bight of cable and completing the laying operation.

At a time when there are so many indications of a genuine resurgence of interest in ocean cables as the oldest and most dependable medium for international communications, anything which may affect their cost, their longevity and ease of repair at great depths is bound to be of real concern to those in the communications field who are aware of the spectacular advances which are now being made in transmission technique.

There is every reason to believe that this cable can be recovered and re-laid without impairment of its strength or coiling properties; and after a test of about three years (it has been in circuit almost 17 months now), assuming it still to be electrically sound, it is planned to do just that, utilizing the opportunity to examine every inch of it for evidence of teredo attack, chafe, and so forth, of course, and relocating it in another area where conditions are known to be none too good.

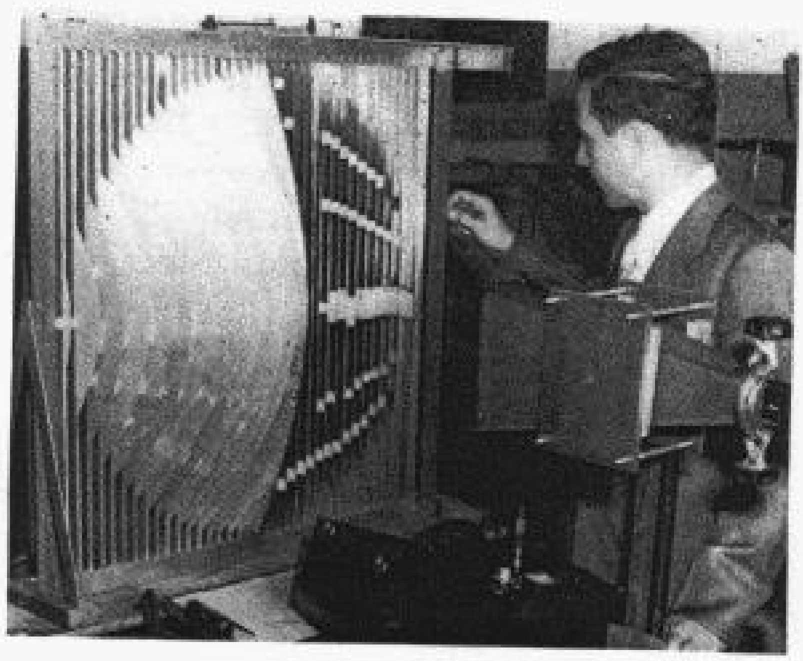
L. H. Hutchins, Jr., Chief Engineer of the Submarine Cable Division of the Simplex Wire & Cable Company, cooperated with Mr. Lawton in the development of the nonarmored submarine telegraph cable. Mr. Hutchins received his degree of Master of Science in Electrical Engineering from the Massachusetts Institute of Technology in 1935. He joined the Simplex Company in 1939 as a Testing Engineer in their Electrical Research Laboratory. While there, he designed and built various types of instruments for the testing of submarine telegraph cables into which field the company was just then entering. In 1941 he was transferred to the Electrical Engineering Department as an Assistant Cable Engineer, assigned to problems in connection with the manufacture of ocean telegraph cables for Western Union, the I. T. and T., and the Alaska Communication System. With the advent of submarine coaxial telephone cables following the war in 1946, he was appointed Project Engineer in which position he took charge of all submarine communications cable engineering activities. Mr. Hutchins is a member of Sigma Xi and AIEE, and a Registered Professional Engineer in the State of Massachusetts.

C. S. Lawton graduated from the University of Michigan in 1919 shortly after receiving his commission as an Ensign in the Naval Reserve. He was with the Federal Shipbuilding Company until March 1922 when he joined our ocean cable plant staff. From 1933 to 1939 he was in charge of the development of the equipment and methods used to plow submarine cable into the bed of the ocean to protect it from fishing trawlers. In 1936 he was appointed Assistant Ocean Cable Engineer and in 1943, as Ocean Cable Engineer, was placed in charge of Western Union's cable ships and depots. On January 1, 1946, coincidently with the establishment of the International Communications Department, he was made General Plant Engineer and as such is responsible for all matters pertaining to the Company's ocean plant and telegraph plant construction and maintenance overseas. He is a member of AIEE.

An Experimental Microwave Lens

The "louvered ventilator" shown here is a small model of a new type radio beam antenna. Since microwaves act similarly to light waves, the energy may be focused by reflectors and lenses. This new type microwave lens developed by Western Union's Radio Research Division is designed so that good focusing may be obtained over an exceptionally broad band of frequencies, making it possible to use the same antenna for several transmitters or receivers.

The lens is composed of thin metallic sheets with Styrofoam blocks to hold the correct spacing. Styrofoam is "transparent" to microwaves and so has no effect on transmission. Construction is simple and tolerances are not very critical as compared with other types of microwave antennas.



A technical paper covering the design and performance of this antenna will appear in a subsequent issue.—C. B. Y.

Wood Preservation

H. A. HAENSELER

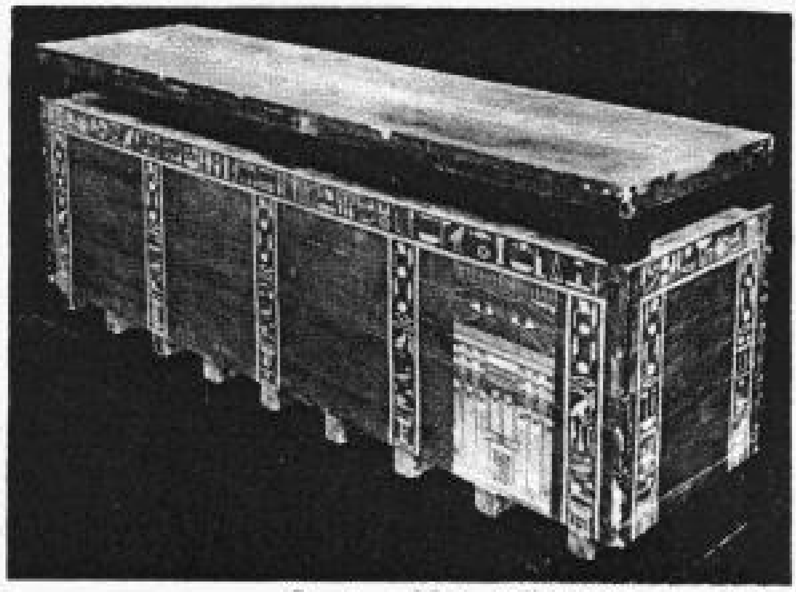
Historical

Wood is one of the most useful materials utilized by man. It is relatively light and strong and is easily worked into various shapes. It forms a part of our houses, garages and fences, our furniture and tools; helps carry communication and power lines, supports the rails of our railway systems, and forms many bridges, trestles and culverts in our highways. The great defect of this material is its lack of resistance to decay and insect attack.

It is not known in what remote age man first became interested in preserving wood from decay, but some profess the belief that it occurred when he ceased his arboreal activities and began to live on the ground in rude shelters supported by stakes or posts. These posts—as is the case even today—would decay first at the ground line and at the top, until some unknown and unsung genius discovered that this decay could be largely prevented by placing the post on a stone and topping it with a shell or stone cap. Our present-day round column, with its base and cap, is considered by some to be a descendant of the wood post of the ancient hut.

While the people who lived during the ancient civilizations undoubtedly were not greatly concerned about decay and insect attack in wood, they nevertheless seem to have had considerable knowledge of means that would prevent decay of organic material. The ancient Egyptians were past masters in the art of preserving the human body and many of their mummies are still in good condition after a lapse of 3000 years. These people used oil of cedar and other aromatic oils to some extent, but their principal reliance for preserving the body seems to have been natron, a native salt, plus pitch or bitumen. They were not interested in preserving wood, however, as their dry climate was not conducive to the rotting of that material.

One Roman historian[1] mentions in his writings that the astringent oil extracted from olives would prevent woodworm and attack on wood, and also refers to methods for extracting oils from cedar and other



Courtesy Metropolitan Museum of Art

Dry wood will not decay. This wood casket remained sound for 3000 years in the dry Egyptian climate

wood species that have natural decay-resisting properties. The famous wood statue of Diana of Ephesus, he quotes, had perforations that were kept saturated with oil, this treatment apparently keeping the statue in good condition although the temple itself was restored seven times. He also speaks of wood immersed in water that remained sound for two hundred years.

There is little information available on wood preservation[2] during the period between the fall of the Roman Empire and the 1800's, but it is known that bichloride of mercury was used in treating timber for insect attack. Probably the first large-scale effort made to find a good wood preservative occurred in England around 1812, at which time she became concerned regarding heavy decay losses in her navy vessels, all of which were of wood. Experiments were made which included "gassing" the ships with antiseptic vapors, but none of the tests seems to have proven successful.

The invention of the steam locomotive caused the greatest progress in wood preservation. Wood was found to be the only material suitable for crossties or sleepers for supporting the rails, and millions of crossties were installed. In England and Europe, where timber was already scarce, successful efforts were made to preserve the ties, and as early as 1938 they were impregnating timber with a coal-tar distillate, heavier than water, which was called heavy oil of coal tar by the English and *Kreosot* by the Germans. Basically, this material was the same as the creosote that is used so extensively nowadays for preserving wood.

During the early period in which England and the European countries were making marked strides in the treatment of wood, there was practically no economic demand for treated timber in our country. At that time, wood in America was almost undesirably plentiful and labor was cheap, thus it was more economical to replace decayed wood with new timber than to treat the material and secure longer life.

The tremendous expansion of railroads in this country following the Civil War created a heavy demand for crossties. Through experience the railroads learned that the untreated ties they were using had a short life, many failing in 5 to 10 years after being placed in line. The economy of securing 20 years or more of service through treatment was obvious, and between 1880 and 1920 a large number of wood pressure treating plants were erected. Primarily, the function of the earlier plants was to treat ties and bridge timbers and piling, but treatment of poles was initiated and has now grown to be an important factor in the total treating output of pressure treating plants.

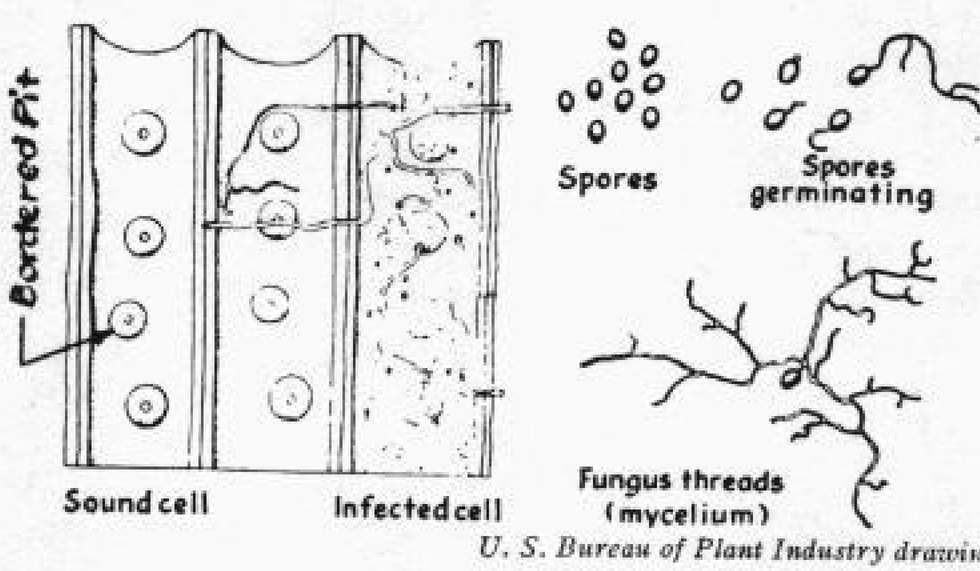
Another type of treatment, the treatment of poles in open tanks by subjecting the wood to a hot bath of preservative followed by a cold bath, developed and expanded in this country between 1910 and 1920. This treatment is applied primarily to species that have thin sapwood and resistant heartwood, such as cedars.

Decay in Wood

Decay in wood is due to saprophytic plant organisms frequently called decay organisms. If one examines under a strong microscope an extremely thin longitudinal sliver of wood that is in the early stages of decay infection, he finds minute threads (hyphae) growing in the wood cells. One of these microscopic threadlets may originate in one cell, pierce the cell wall, travel a distance in the adjoining cell, and then pierce the wall into yet another cell. These rootlets spread in an irregular, haphazard fashion, much as tree roots spread in the soil. They produce complex organic substances called enzymes which break down portions of the wood structure as food for the fungus organism.

There are many species of decay fungi. Some, the "brown rots", live mainly on the cellulose of the wood, leaving a crumbly brownish mass of disintegrated material; others, the "white rots", live mainly on the lignin of the wood, leaving soft whitish masses of disintegrated material which frequently occurs in streaks and pockets between areas of sound wood.

Sound wood may become infected with decay organisms by contact with wood that is decaying, the hyphae or mycelium spreading from the rotting to the sound piece. Decay may also originate in tiny seedlets called spores that are spread by air currents, insects and animals. The toadstool and bracket-like formations that grow on the surface of decaying wood produce these spores, and one such growth can liberate millions of seedlets in a year. The spores, lodging on wood under favorable growth conditions, will germinate and develop into wood-decaying organisms.



U. S. Bureau of Plant Industry drawing

Spores and hyphae of wood destroying fungi

Like all plants, decay fungi require air, favorable temperature conditions and suitable moisture, in addition to the food they absorb. If air is excluded—for example, if wood is kept deeply immersed in water—the piece will not decay. Poles rot more readily at the ground line than at the extreme butt end, largely owing to difference in the supply of oxygen. Cool weather retards and very cold weather totally inhibits decay, which is a major reason why decay is never as serious in northern as in southern climates.

Moisture is a necessity for decay growth and sound wood kept dry and free from contact with decaying material will remain sound. A moisture content of 20 percent or less in wood will totally inhibit decay.[3] In the dry climate of Egypt, wood caskets have remained sound for 2000 to 3000 years.

While all decay fungi require moisture for growth, there are "dry rot" fungi that gain a foothold in moist locations, such as a damp basement, and extend upward to sound, dry wood. They conduct water by means of minutely porous strands of mycelium to the dry wood, the growths usually spreading over the surface of the wood. One species, *Poria incrassata*, has caused considerable damage in the Gulf States. If the source of moisture is removed, "dry rot" fungi become inactive.

Wood Destroying Insects

Wood destroying insects cause millions of dollars of loss annually. The two major offenders are termites, attacking wood on land, and marine borers, living in salt water and destroying our maritime wharves and piers. Of lesser economic importance as individual species, but nevertheless causing great economic loss as a whole, are insects such as the oak pin-hole borer, that perforates wood with myriads of tunnels; the powder post beetle, whose larvae reduce the wood to powder-like substance beneath a thin shell of sound wood; and carpenter ants with their large galleries and chambers in the wood.

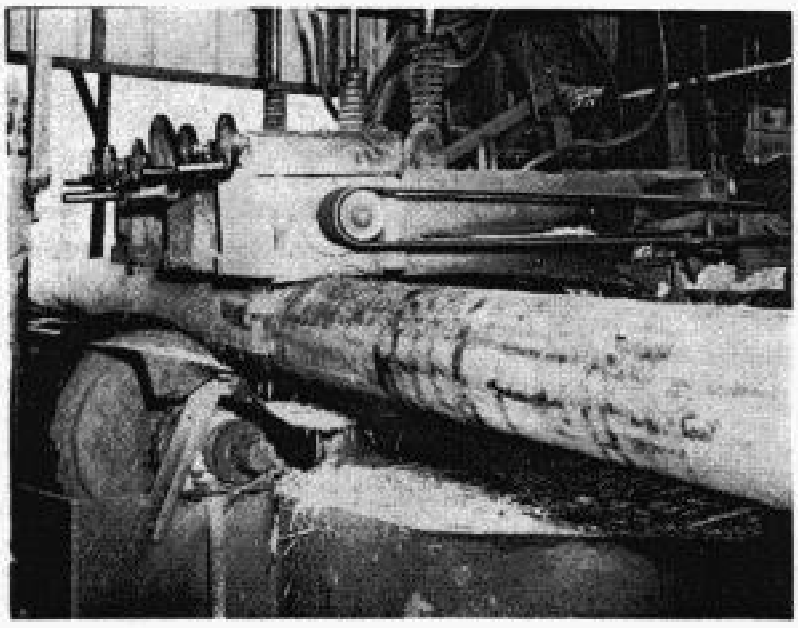
Termites are the master destroyers of wood. These light-shunning insects, related to the roach family, are scattered throughout the greater part of the world, have existed for millions of years and may far outlive mankind. Termite colonies are Soviet-type governments in which the individual is wholly a slave of the colony itself and is channelized and specialized to perform only certain functions. The wood and other vegetable matter they eat is digested for them by internal protozoa. Volumes have been written about these insects, their lives, depredations, and methods for control.

Two types of termites occur in the United States, drywood and subterranean. The former requires very little moisture and may live in the upper part of buildings and structures such as crossarms.[3] Fortunately for us, they occur only in a narrow range, mainly along our southern boundary. Subterranean termites, which must have access to moisture to live, are widely spread throughout the country and are the ones normally referred to when speaking of termites. As a general rule, they occur where there is an appreciable quantity of wood in contact with the ground, such as posts, stakes, stumps, and sawn timbers in or on the top of the ground. In buildings, they will sometimes build clay tunnels from moist ground to the overhead wood, in order to provide the moisture they must have with their food supply.

Wood Preservatives

The ideal wood preservative must be effective against both decay and insect attack. It should be permanent in toxicity, low in cost and easy to impregnate in the wood. It should be noninjurious to the wood and to the people handling the treated material, and the impregnated wood should be clean and paintable.

Creosote, the standard wood preservative used by the Telegraph Company, is the most widely used and thoroughly tested of all wood preservatives. It is effective against decay and insect attack, is relatively permanent, and is noninjurious to the wood. Its efficacy has been proven by a century of use in many parts of the world. However, creosote is not an ideal preservative. It varies in quality and careful inspection is necessary to insure



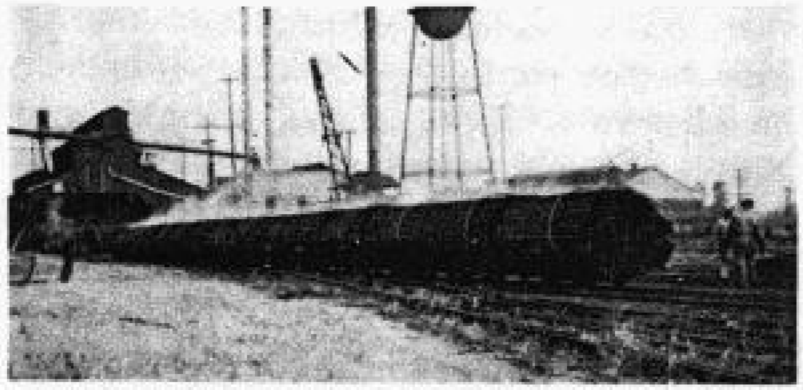
Machine for shaving inner bark from pine poles

the procuring of a satisfactory product. The treated wood is not clean and tends to "bleed" and exude an oily product on the surface of the treated wood. The oil itself will cause the skin of some people to burn and peel slightly.

Many attempts have been made, and are still being made, to develop a wood preservative that is permanent, low in cost, clean and easy to impregnate, and that will otherwise approximately meet the requirements of an ideal preservative. It has been the practice of the Telegraph Company to test the more promising of the new developments, usually in a test plot at Pearl River, La., where decay and termite attack are very severe. The test plot has stubs (10-foot posts) treated with Wolman salts, Chemonite salts, Green salts, and pentachlorophenol. The decay resistance of wood treated with these various preservatives is compared with that of stubs treated with impregnations of 4 pounds, 8 pounds and 12 pounds of creosote per cubic foot of wood. Pine poles treated with pentachlorophenol are being tested in a line in South Georgia, and this year a line that contains poles treated with Boliden salts was released to the Southern Railway.

Around 1928 the Telegraph Company developed and later patented a preservative known as ZMA. This water-borne preservative deposits insoluble zinc meta arsenite salts in the cells of the wood, on evaporation of the acetic acid in the solution. The toxicity of the insoluble ZMA salt against decay fungi was due to the fact that decay fungi organisms produce a weak acid, and this acid would make minute portions of the insoluble salts soluble and toxic to decay fungi.

Field tests carried out between 1929 and 1933 on a large number of ZMA poles installed during that period showed that the preservative was superior to other inorganic preservatives then on the market but was not as efficient as creosote. Accordingly, ZMA treatments were discontinued and the use of creosote was resumed.



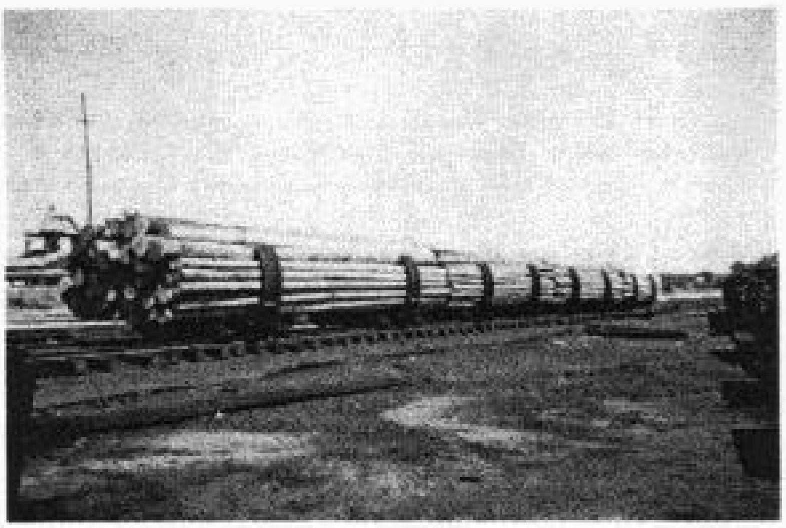
Charge of Western Union crossarms leaving treating cylinder after pressure treatment with creosote

With the exception of the experience with ZMA, the Telegraph Company has used only creosote as standard for the treatment of its poles and crossarms. These timbers, treated in conformity with the Company's specifications for creosote and for treating procedures, have given and are giving definitely satisfactory service, the life expectancy of the material being somewhat in excess of 30 years. A strong contributory factor to the satisfactory results obtained with the treated timber has been the careful and competent inspection of preservative and timber prior to and during treatment.

The most promising of the more recently developed preservatives on the market is pentachlorophenol, a synthetically manufactured product that can be dissolved in fuel oil or lighter petroleum distillates. While the value of pentachlorophenol as a wood preservative has not been fully proven by long-duration field tests, the current tests are in general favorable and pentachlorophenol treated poles are being used by a number of pole-using companies who require a "clean" pole for installation in populated areas. The Telegraph Company is keeping in touch with the performance of this preservative, through its pentachlorophenol treated test stubs of cedar and pine at Pearl River, its poles in South Georgia, and other sources, to see if it will approximately equal creosote in efficiency and economy.

Wood Treatment by the Telegraph Company

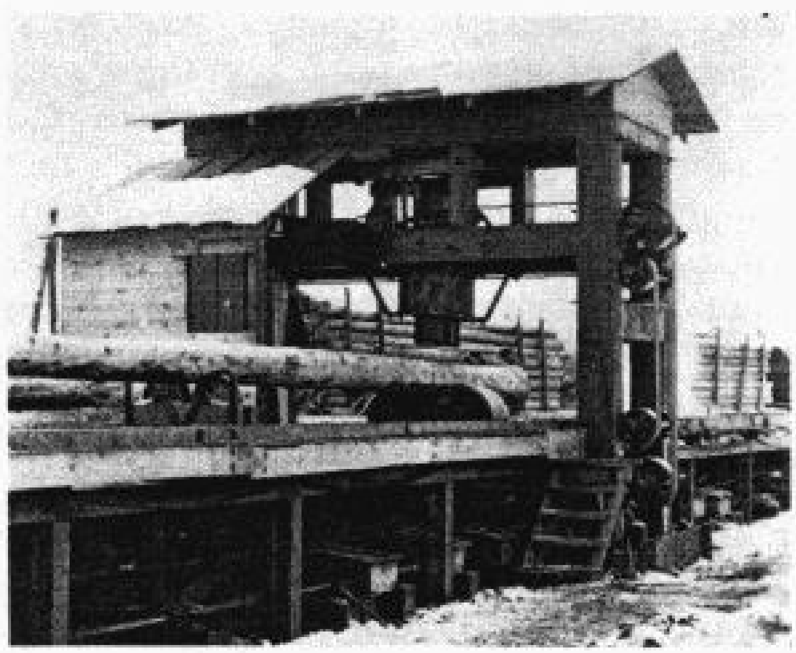
The principal wood items in the outside plant of the Telegraph Company are poles and crossarms. The poles in the plant are southern pine, western red cedar, northern white cedar, some chestnuts that were set prior to the extinction of this species by the chestnut blight, and a sprinkling of Douglas fir and lodgepole pine. The crossarms in the plant are southern pine and Douglas fir.



Charge of Western Union pine poles loaded on treating trams

All poles and crossarms used in the plant are treated with the exception of fir arms, which are of heartwood and satisfactorily resist decay in the areas in which they are installed. Southern pine poles and crossarms are treated by a method designated as the pressure process and cedar poles are treated by a method called the nonpressure or open tank treatment. The Telegraph Company formerly treated many of its cedar and chestnut poles in its own treating plants, but this practice was discontinued and nowadays all treated poles and crossarms are purchased from commercial treating firms who fabricate, condition for treatment, and impregnate the timber with preservative in accordance with the requirements of the Company's specifications.

Southern pine poles and crossarms are treated while the timber is green and full of moisture, as it is difficult to air-season the wood, in the climate where the timber grows, without incurring serious decay losses. In preparing the poles for treatment, the inner bark is shaved off by power operated machines to permit full penetration of the preservative, after which the poles are gained for crossarms and roofed. They are then loaded on trams and placed in steel cylinders that are 6 to 8 feet in diameter and usually 90 to 125 feet in length. In the cylinders they are steamed for 8 to 12 hours at around 256 degrees F, followed by a vacuum to help evaporate the water in the wood. Compressed air introduced into the cylinder compresses the air in the wood cells. Without breaking the air pressure, the preservative is pumped into the cylinder and under additional pressure is forced into the wood. The cylinder is then emptied of the preservative and a vacuum created, with the result that the compressed air in the wood cells expands and carries out with it a considerable portion of the injected preservative. This treatment provides a deep, uniform penetration of preservative without loading the wood with an excess amount of the liquid. Pine crossarms are treated in the same manner as poles, except that lighter pressures and temperatures are used.



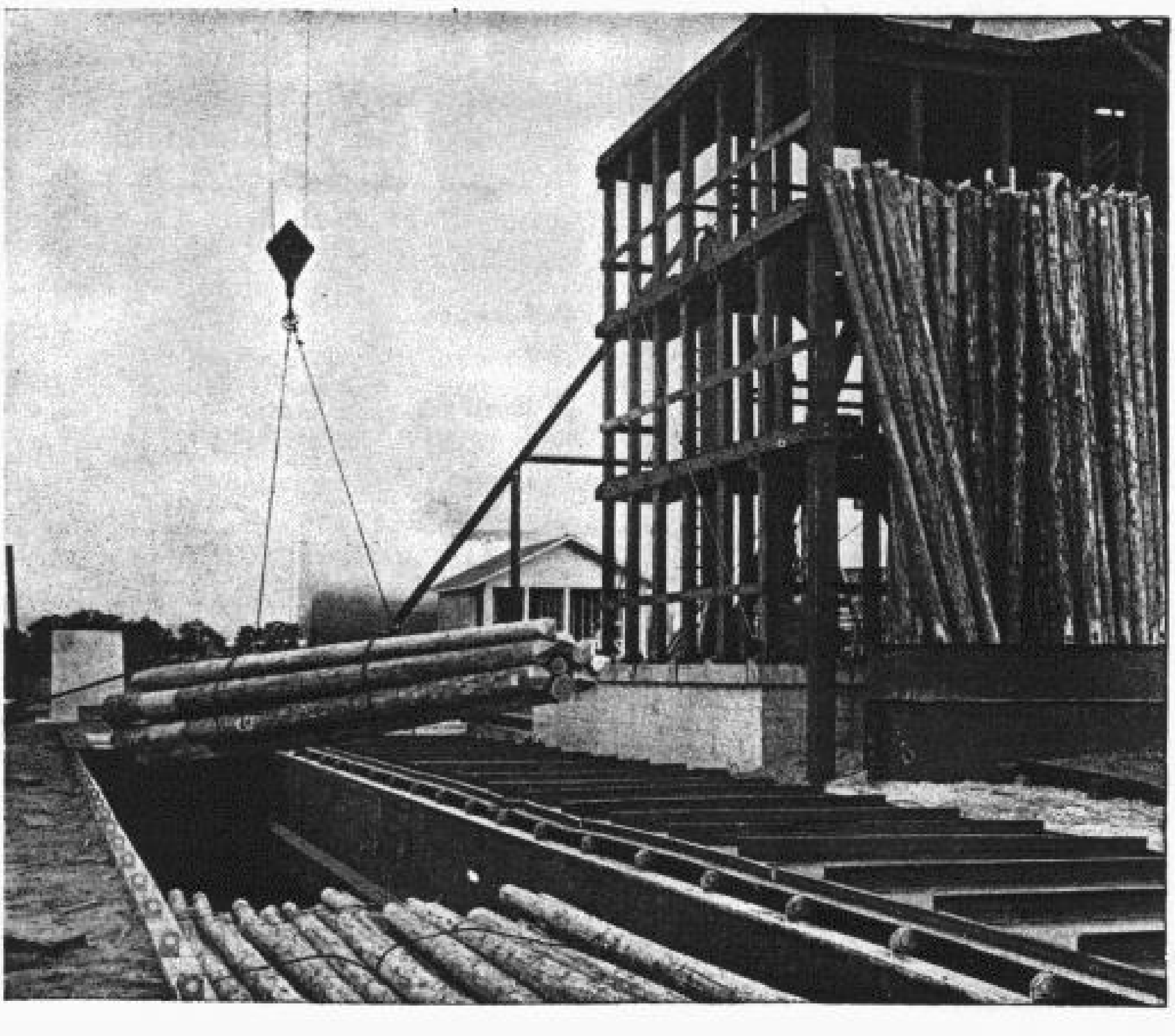
Machine for incising the ground line section of cedar poles

In the open tank treatment of cedar poles, the sapwood in the groundline section of the pole is incised, or perforated, prior to treatment, the incised area forming a belt approximately 3 feet wide around the pole. The perforations in the incised area are uniformly spaced, and permit the preservative to impregnate the wood heavily in this vulnerable portion of the pole. After being incised, the poles are placed upright in open tanks, and their butt ends submerged in hot preservative for a period of 8 to 12 hours. This hot bath evaporates the water in the outer shell of the pole and expands the air in the wood cells. Following the hot bath, the poles are held for several hours in cool creosote, and during this period the vapor in the wood cells condenses, with resultant reduction in internal pressure. Under the small differential between exterior and interior air, the oil is impregnated in the sapwood of the poles.

A considerable number of pole-using companies are now installing cedar poles that have been treated throughout their full length instead of only at the butt end. The treating cycle is similar to that described for open tank butt treatment, but the preservative used is usually pentachlorophenol instead of creosote. The full-length treatment eliminates, in the latter years of the pole in service, the "shell rot" of the sapwood located in the upper section of the pole. While this shell rot does not in general seriously affect the strength of the pole, owing to maximum bending moment occurring near the ground line, the rot is unsightly and is undesirable from a climbing standpoint. As and when the pole plant of the Telegraph Company becomes more stabilized, the full-length treatment of cedar poles will receive careful consideration.

Wood Preservation for Home Owners

Based on the Telegraph Company's experience in the preservation of wood, it appears that the most certain protection against decay and termite attack is to impregnate the wood deeply with a good preservative after it has been sawn and drilled or otherwise fabricated into its



Treating tanks for cedar poles. Upright poles will receive butt treatment, horizontal poles full-length treatment with preservative

final shape. The average home owner finds it impossible to secure wood sills, joists, posts or other wood items that have been satisfactorily pressure treated or open tank treated to provide full protection against decay and insects. Reasonably satisfactory decay and termite protection can be secured, however, if thoroughly dry wood is treated after all fabrication is completed, by thoroughly and liberally applying to all surfaces of the wood at least two brush applications of hot creosote or of pentachlorophenol in a petroleum carrier. Where equipment is available, soaking the wood in the preservative is superior to the brush application. Pentachlorophenol in a light oil (naptha) carrier, is used to some extent for treating wood that requires painting.

A distressingly small portion of the homes of today are built to provide protection against termite attack, and some are poorly built with regard to protection against decay of lower sills and joists. To a certain extent, however, the home owner can lessen the danger of termite and decay infection, and when such attack does take place, can help retard its progress.

The following precautions will help ward off termite attack:

(1) Remove from underneath and around the building all loose lumber, stumps, and so forth, in or partially buried in the soil, as these often form foci for termite attack.

(2) So far as possible, keep all wood members of the building, such as wooden stairs, cellar windows, and so forth, free from contact with the soil.

(3) Ventilate the basement section, so it will dry readily after a spell of wet weather.

(4) Inspect the basement section annually, and destroy any shelter or termite tunnel found on the foundation surfaces.

Where termites are known to be present in the soil around a building, several years protection can be secured by digging a narrow trench around the building to a depth of about 30 inches and poisoning the soil in the trench with solutions of creosote-petroleum, pentachlorophenol-petroleum, sodium arsenite, or with orthodichlorobenzene.

Where a new structure is to be erected, the wood of the building should be well above the ground line, and the top of all masonry foundations in contact with the wood should be capped with a termite-proof cap, preferably a layer at least 4 inches thick of poured concrete.

In regard to protection from decay attack of untreated wood in buildings, the most effective precaution is to keep the wood dry and free from contact with decaying timber. The same ventilation and drying of basements, and removal of loose, decaying wood that will help prevent termite attack, will also reduce the danger of decay infection.

References

1. Natural History, Pliny the Elder.
2. On the Antiseptic Treatment of Timber, S. B. BOULTON, *Proceedings of the Institute of Civil Engineers (English)*, Volume 77, 1885.
3. Wood Preservation, HUNT and GARRATT, 1st Edition.

H. A. Haenseler, after graduating in 1915 from the University of Tennessee, first worked as treating engineer for a wood preserving company; then, while in the U. S. Engineers, his work included assisting in the installation of a mechanical laboratory and in the assembly inspection of locomotives. He joined the Western Union Construction Engineer's division in 1921 to help design a treating plant erected in Illinois, and since that time his activities have been primarily in timber engineering—wood preservation, strength of poles in lines and so forth. Since 1946 Mr. Haenseler's work has included studies on radio beam towers. He is a member of the American Wood Preservers' Association.

Testing 2K56 Klystron Tubes

A. W. DICKEY

ONE of the most important components of Western Union's present radio relay system is the 2K56 Reflex Klystron. This vacuum tube is a microwave generator capable of delivering about 0.15 watt electromagnetic power at a frequency around four thousand million cycles per second. It is used both as a transmitting tube, and as a local oscillator in the superheterodyne type of receiving equipment. In comparison with ordinary types of radio receiving tubes, klystrons, of which there are many kinds, are in a class by themselves. They look different, they perform differently and they are more costly by 100 times or so.

Like other commercial vacuum tubes, however, 2K56 Klystrons have considerable variation in performance and a greater variation in useful life. Some operate satisfactorily for thousands of hours, others for only a few hundred. The manufacturer, as is commonly done, guarantees the tube for a limited time only; if failure occurs within this time, full replacement may be made, or credit prorated for the difference between the guaranteed life and the actual hours of service.

Testing Routine

Because of the uncommonly high cost of the tube, a very close tab has been kept for some time on the performance and life of every one of the 170-odd normally in service, including replacements. Soon after Western Union's New York-Washington-Pittsburgh radio relay system[1] was put into operation, a routine was set up whereby all klystrons that for any reason were removed from service were returned to the laboratory at New York. Here they were tested and tabulated by serial number with all pertinent data recorded, including the maintainer's comments on the tag attached to each tube. The principal objective in such inspection and tests was to determine the hours of service and the cause of failure or other reason for removal. The testing routine, in addition, provided the laboratory with considerable first-hand data on the tube's performance characteristics.

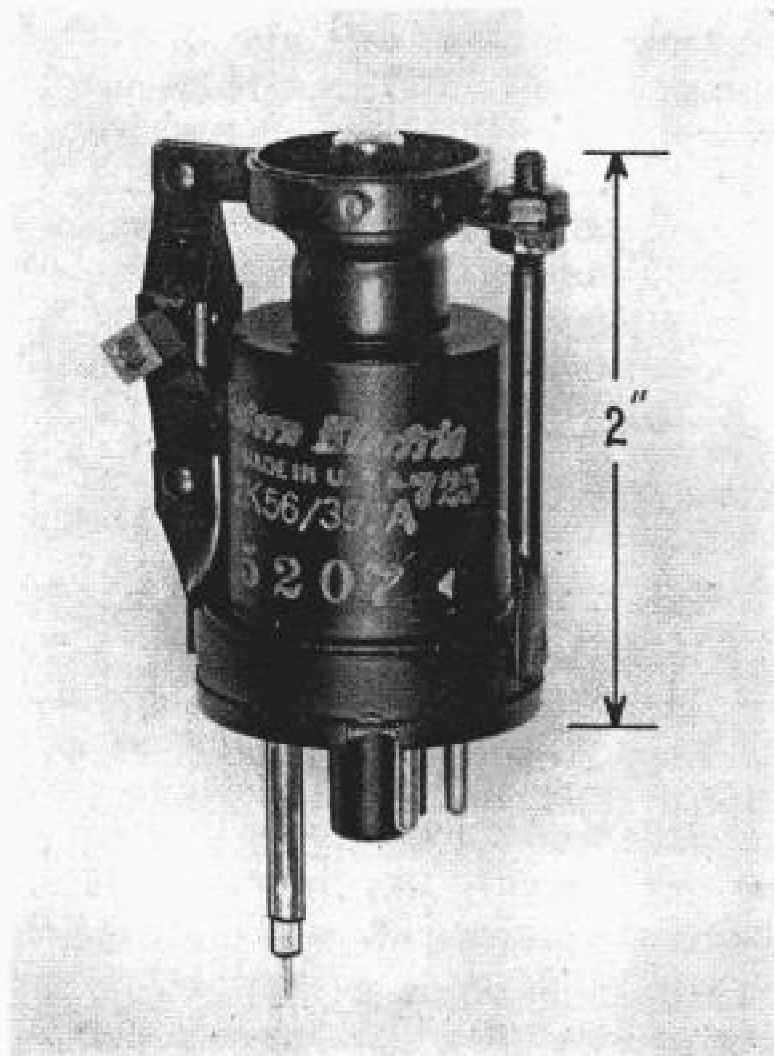


Figure 1. Reflex Klystron 2K56

In the testing of 2K56 Klystrons, microwave power, and the frequency and mode of oscillation, are characteristics of particular interest. The ordinary mutual conductance type of tester used for receiving tubes is, therefore, not applicable. To measure microwave power and frequency requires relatively elaborate apparatus. Furthermore, test equipment suitable for one particular type of klystron generally requires considerable modification before it can be used for testing some other kind.

This article will describe one of the commonly used methods of testing 2K56 Klystrons, and will discuss some of the test data which have been collected.

Before pursuing the subject further, however, a brief review of the tube's construction and manner of operation may be helpful, though superficial. A very comprehensive article covering klystrons in general is to be found in technical literature.[2]

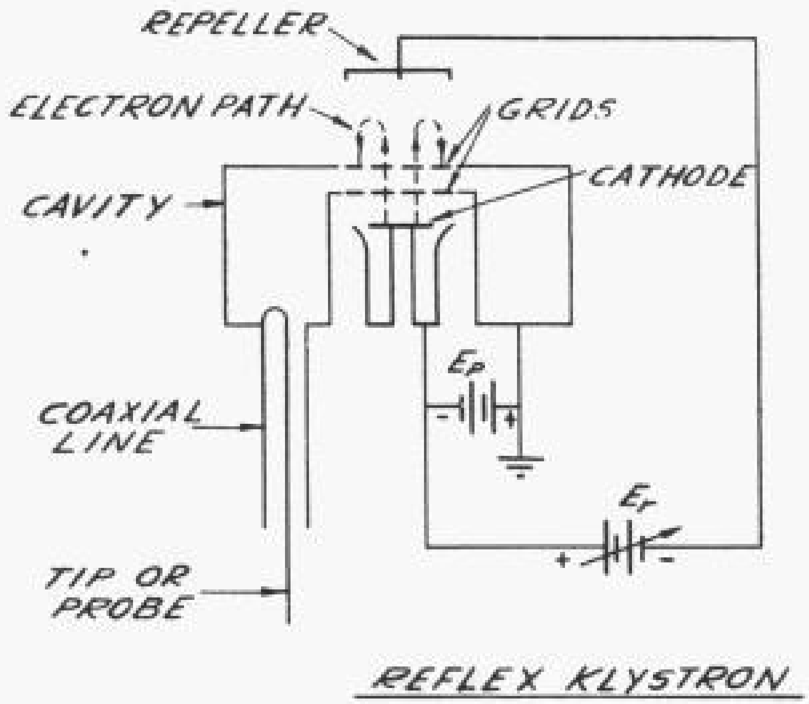


Figure 2. Theory Diagram of Klystron 2K56

A photograph of a 2K56 is shown in Figure 1; Figure 2 shows the essential parts diagrammatically. Electrons from the cathode shoot up through extremely fine grids, reverse in direction, and are dispersed on the grids and walls of the tube. This returning of the electrons to the grids, after having once passed through them, is caused by negative voltage on the repeller and is responsible for the term "reflex" being applied to this particular kind of klystron. Concentrated or bunched regions of electrons occur in the stream at minute but regular intervals of time. When the frequency of occurrence of these bunches coincides with the natural frequency of the induced oscillating fields within the cavity, a sustained oscillation results and appreciable electromagnetic power in the 4000-megacycle frequency region will be radiated from the tip of the coaxial line the center conductor of which is terminated in a single loop inside the cavity. The tube is not efficient, however, as only 2 percent of the total power required to operate it is available at 4000 megacycles.

For a given cavity size there is a certain repeller voltage which will cause the bunching to occur at the right intervals. The cavity size is controlled by a screw and mechanical linkage. Turning the tuning nut clockwise lowers the top of the cavity which is somewhat flexible and draws the grids nearer together, thus lowering the frequency. The nominal range of tuning is from 3840 to 4460 megacycles.

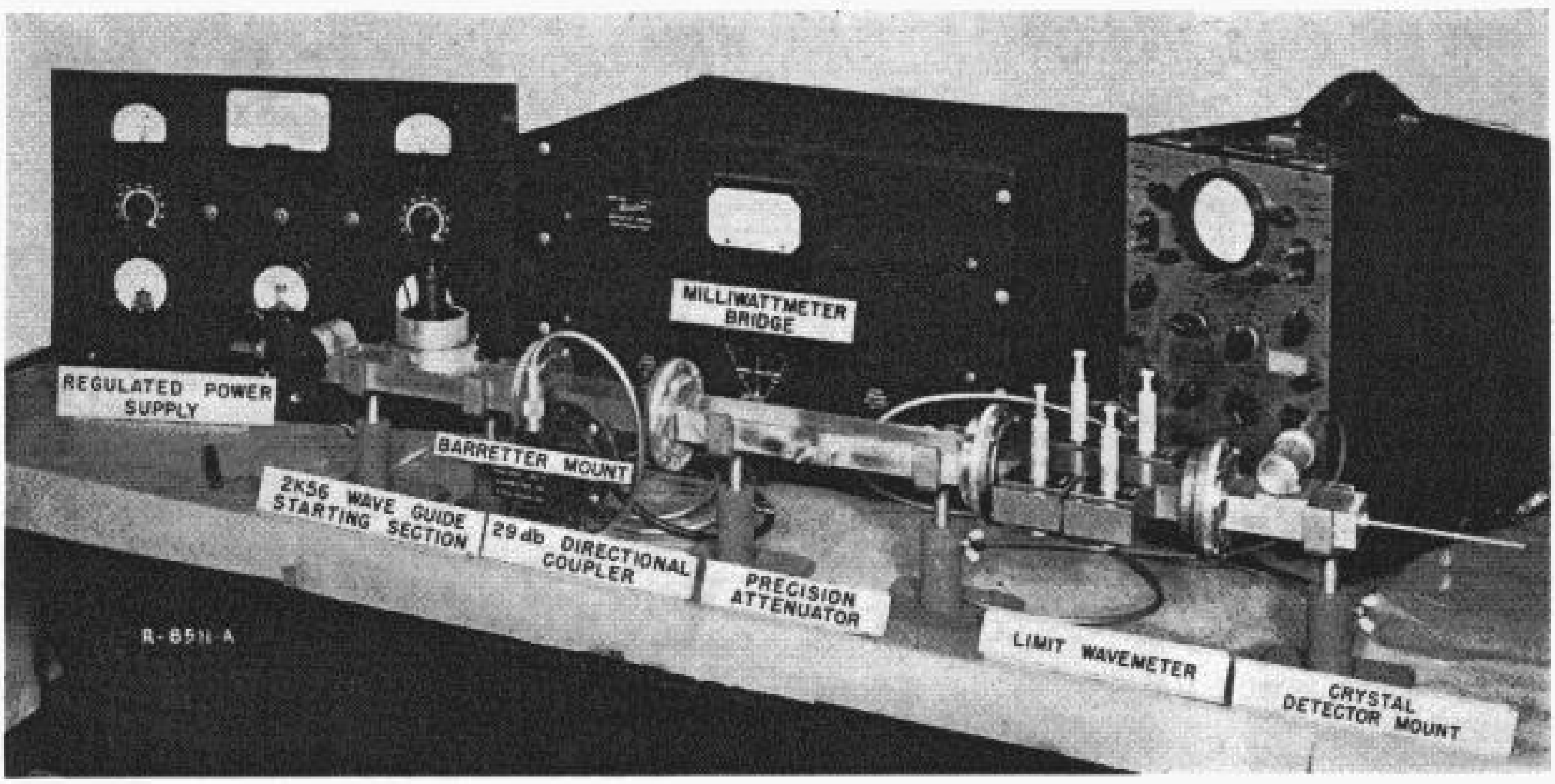


Figure 3. Test set

The Test Set

The testing apparatus shown in Figure 3 and in block diagram Figure 4 is assembled so that substantially all of the electrical tests covering klystrons, called for in Joint Army-Navy Specifications JAN-1-A for electron tubes, can be conducted. This particular set was constructed several years ago by Western Union engineers, based on design information furnished by the Western Electric Company.

There are several ways of arranging the various parts of the wave-guide assembly, and several variations in design of some of the parts. A cursory description of the layout shown in Figure 3 may be of interest because most of the parts are essential in name and function, if not design, in any tester used for 2K56 Tubes.

The klystron is mounted in a special socket attached to a 1-inch by 2-inch wave-guide starting section. This particular size of wave guide is best suited for frequencies between 3950 megacycles and 5850 megacycles. The probe of the tube is extended by means of a fitting in the socket so that it protrudes a certain amount into the wave guide. The movable plunger in this starting section is required to match impedances of the coaxial line with that of the wave guide, i.e., short-circuiting the wave guide at exactly the right distance from the probe. The klystron requires a nominal output impedance of 50 ohms and the design of this particular starting section is such as to secure the best possible performance from the tube as regards mode pattern and power output.

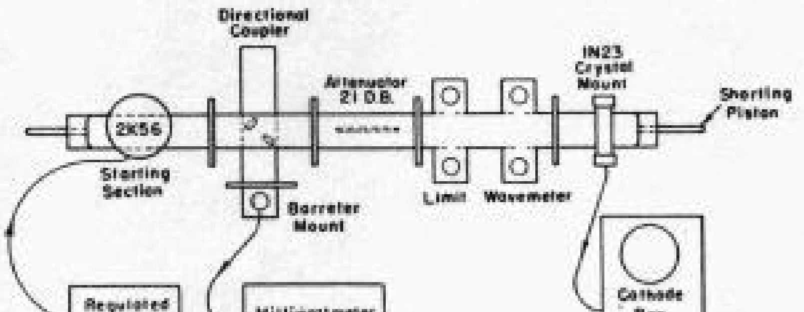


Figure 4. Block diagram of test set

Looking along the wave-guide assembly from left to right, the part next to the starting section is called a directional coupler. This unit has the unique property of leaking off a small fraction (in this case about 0.012 percent) of the power flowing in the wave guide in one direction. It is this fraction of the total power that is actually measured. The next section in the assembly is the attenuator which in this case also acts as a load in the sense that over 99 percent of the microwave power is dissipated within it. Beyond the attenuator there is a section having four fixed cavity wave meters; if it is desired, any of several types of wave meters can be connected here. The final section is equipped with a special mount for holding a rectifying element which in this case is a silicon crystal Type IN-21B. There is also a shorting plunger similar to that in the starting section. The voltage output of the crystal is sufficient to register on either a d-c millivoltmeter, or on an oscilloscope.

Power is Measured as Heat

The process used here in measuring microwave power involves a somewhat indirect method. Connected to the directional coupler is a section called a barreter mount. In this section a very fine platinum wire (0.0002-inch diameter) is held at a critical point within the wave guide so that all the microwave power that is not reactive is dissipated in this wire as heat. The rise in temperature of the wire changes its resistance which, in turn, unbalances a Wheatstone type of bridge circuit. The output of the bridge is read on a meter calibrated in milliwatts. The reading on the bridge meter multiplied by the amount of reduction due to the directional coupler is the power flowing in the main wave guide. This roundabout way of measuring the power is quite practical in comparison with some of the other methods which are sometimes used. For example, microwave power can be made to raise the temperature of water, and the rise in temperature of the water can be converted first to heat units and then to power units.

In general, it is important to know what the frequency is at the time power is measured since the amount of power

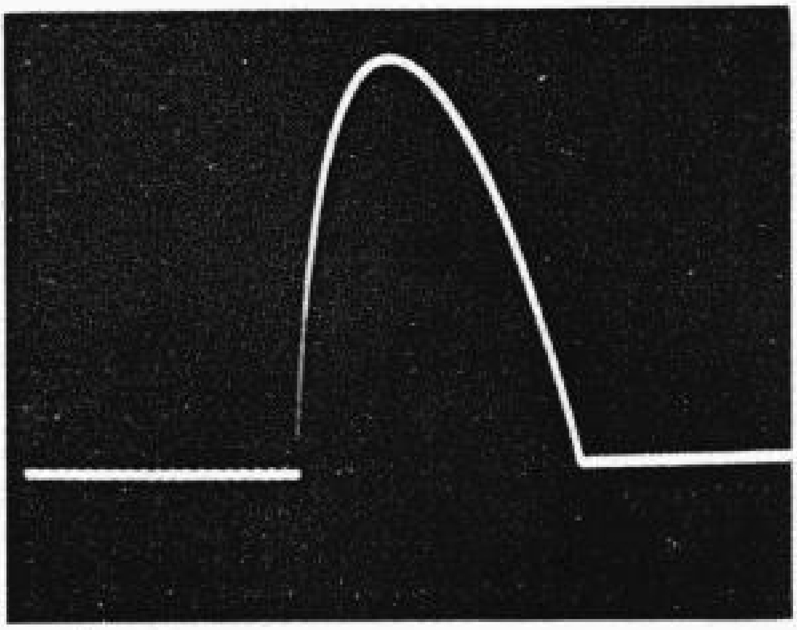


Figure 5a. Normal power characteristic of klystron for one sweep of voltage through the oscillating range

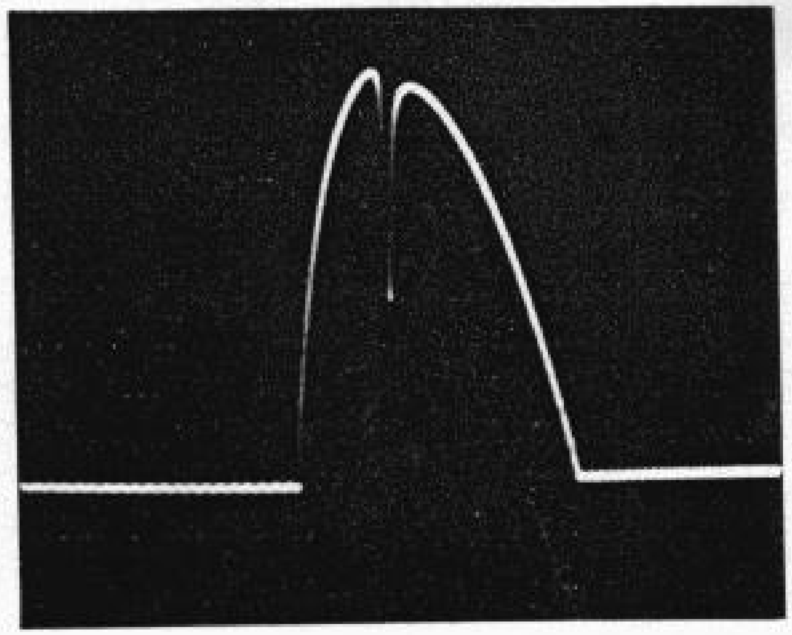


Figure 5b. Normal power characteristic of klystron for one sweep of voltage through the oscillating range with dip caused by frequency meter, the klystron adjusted to deliver maximum power at the particular frequency

generated varies somewhat with the frequency. The "limit" wave meter shown in Figure 4 requires the use of an oscilloscope to give an indication when the given frequency is present. This particular unit has cavities constructed for 3840, 3900, 4200 and 4460 megacycles. Each one of the four cavities can be detuned by the insertion of a small plunger. When the plunger is up, on a particular cavity, and when the frequency of the klystron is adjusted to be that of the cavity, then a small amount of energy is absorbed by the cavity and the power flowing in the wave guide beyond the cavity is less. This effect will cause a dip in the characteristic pattern displayed on the oscilloscope. This "characteristic" shown in Figure 5a is the envelope of the rectified 4000-megacycle oscillations occurring as the voltage on the repeller is sinusoidally varied within a given range, some portion of which is conducive to oscillation. Such a dip is illustrated in Figure 5b. Thus the limits of the range over which a given klystron will oscillate can be quickly determined. This technique is often employed when a number of klystrons are being tested in sequence at perhaps two or three different frequencies. A wave meter such as the Sperry Type 28-B or the new Western Union AT-2 is also quite applicable in this position but such instruments require a little longer time to set at any particular frequency.

To accomplish the intermittent pulsing of the klystron, means are provided in the power supply panel to vary the repeller voltage at a 60-cycle rate through a swing of about 50 volts. If the mean voltage is about −150 volts, there is a region through approximately 25 volts where the tube oscillates and the oscilloscope connected to the crystal mount traces a curve which is proportional to the power in the main wave guide. This display is the "characteristic" shown in Figures 5a, 5b, 5c and 5d.

Western Union AT-2 Wave Meter

When such a trace is produced by a repeller voltage in the neighborhood of −150 volts, the tube is said to be operating on its "middle mode". There are at least two other repeller voltages about −30 and −300 volts where the tube will also

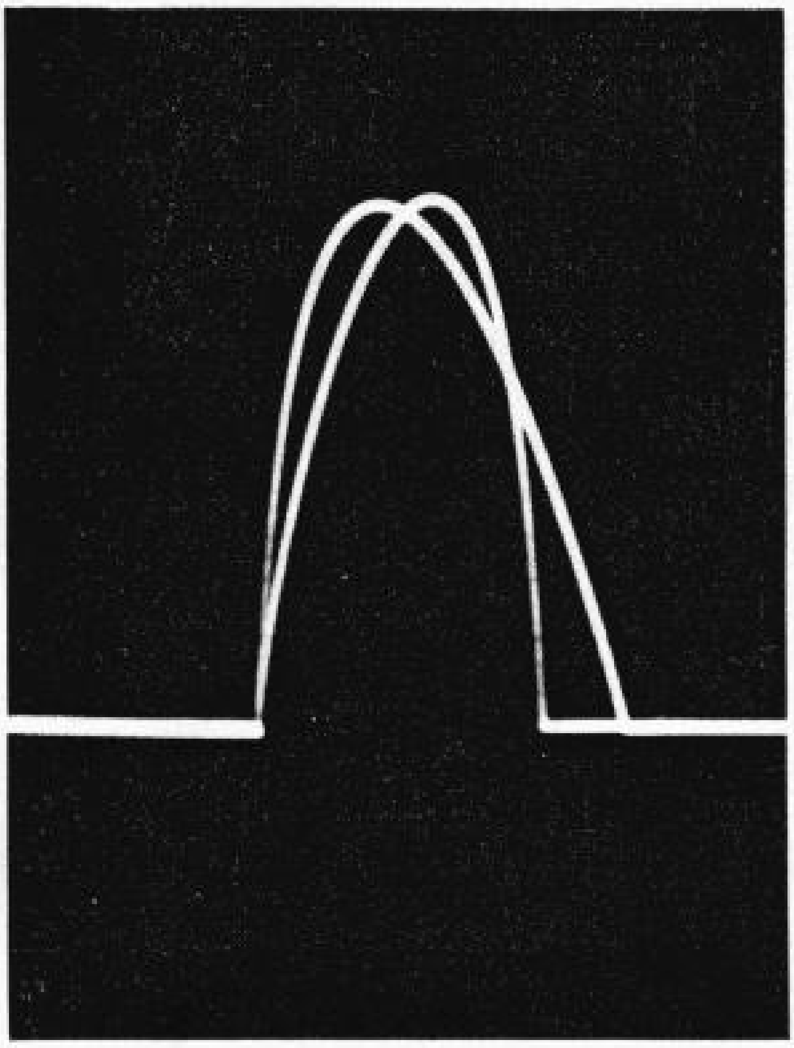


Figure 5c. Normal power characteristic of klystron for one sweep of voltage through the oscillating range for a complete cycle of voltage change

oscillate and produce characteristic patterns on the scope. At the higher voltage the tube generates two to three times as much power as at the middle mode and this higher mode is the one used in the field. The display on the oscilloscope is often made by synchronizing the oscilloscope at twice the sweep frequency of the repeller voltage. Thus, the observer sees both intervals of the rectified oscillation, during one cycle of variation on the repeller, transposed on each other. Figure 5c shows fairly good performance, although many tubes would show the mode patterns coinciding much closer than this. Slight variations in certain construction details of the tube produce a peculiar characteristic known as electronic hysteresis. This is noticeable as a sharp rise or break in the characteristic. It is not serious if it occurs in less than 5 percent or so of the voltage range over which the tube normally oscillates. This effect is shown in Figure 5d.

All d-c voltages for the test set except those required in the wattmeter bridge are derived from the special power panel.

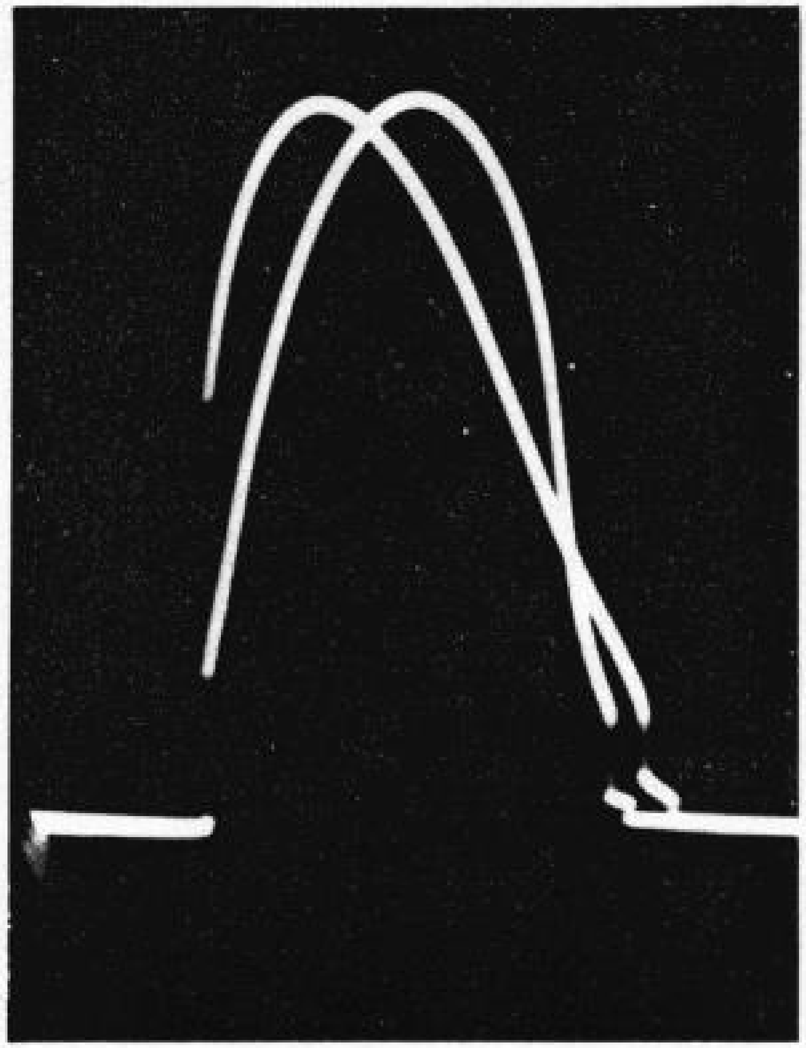


Figure 5d. This "characteristic" is produced by a klystron having "hysteresis"

This panel also provides metering and controls for all phases of the tests except the actual power measurement. Figure 6 shows the circuit diagram for this panel.

Test Procedures

Some understanding of the test procedures can be obtained from a glance at the tabulated list of tests. This list is a condensation of those described in JAN-1-A specifications. In general a tube that falls within the minimum and or maximum limits shown for each test is acceptable for service.

Two of the more important tests are Test 2, the cathode current test; and 6, the oscillation test. To perform Test 6, the plunger of the 4200-megacycle wave meter is released thus tuning the cavity to this frequency. Then the mechanical tuning control on the tube and the repeller volt-

WESTERN UNION TEST SHEET FOR 2K56 TUBE

*REF.		TEST NO.	TEST	CONDITIONS		MIN.	MAX.
F-61		1	Heater Current		If:	0.410	0.470 amp
F-6f	(6)	2	Cathode Current	Oscillation (1); (See Test 6)	Ik:	18	32 ma
F-12g	(1)	3	Total Repeller Current	Er = —150 vdc;	Ir:		7 μa
F-12g	(2)	4	Repeller Leakage Current	Er = —150 vdc;	Ir:		5 μa
R-12g	(3)	5	Repeller Gas Current	Er = —150 vdc;	Ir:		2 μa
F-12c		6	Oscillation (1):	Mode A; Er-Po max; F = 4200 mgc	Po:	80	mw
F-12d		7	Emission	Oscillation (1); Ef = 5.8 v;	$\frac{\Delta Ik}{Ik}$:		0.15
F-12f	(3)	8	Repeller Voltage	Oscillation (1);	Er =	−125	−175 vdc
F-12c		9	Oscillation (1-A):	High Mode; Er-Po max; F = 4200 mgc	Po:	80**	mw
F-12c		10	Oscillation (2):	Mode A; Er-Po max; F = 3900 mgc	Po:	40	mw
F-12c		11	Oscillation (2-A):	High Mode; Er-Po max; F = 3900 mgc	Po:	40**	mw
F-12i	(2)	12	Electronic Hysteresis	Oscillation (1) (2)			5%

*The numbers listed in the first column refer to those in the JAN-1-A Specifications.

**Although the high mode generally generates more power, this is not always true, hence the same minimums are given as for Mode A.

age control on the power supply are adjusted together until the wattmeter bridge meter indicates that some power is being generated by the tube. The repeller voltage should be within the limits of —125 to —175 volts (middle mode — Test 8). The adjustment of the above two controls should proceed until the tube is generating its maximum power at 4200 megacycles, which is read on the wattmeter bridge. According to the test table, a tube is not acceptable if the power output is less than 80 milliwatts. This would read 0.0001 watt on the wattmeter bridge, since the Barreter receives only 1/800 of the power (—29 db) in the main guide. Under this condition of oscillation the total cathode current as read in the power panel meter should be above 18 milliamperes—this is Test 2. The maximum rf power generated in Tests 9 and 11 is often above 200 milliwatts.

In Test 7, emission is evaluated as the ratio between the change in Ik for Ef= 5.8 v, and Ik at Ef= 6.3 v. Many good tubes have an emission figure less than 0.1.

Conclusions

Of the first 400 klystrons that passed through the laboratory for inspection, about half, either because of long service records or other circumstances, were discarded without subjection to further tests. Approximately 200, however, were given one or all of the tests. Of these, roughly 5 percent were returned to the manufacturer for credit, and 10 percent were returned to the field for further service.

In the 10 percent group were some klystrons that had to be repaired before they would function properly, one common trouble being that the tip of the center conductor in the coax line and its surrounding dielectric material are often damaged in handling. Records show that these tubes have generally given good

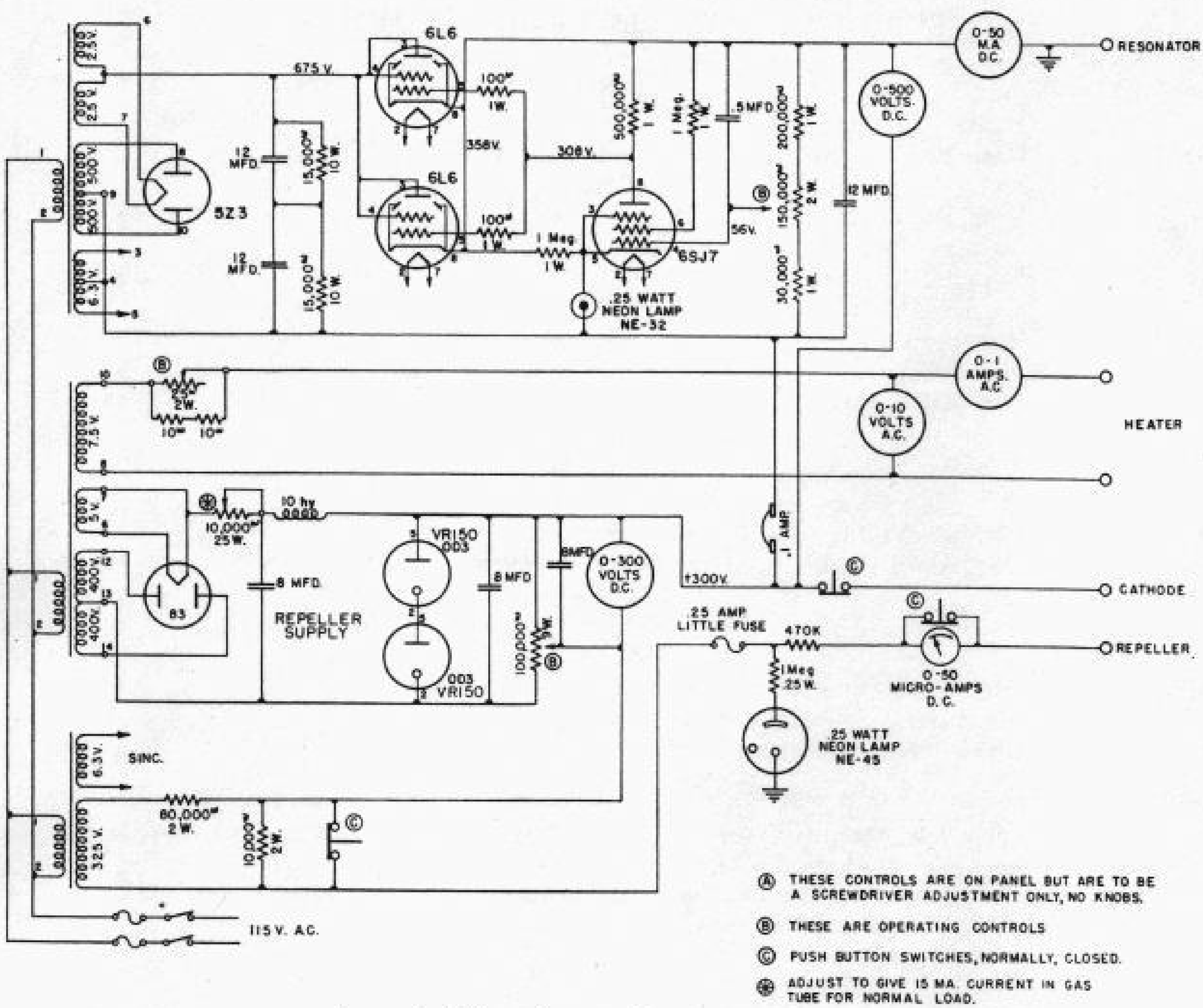


Figure 6. Wiring diagram of power supply panel

service after repair—in a number of cases equivalent to that of new tubes. The most common cause of removal from service is low cathode current, i.e., the cathode wears out. Another fairly common cause for removal is instability of oscillation. Some tubes will operate well within a narrow frequency range, but will not perform well over the normal 600-megacycle range.

A considerable number of the used klystrons have been found to function well enough for laboratory purposes, thus giving the laboratory a good source of klystrons for experimental work.

The records show that the klystrons used during the first year or so after the beam system was first put into operation gave somewhat longer life than those in the system during the third and fourth years. During the last two years, however, there has been an upward trend in the average life so that it now approaches 10,000 hours. Some of this improvement is undoubtedly due to better maintenance practice.[3] During the earlier years of experience there was a tendency to adjust and otherwise handle the tubes more than was necessary. The longest tube life recorded is 26,800 hours.

A comparison of the laboratory records for over 800 tubes with the information sent in by the maintainers shows that the diagnosing of klystron trouble, using the various metering circuits at their disposal in the radio relay equipment in the field, has been over 90 percent accurate. Accordingly, the practice of sending *all* tubes to the laboratory after service in the field has been discontinued. Only tubes which are found to be defective when first put in service, or those which fail before the first thousand hours of service, or appear to be damaged in any way, are returned. Those tubes that fail after 1000 hours or more of service and show no visible defects that might, if repaired, give longer life, are discarded by the maintainers. This of course greatly reduces the amount of laboratory attention given to the matter. It is anticipated that eventually all testing, repair and credit handling of 2K56 Klystrons will be carried out by qualified plant personnel, outside of the laboratory.

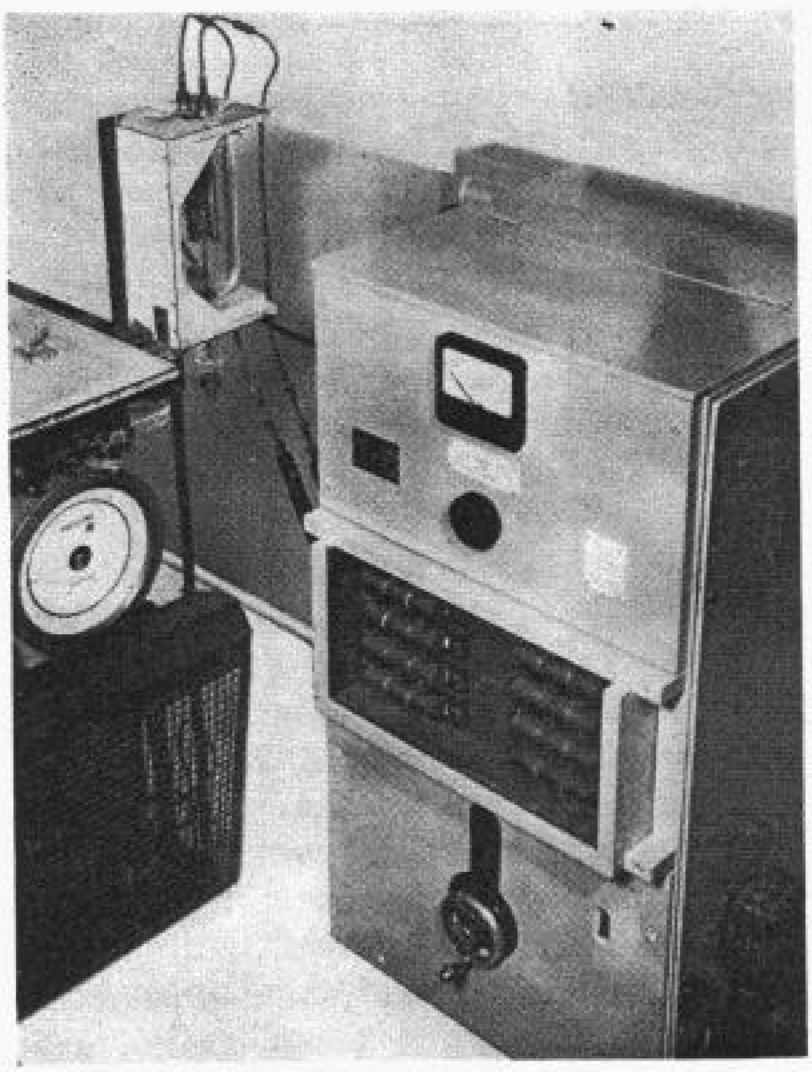
References

1. Western Union's Microwave Relay System, H. P. CORWITH and W. B. SULLINGER, *Western Union Technical Review*, Vol. 2, No. 3, July 1948.
2. Reflex Oscillators, J. R. PIERCE and W. G. SHEPHERD, *Bell System Technical Journal*, Vol. 26, No. 3, July 1947.
3. Maintenance of a Radio Relay System, G. B. WOODMAN, *Western Union Technical Review*, Vol. 5, No. 4, October 1951.

A. W. Dickey, Electronics Applications Engineer, started service with the Engineering Department shortly after graduating from Ohio State University in 1923. During his earlier years he engaged in circuit and equipment design, particularly in the ocean cable field. He participated in much of the laboratory and field work in applying electronic amplifiers to the Atlantic cables and during the war supervised the application of electronic amplifiers on the Seattle-Anchorage cable operated by the U. S. Army Signal Corps. Since 1946 Mr. Dickey has been concerned largely with the Company's radio relay system and has supervised numerous changes and additions to its electronic and microwave components. The division of which he is now head handles applied engineering for d-c telegraph, carrier, radio relay and ocean cable equipment. Mr. Dickey is a member of Eta Kappa Nu and AIEE.

Laboratory Equipment

One of the pieces of specialized equipment available to Western Union research engineers is the high-frequency bombarder and vacuum furnace combination shown in the photograph. This apparatus is in the vacuum tube section of the Water Mill (L. I.) Electronics Laboratory, one of the divisions of the Development and Research Department.



The furnace enclosure, made of glass, is connected to a high-vacuum pump so that heating operations may be carried out in a vacuum or in a special gas atmosphere as required. The material to be heated is placed within a cylindrical cup, made of molybdenum, which is positioned within a helical coil carrying high-frequency current from the bombarder. Circulating currents induced in the cup by transformer action heat it, and its contents, to temperatures as high as 4500 degrees F.—W. D. B.

Wire and Cable in the Telegraph Industry

W. F. MARKLEY

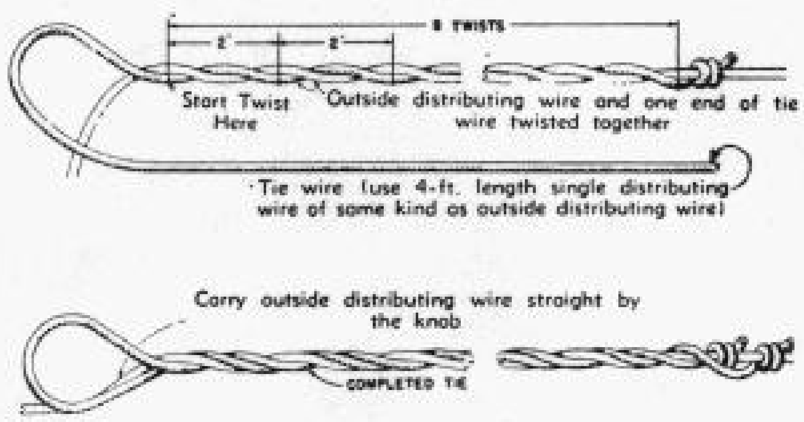
PART III. OUTSIDE WIRES AND CABLES

Distributing Wire

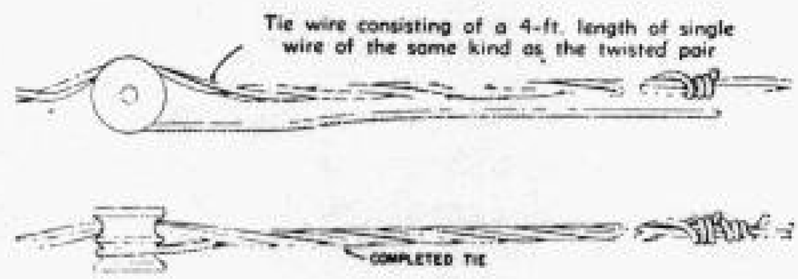
SINGLE and twisted pair, insulated and weatherproof braid covered, tinned No. 16 A.w.g. hard-drawn copper and copperweld wire, commonly referred to as outside distributing wire, is employed in city distribution work in the telegraph plant to the extent of several thousand miles per year in providing and maintaining time, call, ticker, printer, and other services between offices and subscribers, and to provide drops from open line wire into railroad stations, signal towers and industrial plants. In addition, this wire is used in repair and restoration service in storm areas, in reconstruction work involving pole line changes necessitated by reason of grade crossing eliminations, highway improvements, and so forth.

The first sections at which the covering of this wire begins to fail are where the wire is tied or clamped to supports, especially at points of abnormal strain, such as corners or dead ends, and improper methods of attaching insulated wire at such points may reduce its useful life by 50 percent or more. The methods of tieing and dead-ending this type of wire, as illustrated in Figure 17, were developed some years ago to reduce to a minimum the damage to the rubber insulation at tie and dead-end points. "A" of this figure shows how sections of the wire itself are used to tie the conductor to the insulator; the wrapping of the tie wire around the conductor unavoidably introduces some strain on both the insulating compound and the braid. "B" of this figure shows how this wire is held at dead-end points, a method which utilizes a long piece of the same wire, suitably intertwisted with the lay of the pair so as to distribute the load over a considerable length and avoid high unit stress in any one spot in the wire covering. These methods of installation appreciably reduced failure of the rubber insulated outside distributing wire at these critical points of support and gave evidence over the years of considerably improving the useful life of the finished wire as compared with the use of clamps for this purpose.

A — Method of tieing outside distributing wire, using single outside distributing wire as the tie wire.



Single outside distributing wire dead-end.



Twisted pair outside distributing wire dead-end.

B — Method of dead-ending single and twisted pair outside distributing wire, by intertwisting a length of single outside distributing wire.

Figure 17. Method of tieing and dead-ending outside distributing wire

These tieing and dead-ending practices for this wire serve to indicate the extent of abuse to which this material is subjected during installation and service. More severe abuse to the wire occurs in reconstruction work and in the restoration of service in storm areas when this wire is pulled over fences and crossarms and under rails, tied to poles and trees,

A paper presented before the Winter General Meeting of the American Institute of Electrical Engineers in New York, N. Y., January 1953.

and allowed to remain in water and ice for long periods.

Although the rubber insulation gave a reasonably good account of itself in this service for many years, it possessed several weaknesses which not only shortened the life of the wire but resulted in its inadequacy for certain types of service. For instance, the rubber insulation had a relatively short life once the braid had deteriorated, which occurred at tie and dead-end points; also, the use of this wire in restoration of service, referred to, when the wire was submerged in water and wet snow, provided relatively poor transmission characteristics.

In 1942, Western Union pioneered in the development of the first self-supporting thermoplastic-insulated wire designed for this type of outdoor service in the communications field. In the early consideration of plastic insulation for this application, there was considerable apprehension about the suitability of this type of material in view of the fact that the finished wire in outdoor service is subjected to an extremely wide range of weather conditions throughout the United States, as well as to considerable rough handling during installation and service. At the outset, it was apparent that plastic insulation alone, without any outer mechanical protection, would not be adequate because of the cold flow characteristics of this material, particularly at tie points and dead ends.

After considerable laboratory work, a vinyl compound was selected for this service. As an external covering for the insulated conductor, the application of a weatherproof braid appeared to be the most advantageous type of protection from the standpoint of both economy and performance, that could be satisfactorily adapted for use over the plastic insulation. In the first complete wires that were prepared, it was found that the saturating and finishing compounds employed for weatherproofing the braid adversely affected the vinyl compound. The volatile component of the hot saturating compounds degraded the electrical characteristics of the vinyl insulation and the heat of application of these compounds softened the insulation to the extent that the conductor would float in the insulation during processing of the braid. After experimenting with a number of different types of tape applied over the insulated conductor to serve as a barrier for the saturating compounds, it was found that a thin Kraft paper tape applied longitudinally and simultaneously with the braid would provide adequate protection for the plastic compound in the final processing operations of the finished wire.

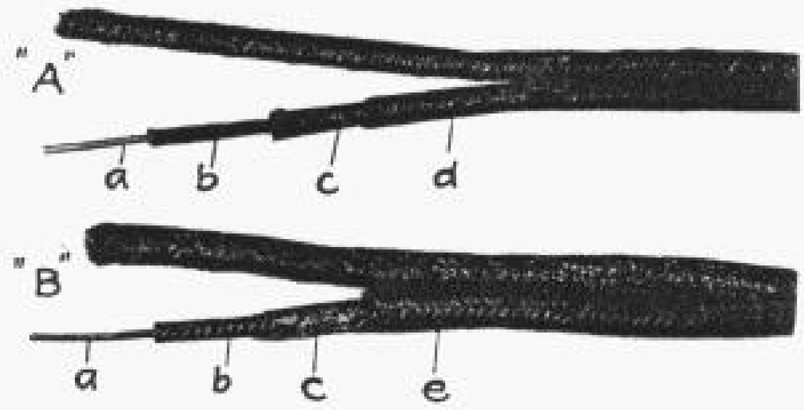


Figure 18. Outside distributing wires
"A" City distributing wire
"B" Tree wire
a — untinned conductor; b — 1/32-in. vinyl insulation; c — Kraft paper tape; d — No. 30s 2-ply weatherproof cotton braid; e — No. 10 Seine twine weatherproof braid

Figure 18 at "A" shows the design of the plastic-insulated wire. This vinyl-insulated untinned conductor with its weatherproof braid, treated with modern durable asphalt compounds and Montan wax, provides a finished wire having an estimated life in excess of 25 years and a mechanical and electrical stability far superior to the previous rubber insulated type. The performance of this wire, both mechanically and electrically throughout the United States under all weather conditions and service requirements, has greatly exceeded original expectations. In the companion type of this wire, illustrated at "B" in Figure 18, required where extra severe abrasion is encountered, such as in runs through trees, the outer braid woven from No. 30s 2-ply cotton is replaced by a heavy braid made from No. 10 seine twine. The substitution of the vinyl compound for the rubber insulation on outside distributing wire has effected a decided improvement.

Western Union has been experimenting, for this service, with conductors insulated with extruded 1/32-in. wall of so-called high molecular weight "rigid" vinyl compound that has been modified slightly to improve flexibility. Rigid resins have sufficient plasticity to enable them to be extruded, worked and processed without the addition of plasticizers. These resins have the outstanding electrical, physical and chemical properties of vinyl base resins normally employed for the various wire and cable applications. No outer jacket of any kind is applied to this wire, as the rigid vinyl appears to have adequate hardness and abrasion resistance over a wide temperature range.

Samples of this wire were subjected to cold flow and cutting action. In this test a loop of the wire is first assembled on an insulator and a second loop given several wraps in a closed helix. This second loop supports a load equivalent, approximately, to half of the breaking strength of the bare conductor. This assembly is suspended outdoors. At frequent intervals the assembly is removed for observation and the wrapped sections of the loops immersed in water and subjected to electrical tests to determine the extent of damage to the insulation.

The rigid vinyl insulated wire subjected to this test has made an excellent showing so far, except that the insulating compound appeared to lack adequate flexibility and impact resistance. It is interesting to note that in this test extruded plasticized vinyls and polyethylene, all without a protective jacket of any kind, will cut through completely in a matter of weeks depending upon the thickness of insulation; the Western Union standard vinyl insulated and weatherproof braid covered outside distributing wire, will suffer no appreciable damage after an exposure of one year or more.

Further tests are being planned for outside distributing wire having rigid vinyl insulation. Such a design simplifies processing and reduces production costs. It is obvious, however, that existing methods of installation, referred to, may have to be revised to insure adequate holding power at tie and dead-end points for this simple insulated conductor.

Line Cable

For cable in city distribution service and pole line runs, where the length is not too great, it is customary to employ, in the telegraph plant, lead-covered cable comprising paired No. 19 A.w.g. dry paper-insulated annealed copper conductors laid up with a concentric lay. This cable, commonly referred to as "CNB" cable, is supplied in sizes varying from 6 pairs to 455 pairs, and is employed in quantity, both aerially and underground. It is relatively heavy and expensive, involves high installation and terminating costs and in many congested localities necessitates high maintenance cost in aerial installations.

It is believed that the objectionable features of this cable can be overcome by the use of plastic-insulated and jacketed cable employing polyethylene insulation for the conductors to provide the uniformly low capacitance required. In a nominal wall thickness of about 20 mils, polyethylene gives approximately the same range of mutual capacitance values between the conductors of a pair, after allowing for some slight distortion of the insulation that takes place during pairing and cabling, as that obtained in the case of the standard paper-insulated cable. Colored polyethylene is used for coding purposes. No jacket of any kind is applied over the conductor insulation. Indications are that this 20-mil wall of polyethylene will provide excellent transmission characteristics for circuits up to 50 kc.

Figure 19 shows the general design of a cable of this type that is being considered, in a 26-pair size, for an aerial installation on Long Island. The pairs are arranged in concentric lay, without fillers, over which is applied spirally an oiled, heavily creped paper tape; over this tape is spiralled a 4-mil untinned copper shielding and grounding tape followed by an extruded black polyethylene jacket having a radial wall thickness of 5/64 inch.

The jacket stock consists primarily of a high molecular weight polyethylene containing suitable anti-oxidants to insure thermal stability during processing and about 2 percent carbon black to provide resistance to sun aging and adequate outdoor serviceability. This compound is reasonably tough and flexible and relatively light in weight, as indicated by its specific gravity of 0.92.

The 26-pair plastic cable under consideration weighs only about half as much as lead-covered cable and is obtainable at a slightly lower cost. In larger sizes, the plastic cable is appreciably cheaper than the lead-covered cable and the spread between the weights of the two cables is much greater than in the case of the 26-pair size.

The vastly reduced weights of the plastic cable as compared with the lead-covered cable will be reflected not only in considerably lower costs of handling and installation, together with the reduced freight rates, but also in the reduced cost of the much lighter supporting messenger and associated hardware that can be employed in aerial installations.

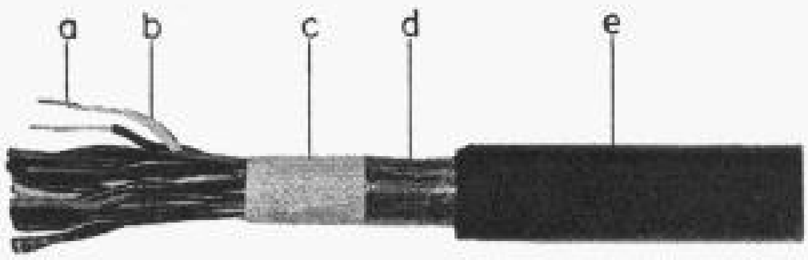


Figure 19. Plastic cable for outside use to replace paper-insulated lead-covered cable
a — untinned conductor; b — 20-mil polyethylene insulation; c — crepe paper bedding; d — 4-mil copper tape; e — over-all black polyethylene jacket

Another important advantage of the polyethylene insulated cable is the fact that a hole in the sheath, or an otherwise badly damaged sheath that permits moisture to enter the cable, has practically no effect on the efficiency of the polyethylene insulation as a dielectric, whereas with paper cable any serious damage to the lead sheath that enables moisture to enter the cable causes all of the conductors to short-out in a relatively short time.

Although the details on the contemplated experimental field installation of the 26-pair plastic cable, referred to above, have not been definitely worked out, and notwithstanding the difficulties that may be encountered in developing adequate splicing technique, indications are that the cost of the plastic cable in place, as well as maintenance costs, will be appreciably less than comparable costs for the standard lead-covered cable. On the basis of all data obtained to date, it is estimated that the life of the plastic cable will be between 20 and 40 years.

Shielded Line Conductor

The demand arose in the telegraph plant for an inexpensive two-conductor wire (twisted pair) or simple shielded line conductor which would be suitable for short-haul (up to 100 miles) carrier communication at frequencies up to 120 kc per second and which would be self-supporting to enable it to be strung on existing pole lines without the use of a messenger and, thereby, effect minimum installation costs.

At the outset, it was evident that hard-drawn copper or copper-covered steel would be required for the conductor material to provide the desired mechanical efficiency, and that polyethylene would be necessary for the primary insulation to insure the low transmission losses for this service. As the outer jacket for mechanical protection, experience indicated that a modern weatherproof woven cotton braid would be adequate and economical.

Accordingly, in this initial investigation, twisted pair copper wires were considered, in both No. 10 and No. 13 A.w.g., each conductor insulated with polyethylene, over which was applied an aluminum-faced paper tape and a weatherproof braid. Transmission tests that were made on samples of these twisted pairs indicated disappointing electrical losses, which appeared to be due in large measure to the close proximity of the separate metallic shields. Theoretical considerations seemed to indicate that a single over-all shield would be decidedly more efficient.

Samples of these twisted pair wires were then made by twisting together two polyethylene-insulated conductors and applying an over-all single 4-mil metallic shield over the twist followed by a single envelope comprising the weatherproof braid. Laboratory tests on short samples of this construction continued to show prohibitive attenuation of 3 to 4 decibels per mile, necessitating the installation of repeaters every 7 or 8 miles.

Theoretical transmission studies were then made on a simplified design of a shielded line conductor comprising a single No. 10 A.w.g. copper-covered steel conductor insulated with a heavy wall of polyethylene over which a metallic shield comprising a soft 5-mil longitudinal copper tape (equivalent to 11½ A.w.g. copper) is applied; for mechanical reasons a 3-mil spiral copper tape is applied over the longitudinal tape. The details of this construction are shown in Figures 20.

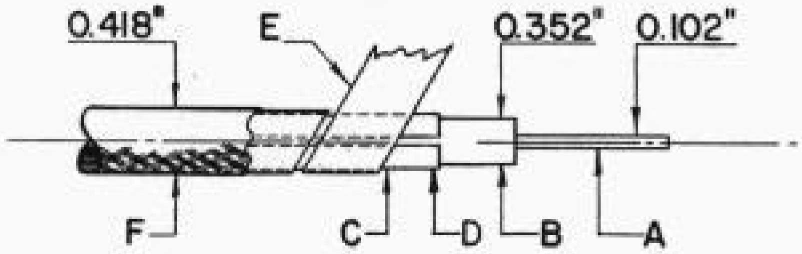


Figure 20. Shielded line wire

"A" No. 10 A.w.g. untinned hard-drawn copperweld wire (40 percent conductivity; tensile strength = 1130 lb.; d-c resistance = 2.55 ohms per 1000 ft.).
"B" Polyethylene insulation (Brown-Bakelite DE-6490).
"C" 5-mil soft untinned copper tape applied longitudinally (equivalent to 11 1/2 A.w.g.).
"D" Maximum gap shall be 1/16 in. and edges of copper tape may touch occasionally.
"E" 3-mil soft untinned copper tape spirally applied without overlap; nominal gap between adjacent convolutions 1/16 in.
"F" No. 30, 2-ply soft cotton closely woven braid (max. braid angle = 62.5 deg.). Weatherproofed per W.U. Specs. 1638-C.

Weight of Component Parts of Cable:

Conductor (10-ga.)	= 0.029 lb. per ft.
Polyethylene (1/8-in. wall)	= 0.034 lb. per ft.
Copper tape (5 mils)	= 0.020 lb. per ft.
Copper tape (3 mils)	= 0.012 lb. per ft.
Finished cotton braid	= 0.012 lb. per ft.
Total	= 0.107 lb. per ft.
	= 107 lb. per 1000 ft.

From calculations based on the dimensions in Figure 20, the ratio of inside diameter of the shield to the diameter of the central conductor approximates 3.5 as compared with the ideal ratio of 3.6 to insure minimum attenuation for this design. Indications are that, with the shield applied longitudinally, so as to approximate a continuous solid tube, instead of a helical tape serving, a more effective design is obtained from the standpoint of electrical losses particularly at television frequencies.

This construction for the shielded line conductor is considered mechanically and economically promising, and is believed suitable for television frequencies if required. The attenuation is estimated at 2.0 decibels per mile at 120 kc per second, which is high but not entirely prohibitive.

The experimental approach to this project made possible by the procurement of a length of the conductor for test purposes is valuable, since the magnetic properties of the copper-covered steel core in this application are not too well known. Furthermore, the mechanical characteristics of the thin copper shield employed in a self-supporting conductor of this type are also somewhat speculative. From tests that will be conducted on this experimental length, it should be possible to estimate with fair accuracy the properties of any moderate departure in the proposed design. It is generally recognized that a gaseous dielectric would effect a marked reduction (ratio of 3 to 2) in the attenuation, but at present such a design seems economically impractical.

SUBMARINE CABLE AND EQUIPMENT

Prior to 1940, gutta percha was used almost universally as the insulating material for ocean cable conductors, rubber compounds having been found generally unsatisfactory. All gutta percha cables had been made abroad, either in England or Germany. As World War II shut off the supply of gutta percha, even more effectively than of rubber, pressure for the development of a suitable synthetic insulation for ocean cable increased.

Deproteinized rubber had been used in this country with some success and is still being employed because it offers equally good electrical properties and certain improved physical characteristics as compared with gutta percha. An even better solution was achieved by English scientists in adapting polyethylene or "polythene" as it is called in England. In Europe, polyethylene compounds containing 10 to 15 percent "Vistanex" (polyisobutylene) are also employed, because of the greater ease of processing with existing equipment as compared with pure polyethylene. Since 1943, polyethylene-insulated ocean cable has been manufactured in the United States. Figure 21 shows a telescoped section of polyethylene-insulated deep-sea cable.

The first purchases of polyethylene cable by Western Union were made in 1944. At the present time, the Telegraph Company has in service approximately 800 miles of this type of cable, manufactured both here and abroad, and has on order about 600 miles of single conductor (deep-sea and intermediate types) and multiple conductor (shore-end type) ocean cable in which the conductor insulation will be polyethylene.

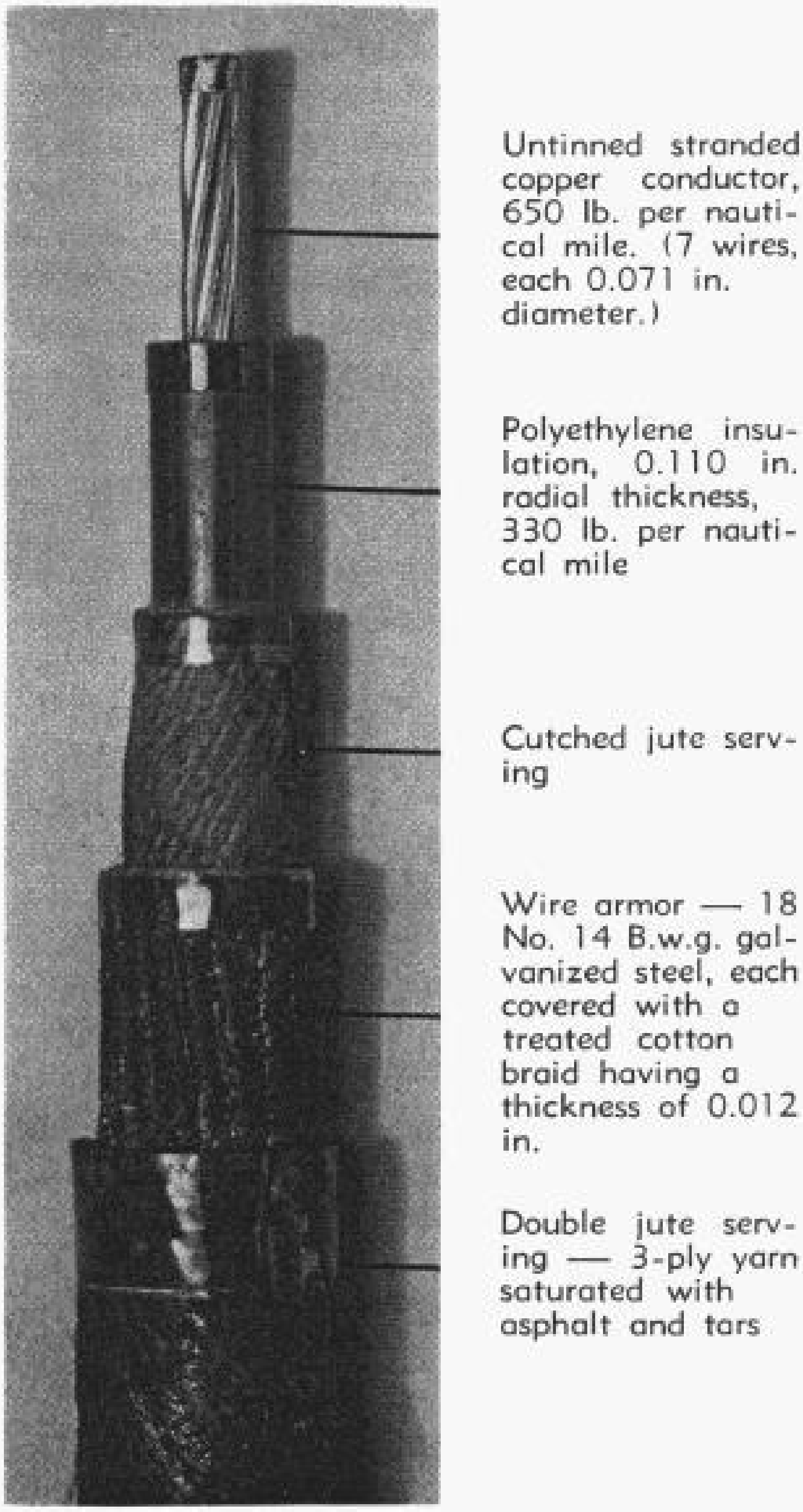


Figure 21. Deep-sea submarine cable, single conductor, Type "D"

Polyethylene compounds are more stable than gutta percha at relatively high atmospheric temperatures, such as those encountered by a cable ship in southern waters, where the cable might be subjected to the direct rays of the sun for short periods before laying. Also, indications are that polyethylene compounds may be substantially resistant to attack by the "teredo" worm, whereas gutta percha must be protected with a serving of copper or brass tape. Polyethylene compounds possess a dielectric constant of 2.2 to 2.3 as compared with about 3.0 for gutta percha, thereby effecting lower electrical losses and improved operating efficiency.

In Europe, polyethylene insulated cable costs less than the gutta percha type and, due to the present low dollar value of the pound sterling, is appreciably cheaper than any ocean cable produced in the United States. For cables manufactured in this country, the deproteinized rubber type is cheaper than polyethylene insulated cable.

Considerable data have been published by the Telegraph Company during the past two years covering the design, installation and operation of intermediate submerged telegraph repeaters in a long transoceanic cable, which represented the first venture into a previously unexplored field and which permitted tripling signaling speed in some cases, with resultant increased message capacity.

It is obvious that the equipment housed in this repeater must be designed to insure reliable, unattended, long-life operation under unusual conditions. The instrument wire required for making the electrical connections in this equipment must be provided with an insulating compound having extreme toughness and abrasion resistance to withstand the abuse during installation and service resulting from the sharp bending and flexing encountered and must have superior chemical resistance against the action of the low vapor-pressure oil in which the entire unit is immersed. Figure 22 shows the chassis of one of these repeaters, with the outer steel casing removed, to illustrate the wiring technique.

Fluorothene insulation was specified for the dielectric for the No. 18 A.w.g.

solid copper instrument wire required for this application. This insulating material was selected because of its extreme toughness (4500 psi) and chemical stability. High molecular weight polyethylene would probably have adequate chemical resistance but there was some doubt as to its mechanical stability.

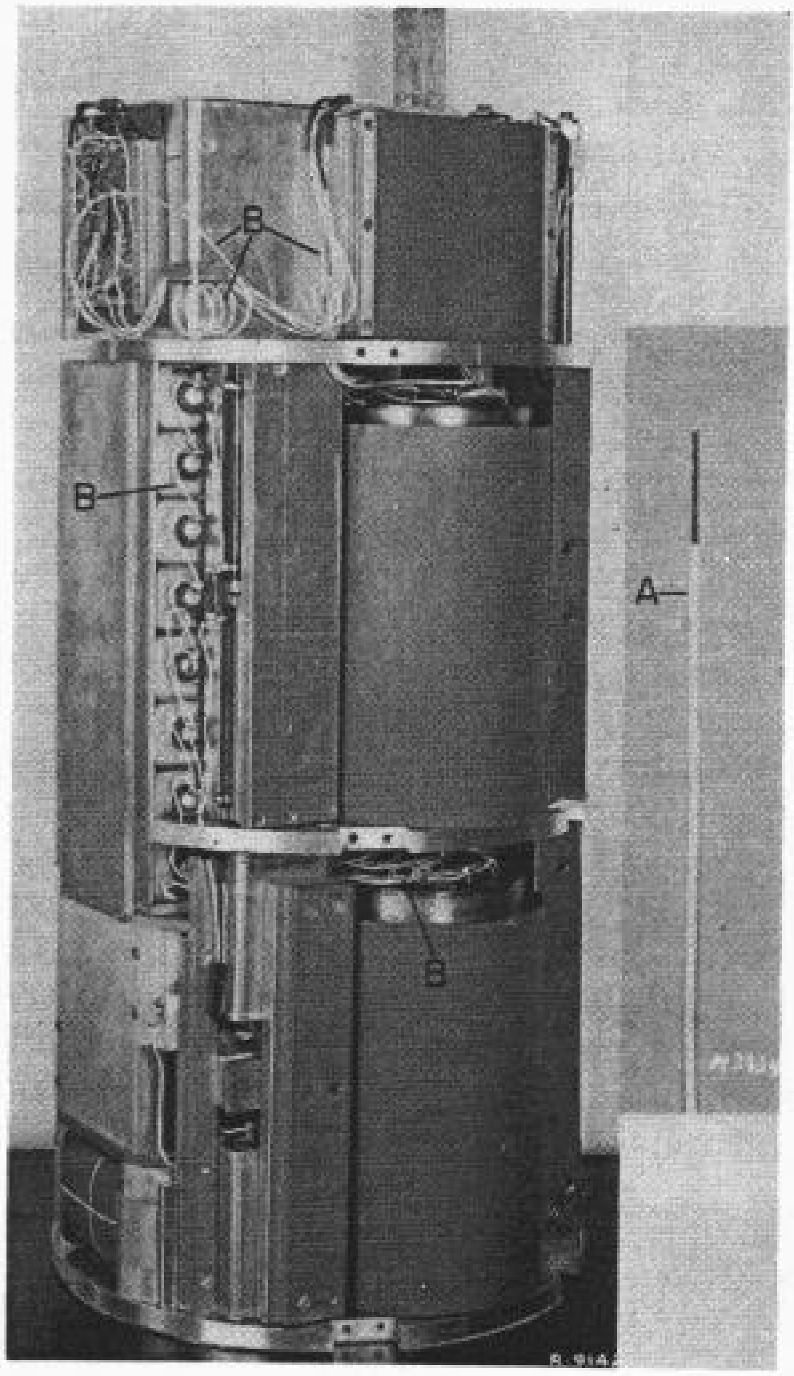


Figure 22. Submerged telegraph repeater with outer steel casing removed
"A" shows No. 18 A.w.g. solid silverplated copper conductor insulated with 10 mils of fluorothene employed for the wiring at "B"

CONCLUSION

The foregoing descriptions serve to illustrate the major uses of the newer insulating materials that have been adopted for various specific applications in the telegraph industry during the past 12 years in supplying the millions of conductor feet of insulated wire and cable installed annually. No attempt has been made to discuss all of the special services where these insulating materials have been specified with extremely satisfactory results.

In the old days, it was necessary to more or less adopt some standard wire or cable for a specific application for which it was not always fully adequate. Today, it is possible to have the bare conductor, the insulating material, and the finished cable tailor-made so as to insure efficient and lasting performance in service under almost any prescribed operating conditions. There still remain many applications where the suitability of the newer insulating materials is under intensive study and where the substitution of these compounds is being actively investigated.

New formulations and techniques, effecting reduced diameters and weights and superior physical, chemical, thermal and electrical characteristics, are continually being developed that forecast major advances of great significance in the art of insulated wire and cable design and present an ever-widening future in this field, not only in the telegraph sphere, but in all American industry as well. It would be extremely conservative to predict that even greater advances in the development of more effective wire and cable insulating compounds will be brought to light during the next decade.

The author acknowledges his indebtedness to the Technical Service Staff of Bakelite Company, Division of Union Carbide and Carbon Corporation, in proofreading and checking the technical data.

Mr. Markley's biography appeared in Technical Review for April 1953.

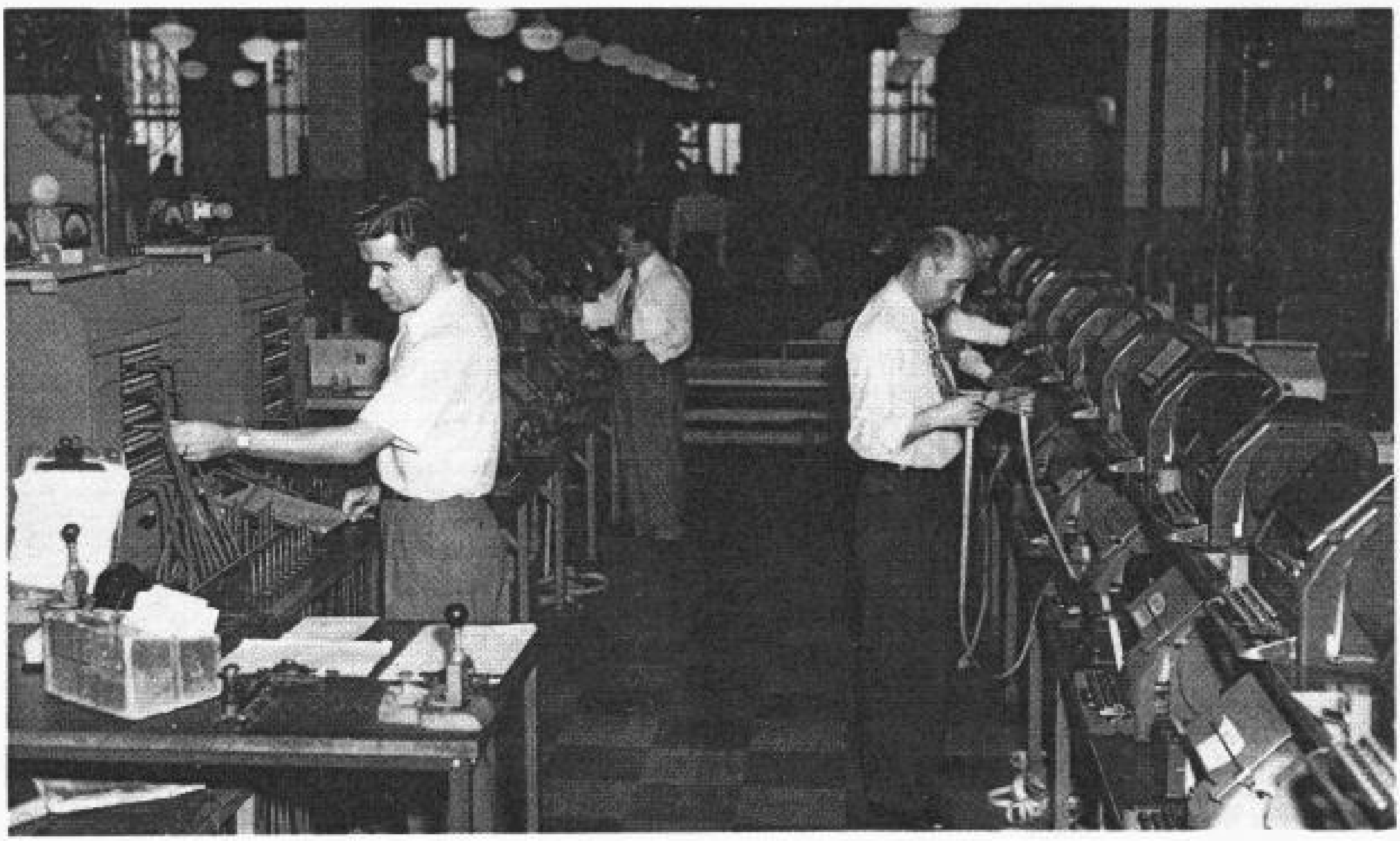
Operation of Telegraph Press Centers

J. C. GRANT

SINCE 1844 when results of the presidential election in the northern and eastern states were sent by wire from Baltimore to Washington, accurate and expeditious transmission of news dispatches always has been an important responsibility of the telegraph industry. Because of the amount and nature of the matter comprising press dispatches, the rates are appropriately lower than for most other telegraph messages; nevertheless, Western Union's wire-telegraph transmission revenue from press dispatches amounts to upwards of three million dollars, and its ocean-cable transmission revenue from that source to more than $400,000 annually.

In recent years the Telegraph Company, in keeping with its mechanization program for high-speed automatic telegraphy, has developed a convenient, practical and efficient arrangement to expedite further the handling of news dispatches. It is believed that the equipment and procedure employed may be of interest.

The arrangement came into existence in 1945, when Western Union was faced with the responsibility of handling a tremendous volume of press dispatches from the United Nations conference at San Francisco. Unlike many important events where the interest is sectional, this conference attracted newspaper representatives from all over the United States and from foreign countries. It was necessary, therefore, to utilize the company's high-speed message network to reach all points with a maximum of speed. It was arranged to set up a number of automatic channels from the site of the conference and terminate them in printer-perforators at the San Francisco main office. With additional multiplex circuits set up out of San Francisco, the press messages in tape form were relayed readily into the cross-country channels and distributed at strategic points to the various newspapers. The arrangement worked out well and provided a very fast and reliable service.



Receiving and sending equipment in the New York switching section

In 1947 it was decided that the perforated tape method would be ideally suited for handling the large volume of press from numerous baseball spring training camps in Florida, and a press relay arrangement similar to that used in San Francisco was devised. Because there were so many camp "sites" at different places in Florida, New York was selected as the tape relay center and the switching equipment, seven printer-perforators and seven distributor-transmitters, provided there. Teleprinter circuits were set up from New York to the larger cities so that press dispatches from Florida could be tape relayed at New York to the destinations. This arrangement also served its purpose well.

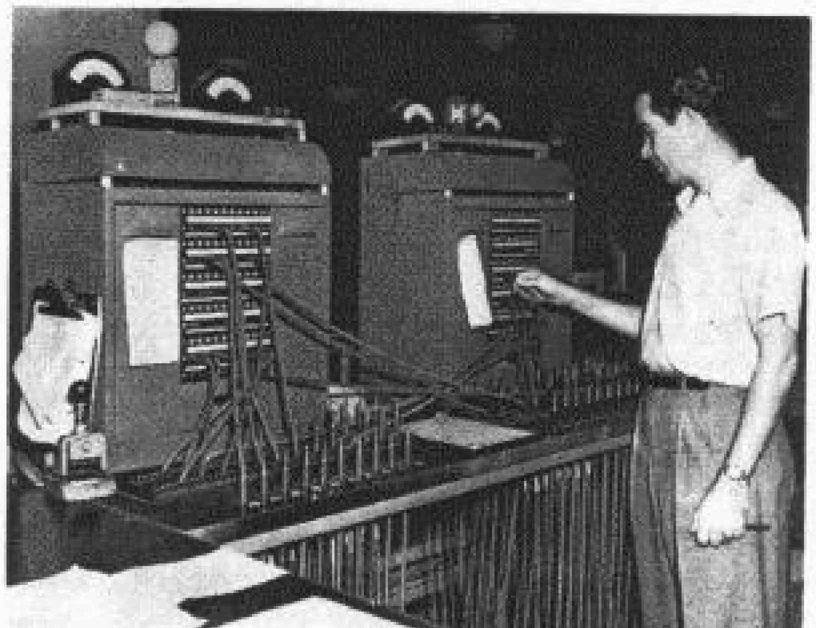
The next project was to improve the service on the large daily press file out of Washington, for which tape relay seemed to be the answer. The New York center was enlarged to 15 printer-perforator positions and on May 19, 1947, Washington news began flowing via this press center. After some kinks had been ironed out, the arrangement was quite successful and definitely proved the advantage of handling such traffic via tape relay press centers.

In 1948, the New York center was expanded to 25 printer-perforator positions and similar centers were established in Chicago and San Francisco, primarily to handle the file from the political conventions which were held in Philadelphia that year. From that time on, each expansion of these three centers was a success, and today Western Union is handling approximately 75 percent of its press file through the press centers. The three centers are connecting links on a 24-hour basis between all principal cities in the United States and provide a prompt movement of news dispatches at any hour.

Special Equipment Provided

The tape relay centers are equipped with a number of double-decked operating positions. A Type 14 printer-perforator unit and a distributor-transmitter unit are installed on the lower shelf, and a Type 2-B teleprinter and a container for sent reperforator tape are located on the top shelf of each position. In addition to the operating positions, receiving and sending concentrator turrets (cord and plug) are associated with each press center. Each of the receiving printer-perforators terminates in a cord at the receiving concentrator turret. The distributor-transmitter and the 2-B printer keyboard units at an operating position are wired in series and terminate in a cord at the sending concentrator turret. A 2-position switch located on the top shelf of each position permits placing the 2-B keyboard in either the sending leg associated with the distributor-transmitter (outgoing circuit), or in the sending leg associated with the printer-perforator (incoming circuit) as desired.

The various lines terminate in the receiving and sending concentrator turrets, and each turret jack is labeled with the call letters or name of its normal circuit termination. Additional jacks are provided to facilitate setting up temporary circuits on short notice, and these are labeled with the switchboard loop numbers. For normal operation each jack in the receiving concentrator turret is wired with both the sending and receiving legs of the facility involved. On these 1-jack destinations, therefore, reception of incoming and transmission of outgoing traffic are normally performed as separate operations. The circuits terminating in the turrets are generally duplex operated,



Incoming and outgoing concentrator turrets and cords associated with printer-perforators and distributor-transmitters (New York)

however, so on some heavily loaded circuits, separate sending and receiving jacks are provided in order to permit simultaneous reception of incoming press and transmission of outgoing press on one circuit.

Each of the printer-perforator units can be corded to any of the receiving concentrator jacks for reception of press matter from outside points. Each distributor-transmitter may likewise be corded to any of the sending concentrator jacks for transmitting to a specific destination. The 2-B printer which is wired to the receiving leg circuit associated with each distributor-transmitter is used for securing individual acknowledgments on each unit of press transmitted.

Operation of Equipment

The New York, Chicago and San Francisco press centers are interconnected with one or more circuits. Reperforator offices in Western Union's nationwide switching system have one or more channels to the press center nearest them and may also have channels to press centers in other areas. These and other distant points within the press center area having a large volume of press may normally remain corded through the receiving concentrator turret to a receiving printer-perforator unit, an arrangement which permits continuous transmission into the press center without the necessity of getting a "go ahead" for each press item.

Offices which are terminated in the turret but which are not normally corded to a receiving printer-perforator position must place a call and secure a "go ahead" notice before transmitting press news to the center.

Receiving Press at the Center

As previously stated, any office terminated in the turret but not normally corded to a receiving printer-perforator must transmit a bell signal calling notice to the center, upon which a lamp will glow above the corresponding jack on the turret. The press center supervisor cords an idle printer-perforator to this jack and advises an operator of the call and the position number on which it has been terminated. The press center operator starts the printer-perforator, sends a "go ahead" notice and covers the circuit as may be necessary during reception.

Except for those from reperforator offices, each item of press transmitted into the center is preceded by a pilot wire containing the approximate number of words, name-to, and the destination city, separated from the press message by five spaces. As soon as this pilot is received, the press center operator records on a special "Pilot for Press" form the distant office number, the word count as indicated in the pilot, time of receipt of the pilot, the point of origin, the name-to and

Concentrator unit at New York for newspapers having page printers

destination, and the receiving position number. The operator then takes the pilot form to the concentrator turret supervisor's position, stamps the next press center consecutive sent number thereon in the space provided, and gives the pilot form to the supervisor. The operator then returns to the receiving position and endorses the consecutive press center number on the printer-perforated tape at the beginning of the special.

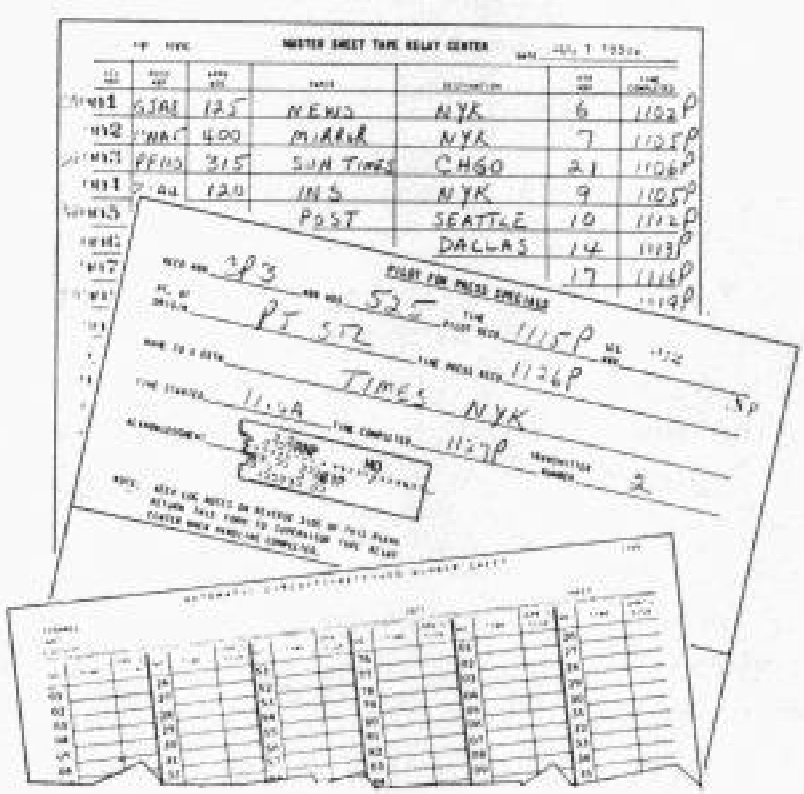
In addition to the pilot form described above, standard received number sheets are kept for each office sending into the press center. These are retained at the receiving printer-perforator position for those channels which are normally connected through the receiving concentra-

J. C. Grant started with Western Union in 1923 as a messenger in Forsyth, Ga. After learning telegraphy he worked for several railroads in the south and rejoined Western Union in 1929 at Baltimore. A year later he entered the T&R Department and worked as assistant repeater and wire chief, transferring to the Eastern Division Traffic Superintendent's office in 1936. From 1937 to 1941 he was assistant traffic dispatcher in the Chicago dispatching bureau, moving to Vice President Shute's office in 1941. While in the T&R and Dispatching group in the Vice President's office, he became interested in the handling of press and has devoted considerable time to this phase of the company's operations. Mr. Grant is General Press Representative and personally supervises the movement of press traffic at the major events throughout the country.

tor turret on a tabled-out basis. For those channels which are not tabled out the number sheets are kept at the turret supervisor's position for use as needed. Any omitted, duplicated, or errored sequence of numbers is corrected with the distant office involved by "RQ" or other means as prescribed in existing automatic and reperforator operating instructions.

Transmitting Press Dispatches

The press center turret supervisor transcribes on a "Master Sheet" the received number, approximate word count, and name-to and destination, opposite the next local sent number which is stamped at the beginning of the day in the left-hand column of the master sheet. The press center consecutive sent number stamped on the pilot must agree with the local number indicated on the master sheet. The supervisor then determines if the distributor-transmitter is idle at the position on which the press special is being received. If the distributor-transmitter and the desired destination circuit are idle the supervisor completes the necessary cording, endorses the distributor-transmitter number on the master sheet and on the pilot form, and returns the latter to the position where the press is being received. If it is necessary to transmit the press from a distributor-transmitter other than the one at the receiving position, the operator manually carries the tape to the distributor-transmitter position indicated on the pilot form when the press special has been completely received.



Master Sheet, Pilot for Press Specials, and Received Number Sheet used in Telegraph Press Centers

Where possible, transmission is started to the destination or next central office immediately following the return of the pilot form to the receiving position which usually averages about two minutes. The operator begins transmission by manually transmitting the press center call letters and the local number stamped on the pilot. Any reperforator or other numbers appearing in the perforated tape are included in transmission to the destination. The operator observes the tape in transit and corrects any error that may be detected by stopping the distributor-transmitter and inserting corrections with the manual keyboard of the 2-B teleprinter.

When transmission is completed, the operator secures an acknowledgement on the 2-B teleprinter and attaches it to the pilot form in the space provided. The sent tape is then rolled up and placed in the sent tape container on the position from which it was transmitted. The "time completed" endorsement is made on the pilot form and the form returned to the supervisor's position. The supervisor completes the handling by recording time completed on the master sheet and disconnects the distributor-transmitter from the concentrator jack.

All of this bookkeeping may appear to be unnecessary but the method was devised after numerous experiments to eliminate any possibility of misplacing tapes. Since its adoption no "lost" tapes have been reported, which is one of the many factors that give the Telegraph Company prestige with its fourth estate friends. Continued improvement in press center techniques is bound to be reflected in further growth of revenue.

Patents Recently Issued to Western Union

Electronic Code Telegraph Reading and Repeating System

W. S. W. Edgar, Jr.
2,641,641—June 9, 1953

An electronic reading or comparing circuit detects the presence, in transmitted signals, of any predetermined character or series of characters. This arrangement is adaptable to the reading or comparison of code switching signals for determining or checking an automatic switching operation, for detecting supervisory signals or for the control of any mechanism in response to a predetermined code.

Electronic Code Telegraph Reading and Repeating System

W. S. W. Edgar, Jr.
2,641,651—(A division of 2,641,641)
June 9, 1953

An electronic selection circuit converts multiplex signals into simplex or start-stop signals and eliminates blank signals from retransmission. Code impulses are transmitted to the line by a trigger circuit which converts 5-unit code to 7-unit code. Repetition of blank signals is prevented by applying a large positive bias to the grid of a trigger tube to lock the trigger circuit.

Facsimile Apparatus

R. J. Wise and R. D. Parrott
2,646,335—(A division of 2,469,423)
July 21, 1953

A facsimile scanner embodying a vertically disposed transparent drum inside which the loosely rolled message sheet is dropped and closure of a covering lid initiates scanning. To hold the sheet against the inner surface of the drum a large spiral spring of a few turns and extending the length of the drum, with one end fixed to the drum and the other to the drive shaft, expands against the sheet as rotation starts.

Sheet Wrapper Mechanism for Facsimile Machines

C. Jelinek, Jr.
2,647,034—July 28, 1953

An improvement in mechanisms for wrapping a sheet of paper around circular end supports into a rigid cylinder so as to permit inside scanning by either a stylus or an optical ray. A thin metallic sheet wrapper having a shaped end forms and encloses the sheet into the cylindrical form.

Telecommunications Literature

FILTER DESIGN DATA FOR COMMUNICATION ENGINEERS—J. H. MOLE—John Wiley & Sons, N. Y., 1953. 252 pp., $7.50. This book is a notable addition to the literature on electric wave filters. It differs from many of the available treatises by numerous and convenient charts, some of which accomplish in one reading what would require several trial and error stages by more conventional methods. The use of the first twelve pages to orient the reader in the terminology and plan of the book is another virtue and makes it easy to follow any section of interest without a long search for definitions. Three other particularly valuable chapters are those titled: Junction Losses, The Effects of Dissipation, and Tolerances on Element Values. The charts for composite low-pass and high-pass filters are especially valuable time savers in all but the occasional case where the ready-made selection of *m* values does not provide the desired terminating section impedances. Of course each individual designer prefers his own charts but he may well be inspired to produce better ones after seeing Dr. Mole's contribution to the art.

It is unfortunate that the author did not include the alternative four-element band-pass sections using one three-element arm since they lend themselves readily to reactionary transformations and permit either inductors or capacitors to predominate as the designer wishes.—R. C. TAYLOR, Engineer, Transmission Research Division.

RADIO AND RADAR TECHNIQUE—A. T. STARR—Pitman Publishing Corp., London, Toronto, N. Y., 1953. 812 pp., $15.00. The dollar-outlay for this new British-produced encyclopaedic guidebook to the physics and mathematics of "radio", broadly defined, is justified for the teacher, scientist, practicing research engineer, and technical library. It purposely omits information readily obtainable in elementary undergraduate textbooks; and, devoid of anything but the barest mention of specific applications, packs the broad scope of its title into 510 pages on the physics of communication and electronics, followed by 281 pages of mathematical appendices, and by author and subject indices to the entire volume. The compression-ratio of the work is enhanced by the copious use of tiny but adequate diagrams and graphs. There are no pictures and no tabulations of data.

The seven chapter headings are: "Methods of Communication and Physical Limits" (modulation methods, noise, information theory, pulse and Doppler radar); "The Electromagnetic Medium" (propagation, guided waves); "Microwave and Short-Wave Techniques" (discontinuities, couplers, transformers, resonators, filters, measurements); "Antennae" (dipoles, arrays, horns, lenses, reflectors); "Valves" (emission, discharge, high-frequency effects, klystron, travelling-wave, magnetron, pulse-modulators); "CW Circuit Technique" (network theory, transfer impedances, amplifiers, frequency modulators); "Waveform Circuit Technique" (waveform amplifiers, modern pulsing methods).

Relegation of the mathematics to 30 appendices accelerates the pace of the main text. The appendices include such subjects as Fourier analysis, Bessel's functions, vector analysis, Maxwell's equations, Heaviside analysis, and Laplace transforms; also extensive treatment of modulation, noise, radiation, space-charging effects, and networks. —I. S. COGGESHALL, Director of Planning, International Communications.

BASIC ELECTRONIC TEST INSTRUMENTS — RUFUS P. TURNER—Rinehart Books, Inc., N. Y., 1953. 254 pp., $4.00. For the electronic technician this book fills a need for a treatise on test instruments in television, radio and general electronics. Sufficient basic treatment is given to establish fundamental principles, their operation and construction, and impart a working knowledge of test instruments in simple nonmathematical terms. A comprehensive list of instruments is discussed which is most helpful to the engineers, the service man and the hobbyist. This book will enable the reader to select from the mass of available test equipment those instruments which are most useful for his particular requirements.—W. D. CANNON, Ass't to Transmission Research Engineer.