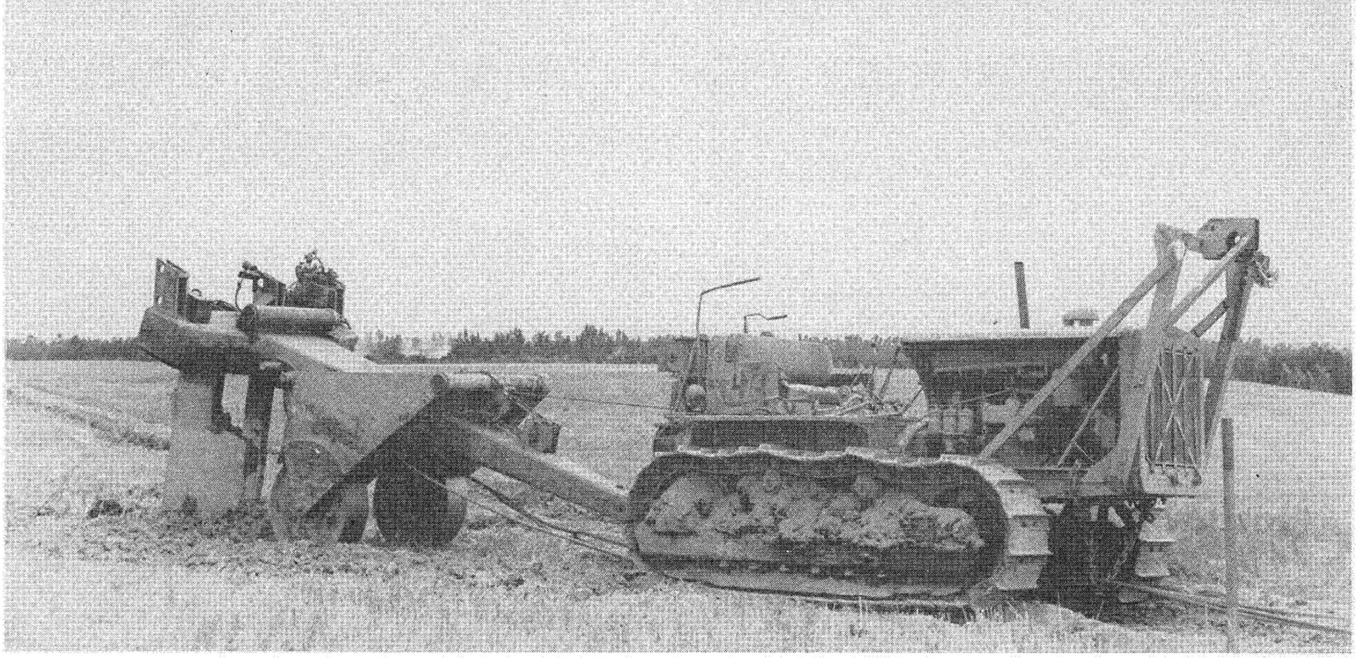


A special type of rooter plow used in opening a slot and later placing a cable six feet deep. The heavy steel ropes are attached to tractors outside the picture.

Buried Voice Channels

By MAX B. ALCORN

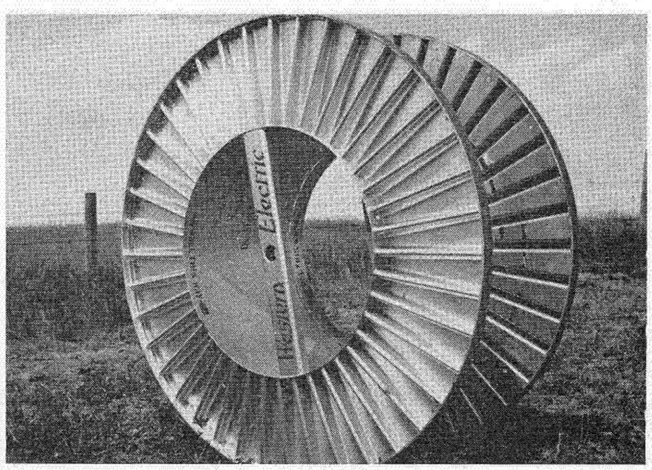
BURIED telephone cables are a logical development from the needs of telephone service and the advancement of telephone art. In the early days of telephony, the need for a cable with many wire voice channels to carry the voice currents within communities was imperative since the practical limit of bare wires on a pole line was soon reached in congested metropolitan areas. After a number of attempts, including the placing of copper wires within individual glass tubes, a cable was developed which provided satisfactory service. Following the pattern set with aerial wires, cables were placed exclusively on poles at first. Then as the telephone system grew, the aerial cables around large central offices became so numerous that they presented a new problem of congestion. The answer, of course, was to place the cables underground. Conduits of various types were used in order to provide for future cables without making a new excavation for each cable. This course of development through the years has resulted in the extensive and expensive underground network of conduits and cables found in all large cities today.

Between the large cities or toll centers somewhat the same history has been repeated in a slightly different form. First, open wire lines carried the messages of those few people who wished to talk long distances. As the city-to-city traffic increased, it became obvious that the number of wires between cities could not economically be increased sufficiently to provide circuits for all those who wished to talk at one time. Carrier systems (a detailed discussion of which is beyond the scope of this article) were developed to provide two or more voice channels per pair of wires. Even though it became possible to transmit as many as 16 voice messages and two telegraph messages simultaneously over one pair of wires, the demand grew to such extent that the use of open wire was no longer economical. Again cable replaced open wire on congested routes.

Cable is less subject to service interference than open wire. Such interference may be the result of storms, accidents, or physical wear. Underground cable, too, normally provides greater service insurance than aerial cable. However, the placing of underground cable is much more expensive because of the conduit system, the resultant short cable lengths, and the high splicing costs involved. As there is less likelihood of service interruption on underground cable than on aerial cable, the logical development in reducing costs was to eliminate the conduit system and place the cable directly in the ground. The ultimate in this direction, of course, is the burying of the cable in the ground without making any excavation in the ordinary sense of that word.

TYPES OF BURIED CABLES

A number of types of buried cables have been produced for different purposes and different conditions. The simplest type of buried cable is made of paper-covered copper wires twisted in pairs and enclosed in an extruded lead sheath which is in turn wrapped in asphalt-impregnated jute. To prevent damage by rodents, particularly gophers, a steel tape about 0.01 inch in thickness may be wound as a helix over the cable sheath before the jute covering is applied. A heavier steel tape is used on another type of cable to furnish more mechanical protection against possible damage from future excavation operations. Both of these steel tapes provide some measure of shielding against electrical induction. Where stray ground currents are known to exist or are expected, an



Stamped and welded sheet metal cable reel. A type commonly used for telephone cable.

insulating thermoplastic coating may be used over the steel tape. Otherwise, electrolytic action may produce holes in the lead sheath at the points where the current leaves the cable and returns to the earth. When the insulation is ineffective or damaged, it may be necessary to maintain the sheath at a negative potential relative to the surrounding earth through the use of "cathodic protection" such as is used on oil or gas pipe lines.

The newest type of buried cable is the so-called coaxial cable. The coaxial cable has conductor pairs which consist essentially of single copper wires in hollow copper tubes. A pair of coaxials can now be equipped to transmit nearly 500 simultaneous conversations by means of different carrier frequencies.

SELECTION OF ROUTE

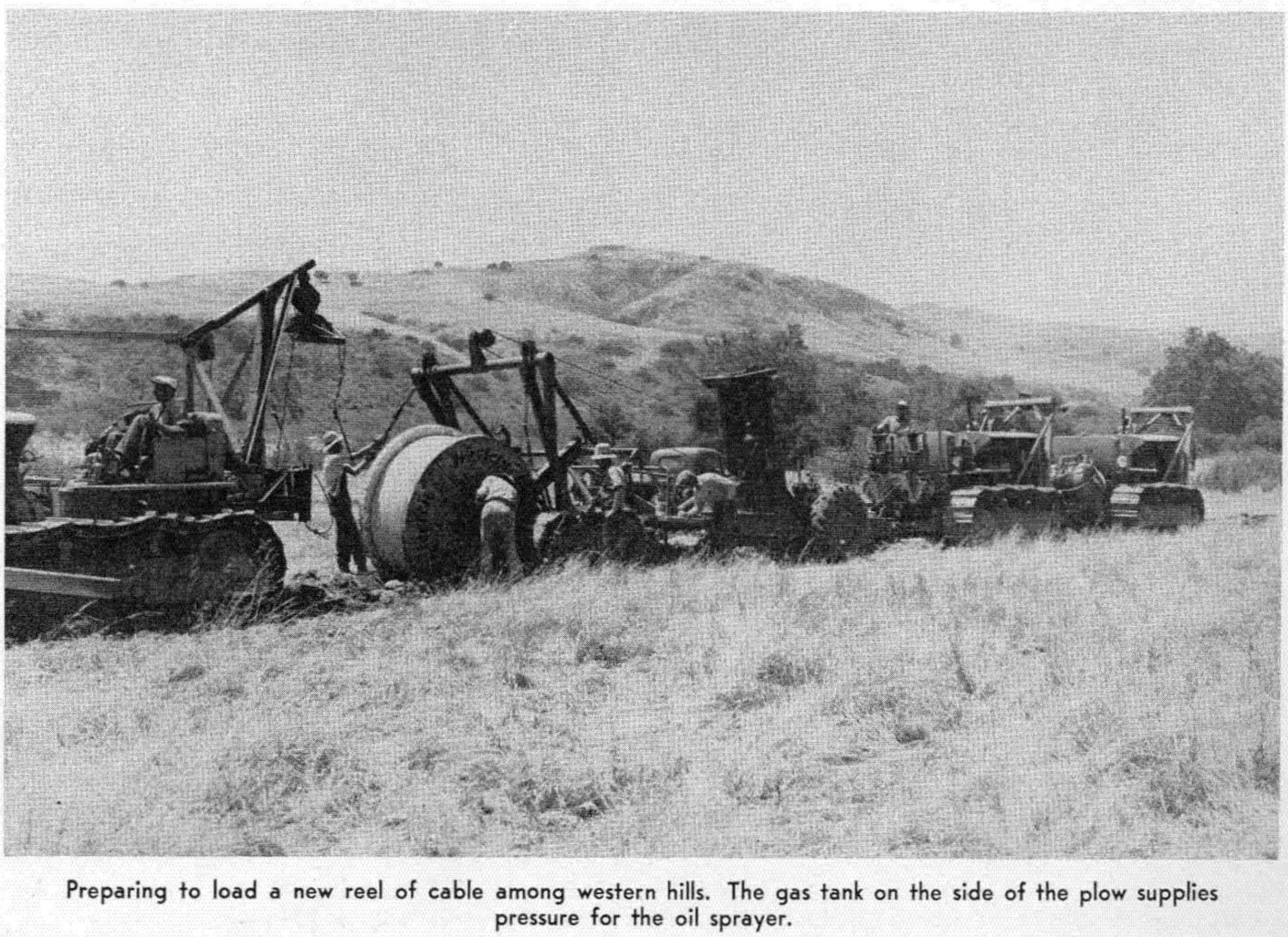
A number of factors are involved in the selection of the route for a buried toll cable. Such features as accessibility, terrain, right-of-way, cost of construction and maintenance, soil, permanence, other utilities, hazards, etc., must be given full consideration. After a study of available maps, an aerial survey is sometimes made to determine the most feasible route. Aerial photographs, with the modern aids to reading them, have proved to be valuable in engineering cross-country cables. With the approximate route traced on the aerial photograph mosaic, the actual location for the cable is explored and staked on the ground. The normal right-of-way is about 15 feet wide, which allows ample room for plowing in several cables without endangering existing cables. Buried cables may be placed by hand or machine trenching or by plowing. The latter method is the most economical for long toll cables.

CABLE PLACING PLOW TRAIN

The cable plow train consists of several heavy duty tractors, the cable placing plow, and one or more cable reel trailers. The plow used in placing buried cable is essentially a two-wheeled vehicle with a flat share or blade enclosing a tube through which the cable travels. The tube is about three and three-quarters inches wide and terminates at the rear of the share near the base. In principle, the cable slides through the tube and lies on the bottom of the furrow or trench made by the share as it is pulled through the earth. One or two cables one to two and one-half inches in outside diameter may be placed in the same trench at one time. However, the equivalent of four cables may be plowed in when changing reels, since the lead ends of the two new cables are clamped to the tail ends of the two cables already placed. (The overlap of the two cables provides the ends for splicing later.) Besides the four cables, the tube is equipped to pass as many as three copper shield wires at different depths in the trench.

Pneumatic tires normally are used on the plow, but when soft marshy ground is encountered skid plates may be attached and the plow pulled through as a sled. Cables have been plowed into the bottoms of small rivers by actually towing the plow across under water.

If the ground is hard or if the cable is to be placed deep, it is necessary to make preliminary cuts through the earth ahead of the plow train. These cuts can be made by the same type of plow as that used to place the cable or by a special rooter. Occasionally it is necessary to make several passes over the same route in order to cut the trench to the proposed cable depth. A trench six



Preparing to load a new reel of cable among western hills. The gas tank on the side of the plow supplies pressure for the oil sprayer.

feet deep in rather heavy soil required five 110-horsepower tractors to pull the rooter plow. Where the going is easy, the rooter and cable placing plow may be combined in one train and the cable placed in one trip over the route.

The tractors are usually of the 110 horsepower Diesel-engine type, weighing some 40,000 pounds and capable of a maximum drawbar pull of about 30,000 pounds on the lever. One tractor is attached to the plow through a shear pin with a breaking point of 72,000 pounds. This tractor is usually equipped with a four-drum winch, each drum independently controlled and capable of a 6,000 pound pull. Steel ropes on these drums are used to raise and lower the plow share, load cable reels on the trailers, etc.

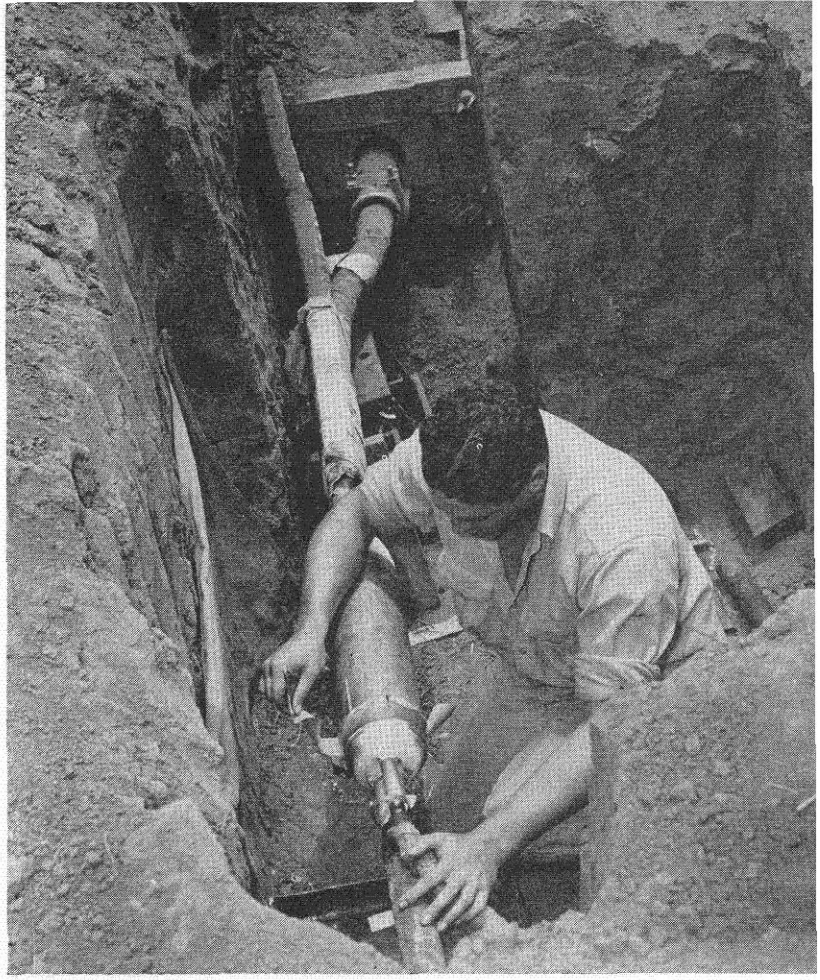
Additional tractors usually are required to pull the plow. When rooting, one tractor may aid by pushing the rooter from the rear. Extra tractors on the front of the train are connected with individual one inch or one and one-eighth inch steel ropes. One tractor is equipped with a large heavy duty winch with a capacity of 70,000 pounds. This winch is used to pull the train across soft terrain. Occasionally situations are encountered which will not provide sufficient traction to move the train or in extreme cases, even support the heavy tractors. In such terrain, the winch tractor is moved ahead to solid ground, anchored, and used to pull the train across. Train speed in either rooting or cable placing is about that of a brisk walk, approximately two and one-half miles per hour or lower. Under good conditions three miles of cable can be placed in an eight-hour day.

The cable reel trailers are towed behind the plow and the cable rolled off the reel directly into the tube of the plow share. The trailers are equipped with track-type treads in order to facilitate negotiation of any type of soil. Cable reels are loaded onto one type of trailer with a winch rope from the tractor winch to a boom which lifts the reel into place. In another type, the trailer has a "jack knife" action which in operation places the saddle under the spindle through the reel and raises the reel off the ground when the pinned members are straightened out again.

The type and size of the cable reel depend upon the type, diameter and weight of the cable. Some reels are sufficiently large to carry approximately 4,000 feet of cable, making a total load of about 10,000 pounds. Wood reels are being replaced with steel reels. One type has the reel rims formed from welded rolled steel shapes, while a second type has sheet metal rims with pressed ribs. Reels of all types make many round trips across the United States from the Eastern cable factories to the Pacific Coast. In prewar times much cable was shipped by boat through the Panama Canal to the western states.

The friction between the impregnated cover on the cable and the plow share tube is sometimes relatively high. This is increased by the inertia of the reel and the friction of the reel turning on the spindle. When two cables are being placed, the one on the inside of the curve going through the plow may show a tension as high as 5,000 pounds as it passes. Such a high value is quite undesirable from both the mechanical and the electrical points of view. To reduce the tension below a safe maximum of about 1,000 pounds, oil is sprayed on the cable as it enters the plow share. Nitrogen or compressed air is used with a pressure feed oil tank to spray approximately four gallons of oil on every mile of cable.

Since the rooter and the plow disturb the soil for some distance on each side of the trench, a mold board is sometimes attached underneath the cable reel trailer to force the earth back into and over the trench. The auxiliary tractor which delivers the cable reels follows the plow train and compacts the earth under its tracks as well as providing extra motive power when required.



Splicer finishing a "wiped joint" over a splice. Cables bending away from the main cable are stubs to loading coil cases which are buried in their shipping boxes. The splice will be covered with a metal mesh and a protective covering before the pit is filled.

EQUIPMENT BURIED WITH CABLE

After the sections or reel lengths have been plowed into place, pits are dug at the junction points and the cable spliced together to form continuous circuits. Elaborate and accurate electrical tests are made at certain splices to assure good transmission characteristics of the circuits when the whole project is completed. At the splice points various supplementary equipment may be added to the cable, such as gas pressure apparatus, electrolysis test wires, or loading coil cases. All of the equipment buried is coated to protect it against the action of soil chemicals. When the work in a pit is finished, the soil is replaced and the location marked with a monument.

Monuments or markers are placed along the route of the cable to identify its position. This is necessary where the cable cuts across country in order that its location may be determined readily by those excavating in the vicinity of the cable and by cable maintenance men in case of trouble. Electrical means of locating the cable are sometimes used, but even then the markers are helpful because they reveal the line of the cable and provide reference points. Vacuum tube equipment is also available to determine the location and the depth of the cable within a few inches, if precise information is required.

CURRENT ON CABLE SHEATH

The normal depth of plowing is approximately 18 to 36 inches. However, several sections have been placed at a depth of six feet. The depth is determined by the type of surface operations which may be expected and the

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prepared by E. L. Furlong, and an exceptionally fine skeleton (*Figs. 1 and 2*) the first of its kind, has been mounted by William Otto, preparator in Vertebrate Paleontology.

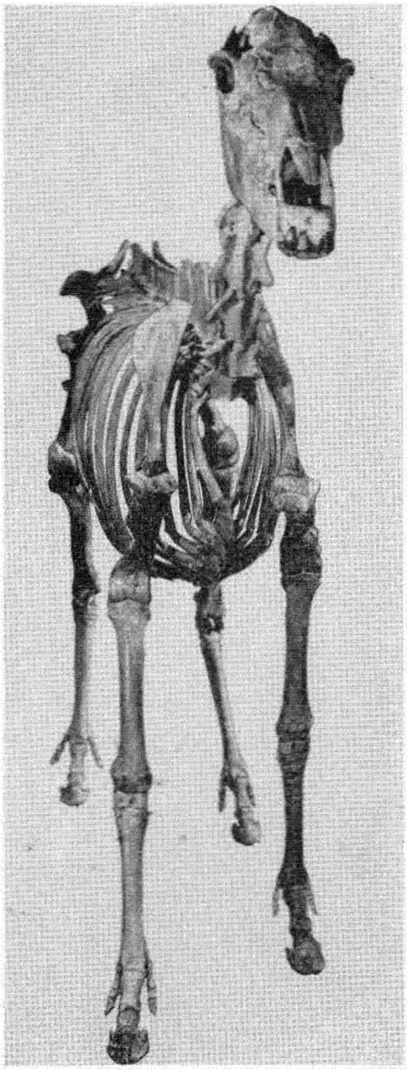

FIG. 2

The skull in this animal is of an adult male. The skeleton as it stands compares in size with that of the Burchell zebra, being a trifle over 3 feet 9 inches, or approximately 11½ hands, tall at the withers. However, the proportions of this Pliocene horse are noticeably different from those of modern *Equus*. A striking difference is seen immediately in the small size of the head. In the fossil specimen the skull is distinctly smaller in relation to the size of the body than it is in the zebra. While the body is proportionately as long as in the Burchell zebra, the sides are flatter, the chest appearing narrower and "slab-sided." The limbs are, likewise, differently proportioned, the principal bones of the fore and hind feet being very much longer in relation to the arm and thigh bones, respectively, than they are in the zebra. This extra length in the feet of *Neohipparion* caused its limbs to be some six per cent longer, in relation to the size of its body than even the highly-specialized limbs of the modern race horse. The side toes are beautifully preserved, and, as shown in the skeleton, are distinctly shorter than the middle toe. They do not touch the ground. The hoof of the third or middle digit is larger than in the zebra, and shows a small median fissure. In running, *Neohipparion* could probably exceed the speed of the zebra, at least for short distances.

The mammalian associates of *Neohipparion leptode*, when it roamed the grasslands in what is now the arid Thousand Creek region of northwestern Nevada, were the more progressive horse, *Pliohippus*, short-legged rhinoceroses, large camels, curious twisted-horned antelopes, peccaries, cats, dogs, badgers, and rodents.

Progress with Roads

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measuring space with time. Perhaps we are confronted with the need of more highly developing a mental process by which, given walking, driving and flying speed, we may arrive at the minimum of time for a given journey. Will this result in improving and increasing our mental ability, with beneficial progress?

PROSPERITY—DEPRESSION

We have seen that many of the notable civilizations of early history, the Egyptian, the Carthaginian, the Chinese, the Incan, and the Roman, during the height of their power, built hard surfaced roads over which the civilizing influences from any portion of the empire could flow to any other portion. All of these early civilizations reached a peak and declined, their road systems deteriorating with them. It is impossible to determine which was the cause and which the effect, but it is interesting to note that a decline of one element accompanied a decline of the other.

In the early 1930's the United States experienced the worst depression in its history. The depression was more than nation-wide; it was world-wide, and many able students marked it as the beginning of the end of our modern civilization. Road building decreased materially in the United States in this period. There was very little new construction, and many existing roads were allowed to deteriorate through lack of maintenance. Later, a definite increase in road building occurred, which in turn, was greatly slowed by war activity. In spite of this check, some major projects, such as the Alaska and Pan-American Highways, have been materially rushed forward, and we have a very practical hope in the years to come of greater and more extended international highway travel than ever. It has often been contended that these international highways may constitute one of the greatest civilizing influences of modern times, and it seems not too much to expect that we may still progress with roads.

Buried Voice Channels

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amount of protection desired against possible damage to the cable. Even at these depths some little trouble is caused by lightning in those areas where electrical storms are common. A number of installations have been made in which one or more copper lightning-protection or shield conductors have been buried above the cable, but these have not been completely effective. Some consideration is now being given to the use of a copper sleeve covering the normal lead sheath of the cable itself.

To determine the existence of current on the cable sheath, a recent installation was equipped with test points approximately every 3,000 feet. At these locations, two wires permanently attached to the cable sheath, 10 feet apart and insulated from the earth, were brought to the surface and terminated in a housing for the convenience of the tester who makes periodic checks of the current flowing on the cable sheath. Periodic tests are necessary, for, despite the fact that the cable is buried, there are a number of causes for changes in the effectiveness of the insulation, not the least of which are the rodents or pocket gophers previously mentioned. Only that part of the United States roughly east of the Mississippi River, exclusive of an area in the Southeast, is free from these pests.

GAS PROTECTS CABLE FROM MOISTURE

Since the paper insulation of the cable conductors readily absorbs water, every effort must be made to exclude moisture. Even a small amount of moisture reduces the insulation resistance and a little bit more may short-circuit two or more conductors and put circuits out of service. To protect the most important cables from the entrance of moisture and to provide a means of detecting a sheath break before an interruption of service occurs, the cables are frequently maintained under gas pressure. Nitrogen gas, free from moisture, is used since it is inert, non-toxic, and relatively inexpensive. An underground cable is normally maintained under nine pounds per square inch pressure. Through a Bourdon tube and electrical circuit arrangement, an alarm is sounded in the control office when the pressure in the cable has dropped to six pounds per square inch because of a leak. By making accurate mercury-manometer measurements of the pressure in the cable at a number of points and plotting a pressure gradient curve, maintenance men can determine the location of a leak fairly closely. This method of locating sheath breaks is used when the nature of the break is such that no circuits within the cable have been interfered with. If the normal electrical condition of any circuit in the cable is changed, electrical tests provide a much faster means of determining the location of the trouble. Very small holes leak gas so slowly that many hours, possibly several days, may elapse before the pressure has dropped sufficiently to actuate the gas pressure alarm. However, gas escaping through the sheath break prevents the entrance of moisture, if the hole is small and the water pressure on the cable is less than that of the gas. A desiccant such as anhydrous calcium sulphate or colloidal silica is used to absorb moisture from the paper conductor insulation when a sheath opening is made for splicing or maintenance purposes.

SURFACE WATER ALSO PROBLEM

In hilly or rolling country it is necessary to restore the right-of-way after the passage of the plow train to its original condition as nearly as possible. The cut made by the plow share disrupts the normal drainage and creates a soft channel through the earth. Check dams of many types of materials, earth fills, contour plowing, new channels, etc., may be resorted to in order to retard erosion and force the run-off water to follow some course other than along the cable. Quick growing grasses and other vegetation are also used to hold the soil in place. Protective measures may be required for several years after the ground has been disturbed before the situation is again stabilized.

When ravines, streams, marshes, rivers, bays or similar obstacles must be crossed, a number of different methods and types of construction may be used. In certain instances, as has already been mentioned, the cable may be plowed beneath the surface of stream beds. In other cases, one of the many types of submarine cables may be the most practical means of crossing. Anything from a string of floating oil drums to a specially equipped boat or barge may be used in placing submarine cable, depending upon the conditions. Sometimes, instead of using a submarine cable, a land type cable is attached to a bridge or placed on a self-supporting structure of its own. The method of crossing chosen is based on a study of possible causes of damage to the cable, hazards to the continuity of the circuits, economics, and future plans of the public and the telephone company.

BURIED CABLES FOR LONG DISTANCES

Buried cables are particuarly adapted to long toll routes involving many circuits. They are used across mountains, plains, agricultural land, and desert areas. Sometimes direct routes are the most economical; hence the cable may not follow highways or railroads but cross country after the fashion of the crow and the airlines. A strange combination of tractors, heavy trailer equipment, and cable reels, far from the beaten path, may seem at first to present an incongruous scene, but it may be just another plow train burying telephone cables for the most progressive telephone system in the world and for the most talkative people in the world.

Steel in the War

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Specifically with respect to the West Coast, there are now several steel producing plants and many steel fabricators with up-to-date mills and shops which have the latest equipment and facilities for the production of steel and its products. Columbia's new rod mill at Pittsburg Works is considered to be the finest mill in the United States at present. Geneva Steel Company at Provo, Utah, and Kaiser Steel Company at Fontana, California, both have the latest equipment in structural mills. All up and down the Pacific Coast, there are a great many steel, iron, and non-ferrous foundries which can produce practically every type of casting.

With respect to steel fabrication, it may be said that products of practically every type are produced on the Pacific Coast, some in large and others in small quantities, including automobile assemblies, road building equipment, stoves, refrigerators, ships, hydraulic equipment, and many others.

The steel industry realizes that the postwar period will be a challenge. It has great productive capacity which must operate at a reasonable rate to avoid excessive overhead cost and to compete with other metal industries which now also have great productive capacities. Aluminum, magnesium, and plastics are all potential or active competitors with steel in certain applications. New uses will be found for all of these materials, and it is possible that the peacetime markets will be expanded to make them serve the requirements of mankind in ever increasing measure.

ALUMNI NEWS

CALIFORNIA TECH CLUB, WASHINGTON, D. C.

THE Washington California Tech Club held a dinner meeting on Thursday, November 16, at the 2400 Hotel with 75 members and guests present. Dr. Robert A. Millikan, chairman of the Executive Council of the California Institute of Technology, and Dr. Frank B. Jewett, '98, were guest speakers. The meeting was planned to coincide with Dr. Millikan's attendance at the Fall Meeting of the National Academy of Sciences of which Dr. Jewett is president.

Both speakers discussed the role of science and engineering in modern war. Dr. Millikan told of the Institute's enormously expanded program for the development and production of the instruments of war, including rockets and anti-submarine equipment. Dr. Jewett, who is a member of the National Defense Research Committee of the Office of Scientific Research and Development, gave a comprehensive picture of the nation's war research organization.

Brief talks also were made by Dr. R. W. Sorenson, head of the department of Electrical Engineering, and by Dr. Theodore von Karman, director of the Guggenheim Aeronautics Laboratory, both of whom are presently engaged in war research work in the East. Dr. Jewett was introduced by Dr. Richard C. Tolman, Dean of the Graduate School, who now is vice-chairman of the N.D.R.C. The meeting chairman was Frederick J. Groat, '24, president of the California Tech Club of Washington. Club Secretary: Baker Wingfield, '28, 613 Knollwood Drive, Falls Church, Virginia. Telephone: Falls Church 2110-J.