SOME RECENT DEVELOPMENTS IN
LONG DISTANCE TELEPHONE CABLE CONSTRUCTION

A thesis submitted to the faculties of
The School of Engineering and the Graduate School
The University of Kansas

For

THE DEGREE FOR ELECTRICAL ENGINEER

By

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1930

PREFACE

The rapidly increasing use of long distance telephone service is due in a large measure to the speed with which connections are established and to the dependability of the service furnished. Quick connections result both from improved operating methods and the provision of sufficient circuits to avoid delays, even during the hours when telephone traffic is at a maximum. Dependable service follows from improved materials and methods of construction.

Both speed and dependability have been increased through the use of long distance telephone cables. In the more thickly populated sections of the United States, toll cables, both aerial on pole lines and underground in clay conduit, have been used for many years. Recently, the installation of such types of telephone plant has increased tremendously. Coincident with such development have come improvements in methods of construction which involve radical departures from the usual types. Among these are the use of pre-cast concrete manholes, the "splaying" of duct entrances at manholes, and specially designed manholes for "loading coils". Two new types of underground telephone cables have been designed. One is a cable enclosed in fiber duct without the usual concrete protection; the other, a cable protected by an armoring of jute and steel tape and laid directly in the earth without conduit. In the installation of such cables, manholes are omitted except at intervals of six thousand feet where creosoted wooden boxes are substituted for the usual concrete manhole.

The economical installation of the new types of buried cables and the handling of pre-cast manholes and duct splays required the use of machinery to a very large extent. Much of this labor saving equipment has been especially designed for these types of cables. Probably the most revolutionary single machine is one which excavates, lays the cable and backfills the trench in one operation.

Another new departure in toll cable practices is the use of nitrogen gas in detecting openings in the lead cable sheaths. Automatic alarm systems give notice of such leaks and repairs can generally be made before serious interruptions to service occur.

It is the writer's good fortune to be associated with one of the larger telephone companies which has been the pioneer in introducing many of the newer practices and types of construction. He has had considerable to do with the development of a number of these and in view of the interest aroused in other telephone companies, it is believed a description of them will be of value not only to telephone men but to others interested in engineering work. It is with this thought in mind that this paper was written.

St. Louis, April 1930

Clifford W. Nystrom.

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Telephoning over distances of hundreds or even thousands of miles has become so common as to occasion little, if any, comment. This space and time saving convenience is not the result of chance or coincidence but of painstaking study, laboratory investigations and extensive field trials of almost countless kinds of materials and methods.

The early connections between cities were made by bare copper wires supported on cross-country pole lines. The open wire toll line has in the past been the means of connecting distant cities and doubtless will continue to have a broad field of use. It is not usually considered good telephone practice to build pole lines to carry more than fifty or sixty wires. For the heavier lines, the size of poles and the necessity of spacing them at comparatively short intervals make their cost rather high and severe storms, which would break down even the heaviest practicable line, would result in service interruptions on the greater number of circuits and render costs of restoration correspondingly higher.

Instead of building individual pole lines for more than fifty or sixty wires one alternative is, of course, the construction of duplicate leads separated as far as practical so that the same storm might not affect all of them. In the more thickly settled sections of the country, it is obvious that even such a plan has its limitations as the towns and cities are close together and the intervening territory often well built up, with the result that available alternative routes are limited.

Some means of providing more circuits per route and more dependable circuits during storm periods was necessary, particularly on the main trunk lines connecting large centers of population. This led to the development of cable lines. While telephone cables of various types had been in use since about 1879, the first conversation over a long distance cable, if it may be so termed, was in 1902, over one ten miles long extending from New York City to Newark.

The difficulties of transmitting voice frequency currents over cable circuits are considerably greater than those involved in open wire lines. On a pole line, the wires on the crossarms are usually twelve inches apart and the electrostatic capacity between wires so spaced is relatively small. Decreasing the separation increases the capacity and this results in attenuation or a decrease in the transmitting efficiency of the circuit. In a cable the wires are necessarily close together and the insulation required to keep them separated has a greater specific inductive capacity than the air dielectric of the open wire circuit. The result is greater attenuation. Increasing the space between wires by using thicker insulating material would help to some extent but would also limit the number of wires per cable quite appreciably. Increasing the size of the wires raised the transmitting efficiency but also decreased the number of wires in a cable of given size. So the earlier cable engineers had something of a problem on their hands in combating these combinations.

It was fortunate that at this period - about 1900 - Professor Pupin of Columbia University, invented a method of reducing the attenuation by installing inductance coils at intervals along the cables. This process is termed "loading" and the use of loading coils played a large part in the more extended use of cables for long distance telephony.

A still greater aid resulted from the use of "repeaters" which are essentially the same as the vacuum tube amplifiers familiar to all who have radio receiving sets. By passing the feeble and gradually diminishing voice currents in a loaded telephone circuit through repeaters, energy is added and telephoning over long distance cables becomes an accomplished fact. So today, there are long distance cables extending from Boston to Charlotte, South Carolina, and from New York to St. Louis, with numerous branches and shorter cables reaching other cities. Figure 1 shows the present development of long distance cables as well as those which are planned during the five years ending in 1934.

An aerial cable on a pole line is much cheaper to construct than one contained in a vitrified clay underground conduit. Hence, the aerial cable has usually preceded the underground type. It is more nearly storm-proof than an open wire line and large numbers of wires - in some cases as many as six hundred - are placed in the one lead sheath. A typical aerial cable line is shown in Figure 2. Two of these cables on one pole line provide as many wires as twenty-four 50-wire pole lines. During the past two years, limited amounts of cables of still larger sizes have been installed. These have a cross section forty percent greater than the previous maximum size cable mentioned above which is 2-5/8 inches in diameter. Cable of any size is quite expensive, however, and can not be justified unless the requirements for circuits are already large and increasing rapidly.

An aerial cable line, while much more dependable from a continuous service standpoint than open wire, is still subject to trouble. Severe storms may demolish it; fires may destroy it; hunters shoot at birds or other attractive targets on it and cause trouble or even complete cable failure; the rings supporting the cable sometimes wear holes through the lead sheath and rain soaks the paper insulation on the individual conductors in the cable, resulting in noisy lines;

circuit trouble may result from the cable "snaking" or buckling due to temperature extremes causing unequal elongation or contraction in the cable sheath and the steel messenger strand to which it is attached. Remedies for some of these difficulties have been devised with a fair measure of success but it is generally conceded that underground cables are less subject to failures from external sources than those carried in the air.

Most people are familiar with underground telephone conduits and cables from observing installations in their own cities and underground conduit for long distance cable does not differ appreciably from the city type. Figure 3 shows conduit of various cross sections. If more than nine ducts are required, two or more of the smaller units are used; for example, a 15-duct subway would employ a 9-duct tile on which is placed one having a 6-duct cross section. Some of the latest constructed conduits are built for 750-foot lengths of cable.

Underground vaults, termed manholes, are provided at the ends of these individual duct sections so that cables can be pulled into the ducts and spliced together. The depth of such manholes varies with the number of ducts entering them but the length and width are usually 8 feet and 4 feet respectively. In the past, the ducts have entered the manholes in the centers of the end walls. The cables are pulled through the ducts and the ends in the manholes bent back toward the side walls where the conductors are spliced together, a lead sleeve placed over the completed splice, and soldered or "wiped" over the adjacent ends of the cables. Figure 4 shows such a manhole with the cables in place.

The bending of the cables in the manholes has been found objectionable in that the spirally wrapped insulation on the individual wires sometimes becomes displaced and results in contacts between conductors. This, of course, destroys their usefulness and the clearing of such troubles is expensive. Cracks in the lead cable sheath may also develop from bending the cables. It sometimes becomes necessary to move existing cables out from the side walls of the manhole to enable other cables to be installed or work done on the existing ones. This moving may result in further displacement of the paper insulation on the conductors with consequent trouble, or may cause sheath cracks in the lead armor. Another serious result is the probability of a change in the electrostatic capacity between wires. At the time of initially splicing a toll cable, careful measurements are made of the electrostatic capacity of each pair of conductors with respect to other pairs. The pairs in adjacent cable lengths are spliced together in such order that a high degree of uniform capacity is obtained. This is necessary for proper operation of the circuits and a change in the capacity has a detrimental effect and may require a rebalancing of the cable.

It is obvious that any plan which would eliminate the necessity of bending the cables and would not require future moving of them possesses decided advantage. This may be accomplished by bringing the duct entrances into the manholes in such positions that the cables would pass straight through without bends and would not require future moving of them. Such a plan is termed "duct splaying".

Figure 5 shows a splay arrangement for a 6-duct subway. It will be noted that the cables pass straight through the manholes without bends and also that they are separated vertically so that one cable may be worked on without moving others and that the installation of additional cables may be made without disturbing any of those already in place. This method is one of the newer practices in toll subway construction.

Manholes may be built of brick but are more usually constructed of concrete. Forms are, of course, necessary for concrete manholes and must be left in place until the concrete has set sufficiently to permit of their removal. This requires the excavation to be kept open for several days before the cast iron cover with its attendant framework can be placed. In the meantime, the manhole must be protected from traffic by barricades with warning flags during the day and lanterns at night.

In one of the middle western states a 250-mile subway is being built along the principal cross-state highway and several new methods in conduit and manhole construction are being used. One of these is the use of pre-cast manholes.

A portable mixing plant is set up along the conduit route, the manholes cast in one piece at this plant and hauled out as needed. A number of advantages are claimed for this plan. Material can be concentrated at one point, usually adjacent to a railroad spur; continuous operation can be carried on except in freezing weather; road conditions need not cause delays and traffic interference along highways is reduced to a minimum as the completed manhole is hauled out, placed in a prepared excavation and the necessary backfilling done almost at once. This may be contrasted with the more usual plan of having a concrete mixer moved to each successive manhole location, material such as sand, cement, and gravel delivered at 750-foot intervals and individual forms set up for each manhole and kept in place until the concrete has set. The interference to highway traffic which such operations necessarily bring about is greater than with the pre-cast manholes.

Figure 6 is a general view of a pre-casting plant. This outfit is moved from time to time along the route of the subway so that hauls of manholes from the plant to the job are not excessively long. In Figure 7 are shown two of the pre-cast manholes.

At intervals of six thousand feet, a manhole much larger than those used at the 750-foot points is required to house loading coil cases. For a 6-duct subway, a loading manhole 11½ feet long, 5½ feet wide and 11½ feet deep is necessary. It would be impractical to pre-cast, transport and set in place such a structure; however, it may be cast in sections and handled in much the same manner as the small ordinary manhole, and this is being done.

The complete pre-cast loading manhole consists of four separate manholes, two placed end to end and two more set on top of these. The two lower sections do not have slots or openings for ducts nor is a roof provided. They serve the purpose of providing space for the loading coil cases. The two upper sections do not have floors but are provided with slots in each of the end walls to permit the entrance of the ducts. In other respects, they are practically the same as the ordinary pre-cast manhole. A tongue is cast into the outer side of one of the end walls in one of the lower sections and a corresponding groove in one of the end walls of the other. The same treatment is given the two top sections. The tongue and groove arrangement enables the complete loading manhole to be fitted together with precision.

Halfway between the regular or "voice-frequency" loading manholes, or at the 3000-foot points, additional loading of circuits used for transmitting programs to radio broadcasting stations and for other special purposes, is necessary. The loading coil cases are smaller than those at the regular loading points and a rather ingenuous method has been developed to provide space for them by inserting sections of sewer tile, 12 inches in diameter, in the middle portions of the end walls of the manholes. Figure 8 shows a pre-cast manhole of this size with sewer tile inserted into one of the circular openings in one end. If such a method is not used, the depth of the manhole will have to be increased quite appreciably.

The pre-cast idea has also been carried out for the duct splays. Instead of building these individually at each manhole, they are pre-cast, hauled out and set in place. Under this plan, interference to highway traffic is very appreciably reduced. Figures 9 to 13 show the methods of pre-casting and handling these splays.

Two more new ideas regarding conduit work are being tried out. It is the usual practice to lay the 3-foot sections of clay duct in the trench one at a time and to close the joints between adjacent pieces with a cement mortar collar. With the thought of reducing the number of individual pieces of conduit which would ordinarily have to be handled along streets or highways, the pre-cast thought has been applied to conduit joints.

Four of the 3-foot sections of conduit are laid end to end and cement mortar poured into small metal forms surrounding the joints. After the mortar has set, the forms are removed and used for other similar joints. The resulting

12-foot section may then be handled as one piece of tile. The joint work is done at a central location and the completed 12-foot piece hauled out and installed in the trench.

A plan similar except as to joint material, is also being used. Instead of cement mortar, a rather thick pasty mass is made up consisting of sand, asbestos, asphalt, and a distillate such as kerosene. This mixture is applied with a trowel to a strip of burlap sufficient in size to cover the conduit joint and overlap it on top. The coated burlap is applied to the joints like a plaster and allowed to set. The mixture hardens rather slowly and will probably never become as hard or brittle as cement. It is thick enough so that it does not drip into the joint and interfere with pulling in cables and plastic enough to permit of a slight movement of the adjacent pieces of conduit without impairing the tightness of the joint or breaking the seal. Four lengths may be handled as one piece in the same manner as explained above for the cement joints. Figures 14 and 15 illustrate the method of handling and installing the four-section units using either the cement mortar or the compound type of joint.

The advocates of the pre-cast joint plan see a number of advantages in it. There is positive assurance of three perfect joints out of four as above-ground inspection of the 12-foot length may be made; better duct alignment is possible as the four pieces are handled above ground instead of in the trench, and it is claimed that traffic interference along highways is considerably lessened due to handling fewer pieces of material at the trench than would be necessary if each 3-foot section were laid individually. The compound joint also has the advantage that it may be made during freezing weather when cement can not be used.

Clay conduits with concrete manholes are quite expensive to build and involve carrying idle investments in vacant ducts over a relatively long time period. They may be justified or required when successive cables are installed at frequent intervals or where aerial construction can not be placed. They are too costly for a single cable or even for two cables as two or even more can be placed on a pole line. However, since the underground cable should be more free from trouble as pointed out previously, considerable thought has been given to forms of underground cable construction which are less expensive than tile conduit.

A new type of toll cable construction has been used in Oklahoma between Oklahoma City and Holdenville, a distance of some seventy-five miles. The cable line is on private right-of-way except where it passes through towns. $3\frac{1}{2}$-inch fiber duct was laid in a trench thirty inches deep, and ordinary lead sheath cable installed in this fiber duct. The individual pieces of duct are joined by a fiber collar. No protection is provided for the duct except at road crossings or other places subject to future excavations and in such instances, the fiber duct is enclosed in a 5-inch iron pipe. The length of each cable and of the duct containing it are about seven hundred and fifty feet but, except at the voice-frequency loading locations, six thousand feet apart, no manholes are provided. Cable is pulled into the duct in much the same manner as in multiple clay subways and at the 750-foot points, the splice in the cable is covered with a section of fiber duct 6 inches in diameter. A wedge-shaped fiber ring is used to close the space between the regular 3½-inch duct and the 6-inch splice covering. Figure 16 shows one of these splice coverings in place.

Manholes are provided only every six thousand feet where loading coil cases are required. These manholes are made of creosoted wood planks and have a removable wooden top but no floor. Figure 17 shows a wooden manhole assembled above ground and in Figure 18 is one installed in the ground. The top of the manhole is placed about eighteen inches below the ground surface and since the fiber duct itself is usually about thirty inches deep, there is no interference with ordinary agricultural activities.

Warning signs of the type shown in Figure 19 are placed at all points where future excavation work by other than telephone workmen is probable, such as road crossings, pipe lines, etc. Construction costs for the Oklahoma City-Holdenville cable were about the same as those required for building a new pole line and placing a cable on it and are very much less than the costs of a single cable installed in any form of clay conduit.

A still different type of underground cable has been installed in Texas between Fort Worth and Cisco, a distance of 103 miles. In this case, no conduit of any kind was used except where the route passed through towns where ordinary clay duct was provided. The lead sheath of the cable is covered with a wrapping of paper followed by two layers of jute. Two steel tapes, one over the other, are then wound on, each tape being 2 inches wide and 41mils thick. A separation of 1/2 inch is maintained between adjacent turns of the tape and the outer layer of tape is so placed that its center comes over the 1/2 inch space left between the windings of the inner layer. Two wrappings of jute cover the tape. The lead sheath, paper, jute and steel tapes are thoroughly coated with an asphalt compound and the completed cable is given a coat of whitewash to prevent adjacent layers from sticking together on the cable reels. The steel tapes are intended to afford a measure of protection against excavating activities in the vicinity of the cable, and the liberal application of asphaltum is designed to safeguard the steel tapes and the lead sheath against soil corrosion.

As in the case of the fiber enclosed cable, manholes are omitted except at the 6000-foot points and these are of the same size and type as used for the fiber duct job. At the 750-foot points, the cable splices are covered with cast iron cases which are filled with an asphaltum compound. Figure 20 shows a splice case in place on a tape armored cable.

The tape armored cable has the advantage over fiber, or in fact any form of conduit, that it can be installed in rough country where conduit construction would be difficult or even impossible. Conduit into which cable is to be pulled must have a fairly even grade while tape armored cable may follow the contour of the country regardless of its "ups and downs".

One of the very interesting features of these new types of buried cables is the use of special labor saving machinery. In earth, the trench may be dug with excavators of the type shown in Figure 21. Where solid rock is found, air-operated drills are used, the compressor outfit being mounted on a small truck as illustrated in Figure 22. Backfilling the trench excavation is done by machines of the types shown in Figures 23 and 24. Tamping the backfill may be done with the equipment illustrated in Figure 25.

750-foot lengths of ordinary lead sheath cable of the type used for the fiber enclosed installation weigh. with the reels on which they are transported, about three and one half tons. Tape armored cable of the same length and a new type of steel reel on which it is wound, weigh about five tons. The handling of such weights requires equipment that is quite sturdy and since the new types of buried cables are usually installed on private rights-of-way - often across cultivated fields - caterpillar tracks are needed. Figures 26 and 27 show cable reel trailers handling the ordinary wooden cable reels and also the new type of steel reel used for tape armored cable. These trailers are drawn by tractors. In Figure 28 is shown a trailer equipped with a special device for loading the reel and Figures 29 and 30 show a still different type. Any of these cable reel trailers may be equipped with rubber treads on the wheels, Figure 28, or with caterpillar tracks as indicated in the other illustrations.

Another type of equipment is shown in Figure 31. This is a heavy duty truck equipped with caterpillar treads which may easily be removed when the truck travels over highways. This truck has a winch and derrick for handling heavy objects, such as loading coil cases.

Excavations for manholes may be made with a machine of the type shown in Figure 32. In case the underground construction is along a concrete road it is necessary that the shoulder be restored to a condition at least as good as that which was found prior to the cable construction work. Scrapers and rollers of the types shown in Figures 33 and 34 have been of considerable help in situations of this nature.

The Fort Worth-Cisco cable extends over considerable stretches of rolling country. To a casual observer, the grass covered land appears to admit of easy digging, but the soil extends only a few inches above the underlying rock. While most of this rock is not in solid ledges, the use of the ordinary types of trenching machinery is out of the question. Breaking up this rocky formation by means of air-operated drills and picks is a slow and expensive process and for such situations, a type of plow as illustrated in Figure 35 was used. This plow was drawn by one or two tractors as shown in Figure 36, and broke the rock into comparatively small pieces, most of which are removed from the trench by the mold boards of the plow. It was generally necessary, however, to shovel out the loose rock and earth from the trench bottom before the cable was laid. Figure 37 shows a plow excavated trench after the loose rock and earth had been taken out.

After the trench had been opened, either by a trenching machine or plow, the tape armored cable was laid directly from the reel as shown in Figure 38. In level country, time may be saved by attaching two trailers to the tractor, laying the cable first from the reel of the rear trailer and then from the forward one, Figure 39.

There may be situations wherein the method of laying tape armored cable shown above can not be used, that is, when crossing under improved highways, railroads, pipe lines, or other structures. For such conditions, rollers may be placed in the bottom of the trench at intervals of about 14 feet and the cable pulled in over them. The rollers are, of course, removed for future use before the trench is backfilled.

The plow method for opening trenches was so successful that further study was given to its possibilities. As a result, a machine was built which would plow a trench, lay a cable in it, and refill the excavation in one operation.

Figure 40 shows the plow as first constructed. It consists of a steel plate which cuts a narrow slot through the earth and has on its lower end a shoe which cuts an opening, somewhat rectangular in cross section, at the bottom of the trench. The cable is fed through a 5-inch steel pipe from the cable reel to the bottom of the trench. Steel plates extend from the forward or cutting edge of the plow to the sides of the 5-inch pipe. A suitable mechanism is provided for raising and lowering the plow and to regulate the depth of cable below the ground surface. Figure 41 shows the plow in operation.

Since relatively little earth is thrown out by this plow, the backfilling of the excavation is rather simple. Two I-beams are fastened together in such a manner that the space between them is less at the rear than at the forward end. This device is dragged back of the plow and the I-beams force the earth toward the center as the backfiller travels forward with the plow and the loose earth is deposited in the trench and piled up over it. Figure 42 shows this backfilling device.

Difficulty was encountered in the first cable-laying plow in that it tended to "ride up" out of the ground, especially when traveling through earth containing small boulders and tree roots; also, the wheels and framework of the machine were not quite heavy enough to withstand the tremendous strains imposed on it. Two large tractors were usually required to operate the plow. A further fault was the inability to lay the cable deeper than about twenty-two inches. As a result of these factors, the plow was completely redesigned, but the general principle of the first one was retained. The second plow is of much heavier construction, does not "ride up" and will lay cable to a depth of at least twenty-eight inches. Figure 43 shows the plow as redesigned. In operation, the same plan is used as shown in Figure 41.

The plow method of laying tape armored underground cable gives some promise of being somewhat revolutionary, and considerable thought is being given to means of effecting further improvements. Cable laying by this machine is several times as fast as that resulting from the methods illustrated in Figures 21, 38 and 23.

Mention has been made several times that cables of any type are expensive and considering that cables are intended to furnish continuously dependable service, it naturally follows that considerable care should be exercised in installing the cables to prevent damage to the sheath and also to guard against sheath openings occurring after the cables are in place. One of the most detrimental factors affecting the operation of circuits in cable is moisture. An opening in the cable sheath only as large as a pinhole may admit sufficient moisture to cause an appreciable lowering of the insulation resistance between conductors or between pairs of conductors. The presence of moisture results in noisy lines, and in extreme cases, in the complete failure of a cable. To prevent moisture entering cables one of the agencies which is coming into more extended use is the introduction of nitrogen gas into the cable sheaths.

Nitrogen gas is commonly a by-product resulting from the manufacture of oxygen, and nitrogen so produced is anhydrous. However, as a further insurance against the presence of any moisture, the nitrogen is pumped through oil.

At points where adjacent lengths of cable are spliced together, a lead sleeve is placed over the splice and wiped to the sheaths of the adjoining cables. In this wiping or soldering process, there is a possibility of the solder becoming somewhat porous and what may appear to be a water-tight joint may not actually be found so. It is relatively easy to determine whether such joints are water-tight by introducing into the sleeve nitrogen gas under pressure and painting the wiped joint with soapsuds. An opening smaller than a pinhole will be indicated by the formation of soap bubbles. This method of testing the joints is now in rather common use on toll cables.

Such a test as described above would not indicate the presence of openings in the cable sheath located elsewhere than at the splices. A further test for sheath breaks is made after the splicing work in six thousand feet of cable has been completed but before splices at the two ends of such a section have been made. Cable is shipped with the two ends of each length sealed with solder. These seals on each end of the 6000-foot section are left intact and at one end nitrogen gas is introduced at a pressure of about thirty-five pounds and at the other a gauge similar to a steam pressure gauge is soldered into the cable sheath. As soon as this gauge indicates a pressure of five pounds, the admission of gas at the other end of the section is stopped. After some hours, the pressure throughout the six thousand feet of continuous cable sheath equalizes to about twenty pounds providing there are no sheath openings. If this equalization does not take place, it is an indication of an opening at some point between the two ends of the cable. If the cable under test is aerial, the defects may sometimes be found by the sound of escaping gas, audible to a man walking on the ground under the cable, or in the case of smaller openings, to a man riding along on a seat supported by the steel strand carrying the cable. If the opening can not be located by these means, valves similar to those used in automobile tires may be soldered into the sleeves at splice points along the cable and pressure readings taken with a suitable gauge. The opening is, of course, nearest to the valve showing the lowest pressure. Recourse can then be had to the soapsuds method for determining definitely the opening in the sheath. The same process may be used for underground cables but soapsuds can not be applied to the portion of the sheath between manholes and it may accordingly be necessary to replace a length of cable in order to clear the trouble.

Tape armored cables present a somewhat different problem in that the paper and jute, together with the asphalt impregnating compound, may seal small openings in the lead cable sheath to such an extent that the escape of gas is very slow. As an added precaution against defective lead sheath in tape armored cables, each length of cable is shipped from the manufacturing plant containing gas pressure of about fifteen pounds per square inch. Immediately upon receipt of such cable at its destination, the gas pressure is measured and recorded. To facilitate this, valves are placed in each of the lengths of cable at the factory, one such valve being shown in Figure 44. After the cable has been laid in the trench, and usually before any backfilling is done, the pressure is again taken and compared with that found immediately on receipt of the cable. If there is any appreciable drop in pressure, nitrogen is introduced into the cable to bring the pressure up to at least fifteen pounds and further tests made at the expiration of forty-eight hours. If the pressure still falls, it may be necessary to remove the length of cable from the trench and use the soapsuds method to attempt to locate the defect. If it still can not be found, substitution of a new length may be required. A still further precaution is taken with tape armored cable in that a third test of the pressure is made just before the operation of splicing adjacent lengths of cable together is started. In case of any decrease of pressure at that time as compared with the two previous readings, the procedure just outlined may be necessary.

A cable, either underground or aerial, successfully installed is of little value unless it is kept in the best operating condition. Nitrogen gas is again called into use and the cable placed under continuous pressure. Long distance cables may vary in length from a few miles to hundreds of miles; however, due to the necessity of amplifying the rather feeble voice currents in order that speech may be audible at the distant ends of the circuits, repeaters are installed at intervals of approximately fifty miles and the cables terminated at these repeater stations. A long distance cable consists, therefore, of a series of individual cables each approximately fifty miles in length. It has not been considered advisable to attempt to maintain such a length of cable under continuous pressure as a unit and accordingly, sectionalizing plugs are usually installed in the cables every ten miles. These plugs are made by introducing wax or an asphaltum compound into the cable so as to prevent the passage of gas from one "plug section" to the adjacent ones.

The introduction of nitrogen into these 10-mile plug sections is of considerable assistance in keeping the paper insulation on the conductors dry in case of a small sheath break, as the gas pressure will prevent the entrance of water, at least until such time as there has been quite an appreciable drop in pressure. Also, a scheme has been devised whereby telephone testboard employees are automatically notified of a decrease in pressure so that prompt action may avert serious service trouble on the cable. This is effected as follows:

In each 10-mile plug section, there are installed three pressure gauges which are set to close electrical contacts when the pressure in the cable drops to a predetermined value. One pair of conductors in the cable is bridged to these contact points and at the central office or repeater station an alarm bell or other indicating devices are connected to the circuit. Hence, if the pressure drops to a point where the gauge or "pressure contactor" as it is termed, operates to close the circuit, the alarm bell in the repeater station will notify the attendant that there is a sheath opening in that particular cable. This attendant has previously determined the resistance of the alarm circuit from his testboard to each of the pressure contactors so by measuring the resistance of the circuit immediately after the operation of the alarm bell he can determine which particular pressure contactor closed the circuit. Repairmen are immediately dispatched to that location and by visual inspection, by gauging pressure at splice points, or any of the other means previously described, locate the defect and clear the trouble.

In cases of mechanical damage to the conductors, such as caused in an aerial cable by a bullet or a fire, or in any cable by mechanical damage which results in contact between the adjacent wires of a pair of conductors, the trouble may be found by measuring the resistance of the pair from a central office to the defect. Since the resistance per unit length of conductor in the cable is known, the distance from the repeater station to the trouble may be calculated. A somewhat similar method is often used to locate openings in the sheath where sufficient moisture enters to cause either a short circuit between conductors or an appreciable decrease in insulation resistance. A rather interesting automatic application of this principle is employed in toll cable maintenance work.

A number of pairs of conductors in the outer layer, that is, adjacent to the lead cable sheath, are connected in the central office or repeater station, to a relay mechanism which automatically and in regular sequence, switches these pairs of conductors to a sensitive insulation resistance measuring device. Inasmuch as the insulation resistance between conductors is relatively high, being upwards of one thousand meg-ohms per mile of circuit, it is necessary that the apparatus indicating a decrease in such insulation resistance, due for example, to a gradual accumulation of moisture in the cable, be very sensitive as the current flowing from one insulated conductor to another through the moistened insulation is extremely small. Recourse is had to the vacuum tube by which these small currents may be amplified sufficiently to cause the operation of an alarm bell. The essential difference between this automatic alarm and the continuous gas pressure system is that one operates on the lowering of the insulation resistance between conductors while the other depends upon the decrease in gas pressure.

In this paper an attempt has been made to present in a general way some of the newer developments in long distance telephone cable construction. Almost any one of them could be made the subject of a comprehensive paper but it would probably be of interest only to telephone men and only then to those most intimately concerned with a particular phase of telephone work. In view of this, it was thought that the brief outline of toll cables in this paper will be of greater interest and value to students and engineers.

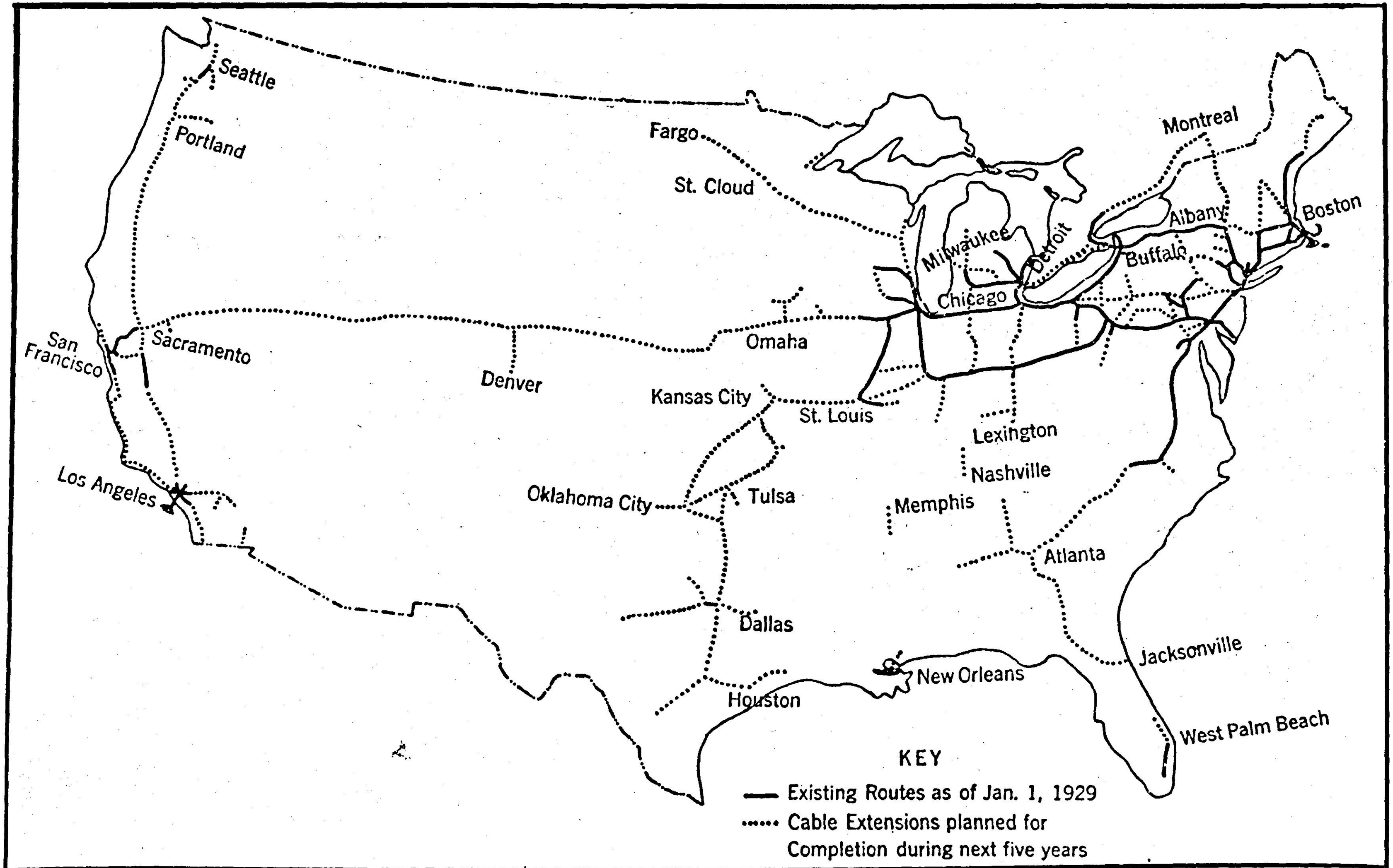

Figure 1. Toll Cable Routes.

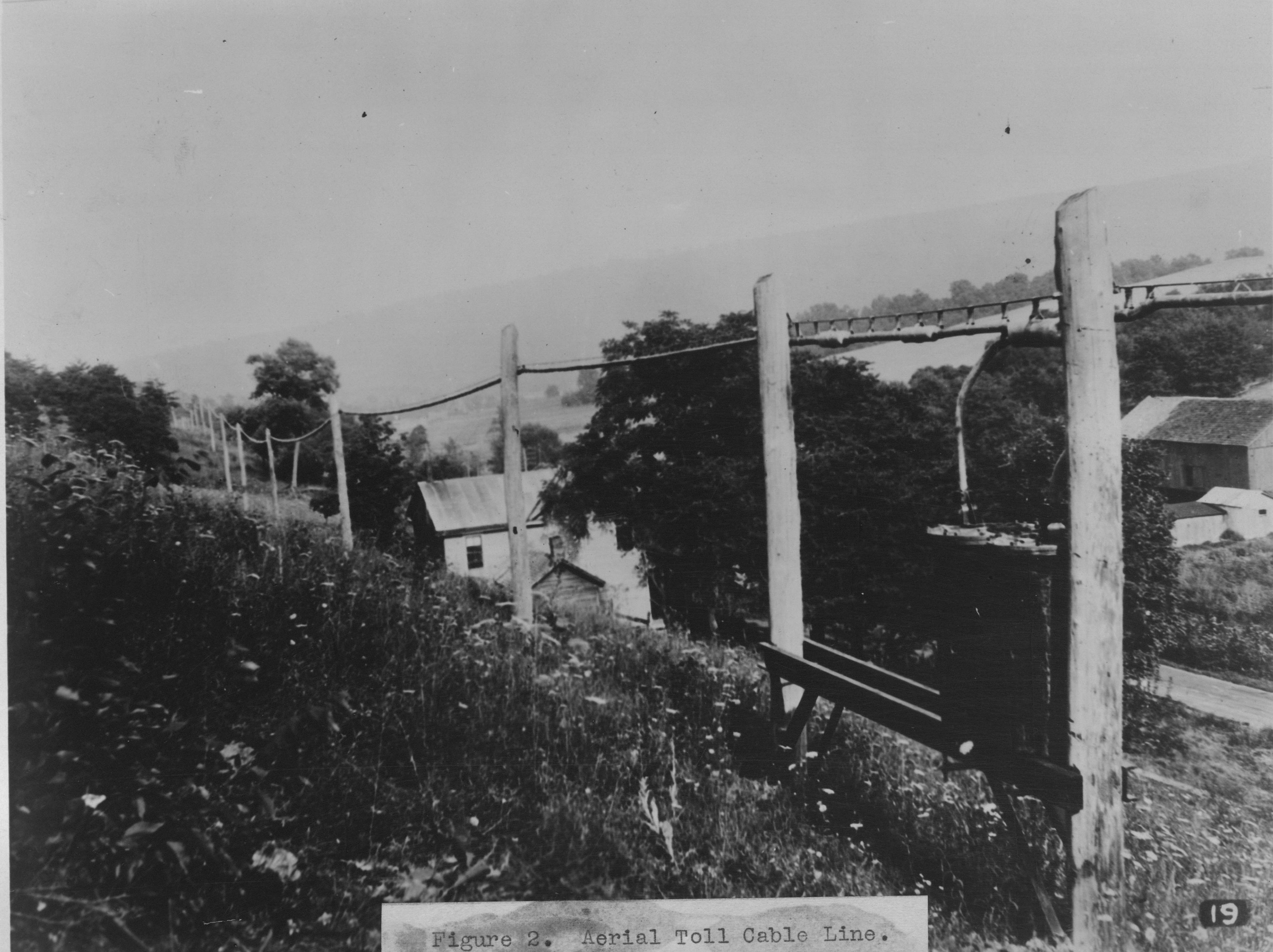

Figure 2. Aerial Toll Cable Line.

Figure 3. Types of Clay Conduit.

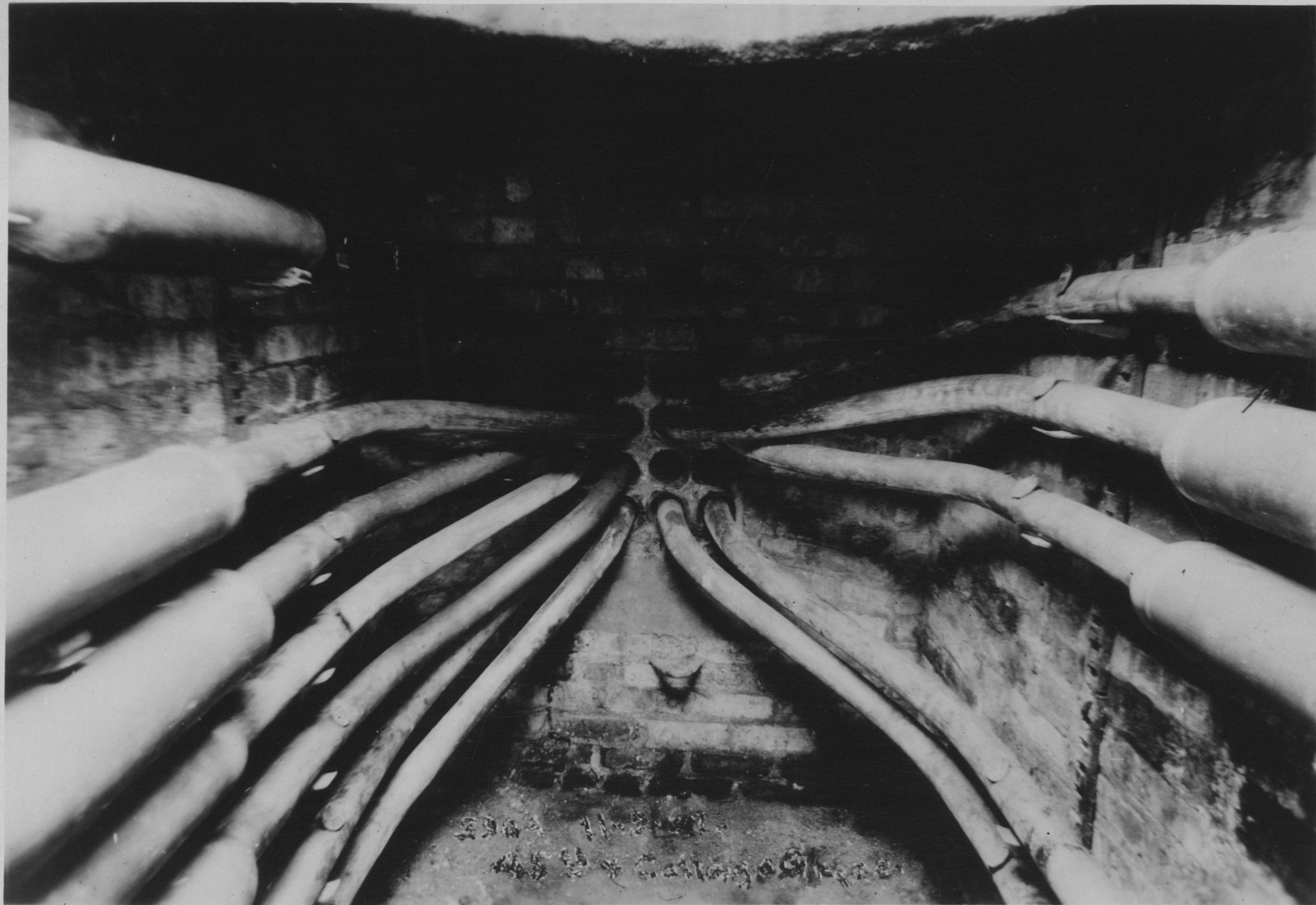

Figure 4. Manhole with Center Duct Entrance.

SPLAYING OF DUCTS
TO AVOID BENDS IN CABLES ENTERING MANHOLES

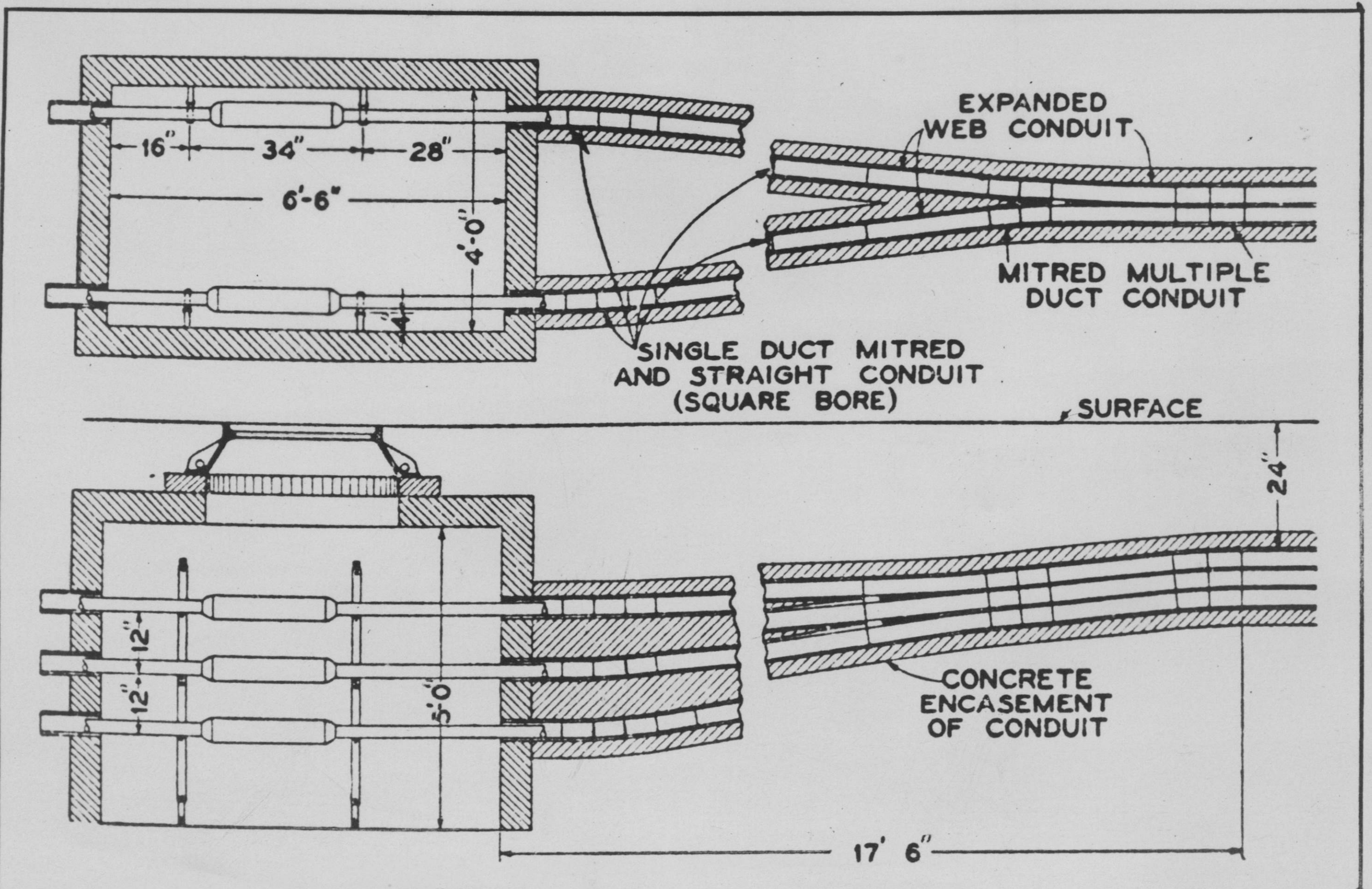

Figure 5. Duct Splay Arrangements.

Figure 6. Manhole Pre-Casting Plant.

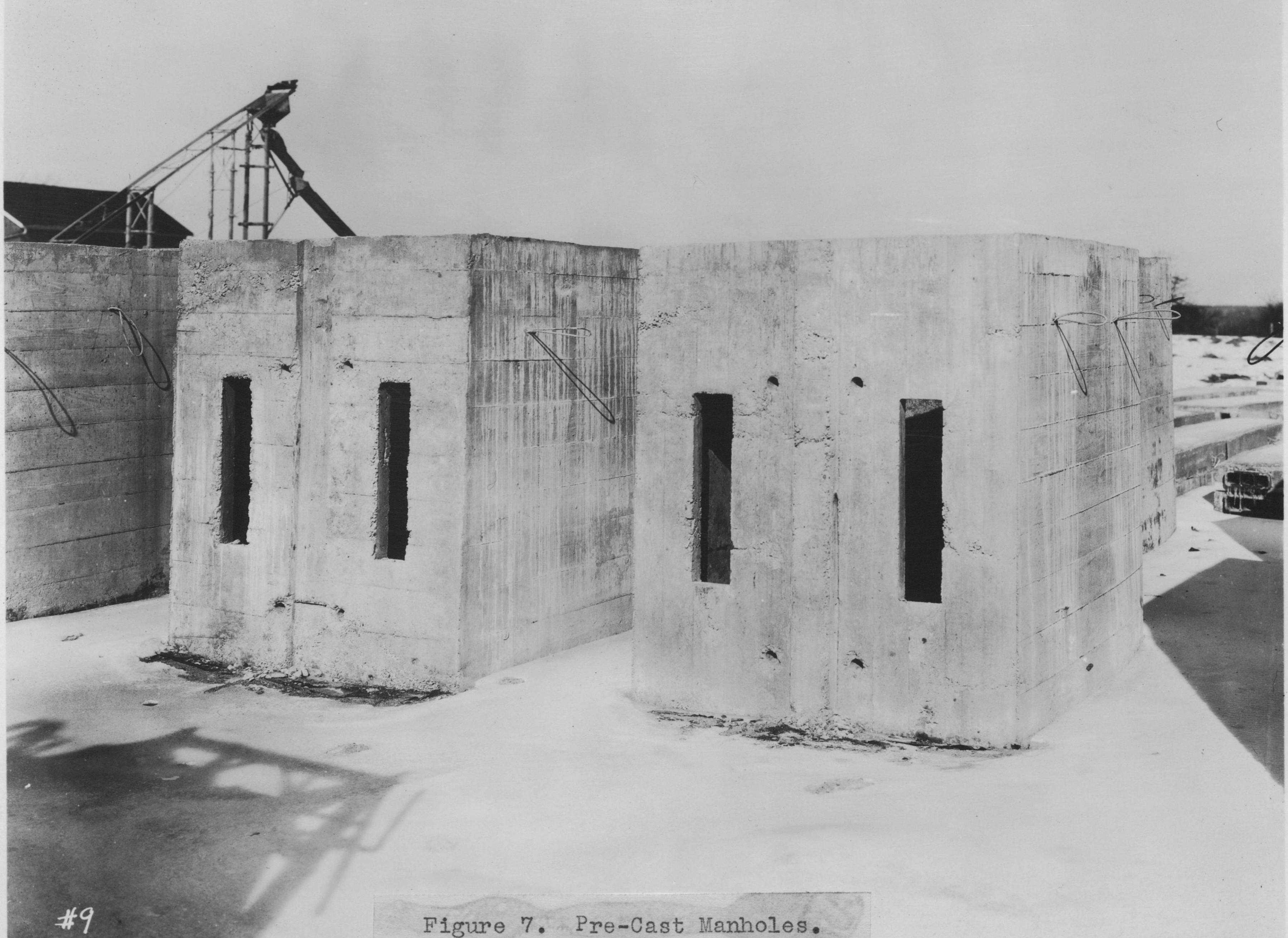

Figure 7. Pre-Cast Manholes.

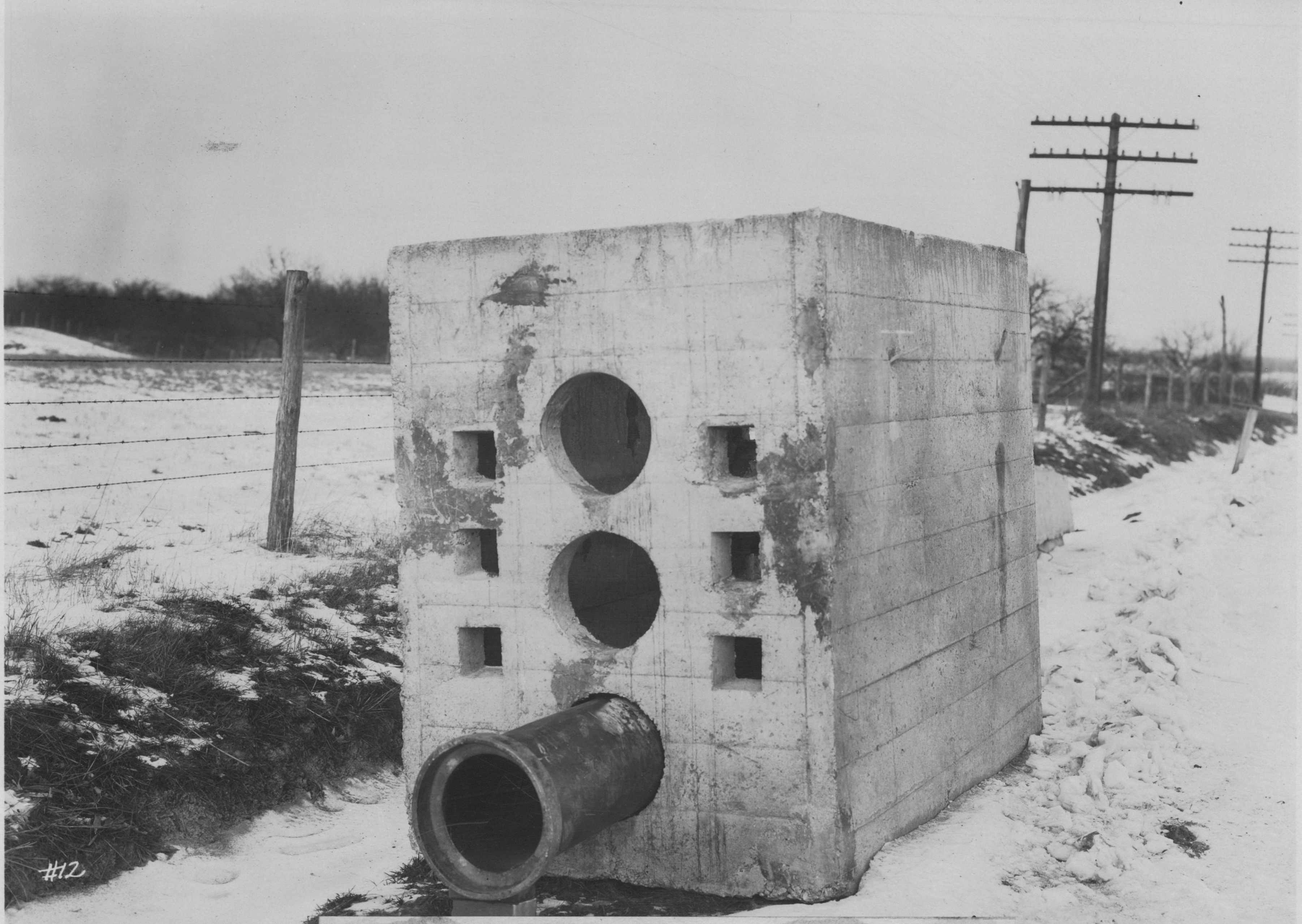

Figure 8. Pre-Cast Program Loading Manhole.

Figure 9. Form for Making Pre-Cast 3-Duct Splay.

Figure 10. Form for Making Pre-Cast 4-Duct Splay.

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Figure 11. Completed Pre-Cast 4-Duct Splays.

Figure 12. Hauling Pre-Cast Splays - Crane is Used to Handle Them.

Figure 13. Pre-Cast Splays in Place at Manhole.

Figure 14. Handling 12-Foot Section of Conduit Having Pre-Cast Joints.

Figure 15. Installing 12-Foot Section of Conduit in Trench.

Figure 16. Fiber Splice Covering.

Figure 17. Wooden Manhole - Above Ground

Figure 18. Wooden Manhole - Installed in Ground.

Figure 19. Warning Sign for Underground Cable.

Figure 20. Cast Iron Splice Case on Tape Armored Cable.

Figure 21. Wheel Type Trenching Machine.

Figure 22. Compressed Air Drilling Apparatus.

Figure 23. Backfiller - Drag Line Type.

Figure 24. Backfiller - Scraper Type.

Figure 25. Tamping Machine.

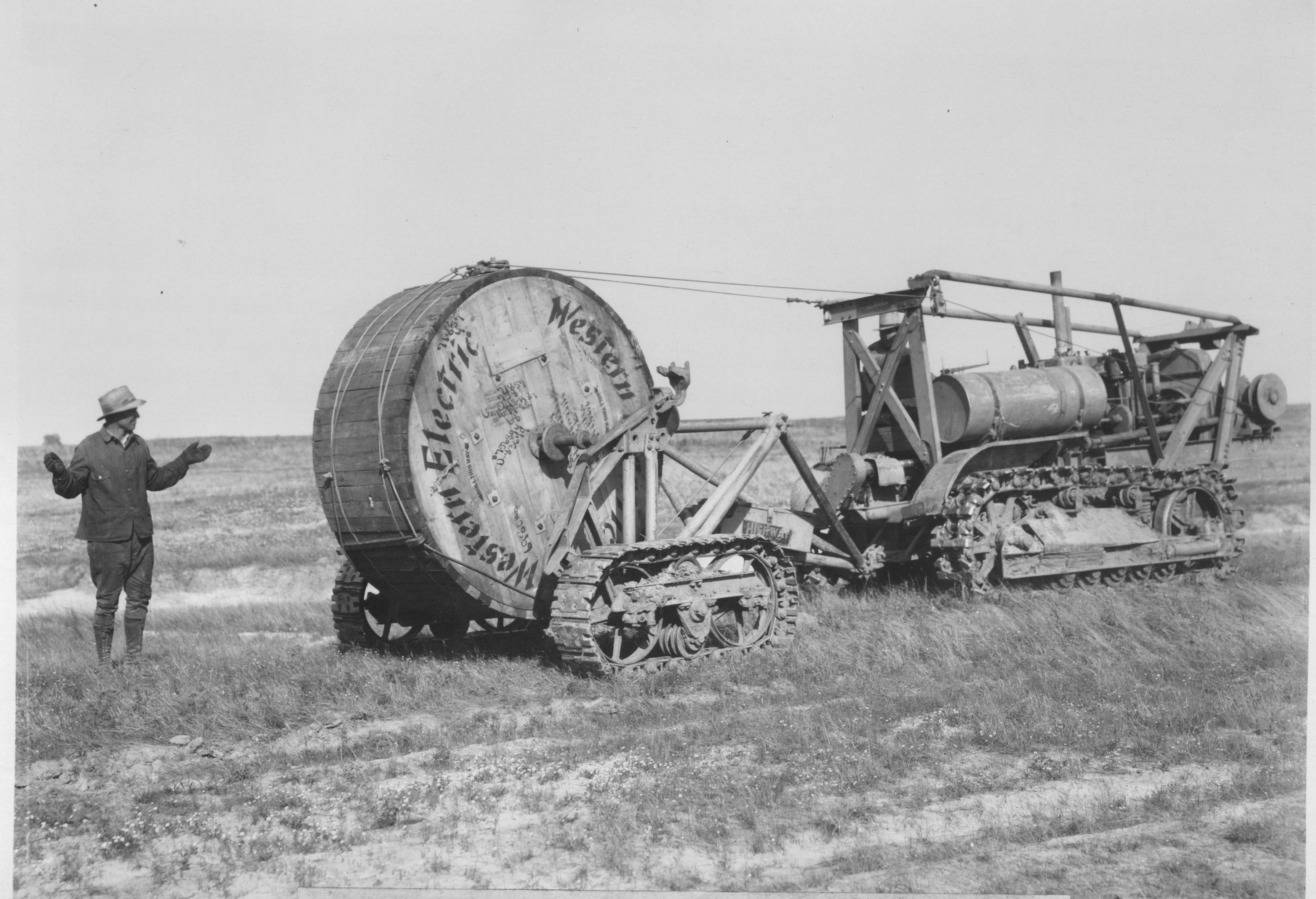

Figure 26. Loading Wooden Cable Reel on Trailer.

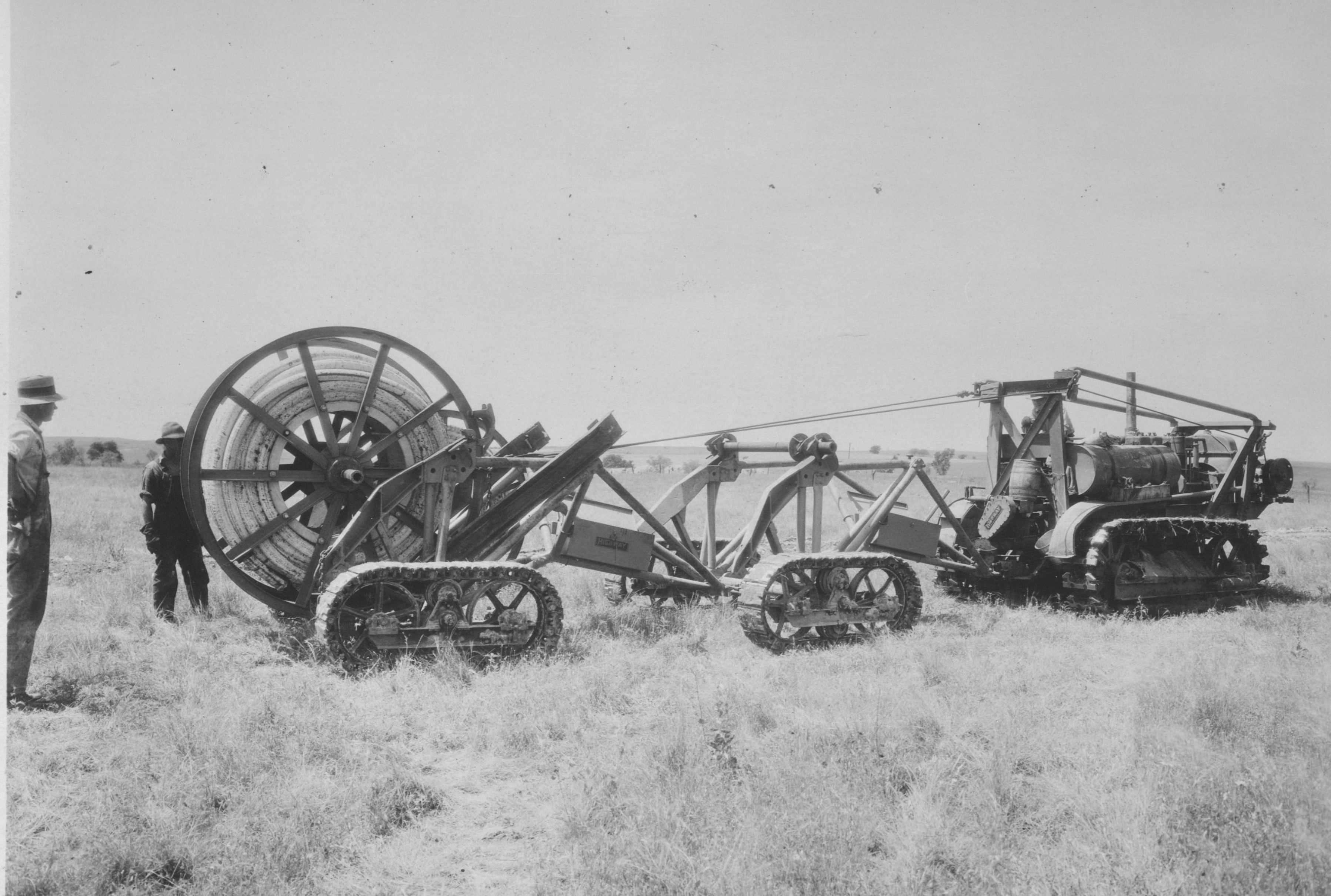

Figure 27. Loading Steel Cable Reel on Trailer.

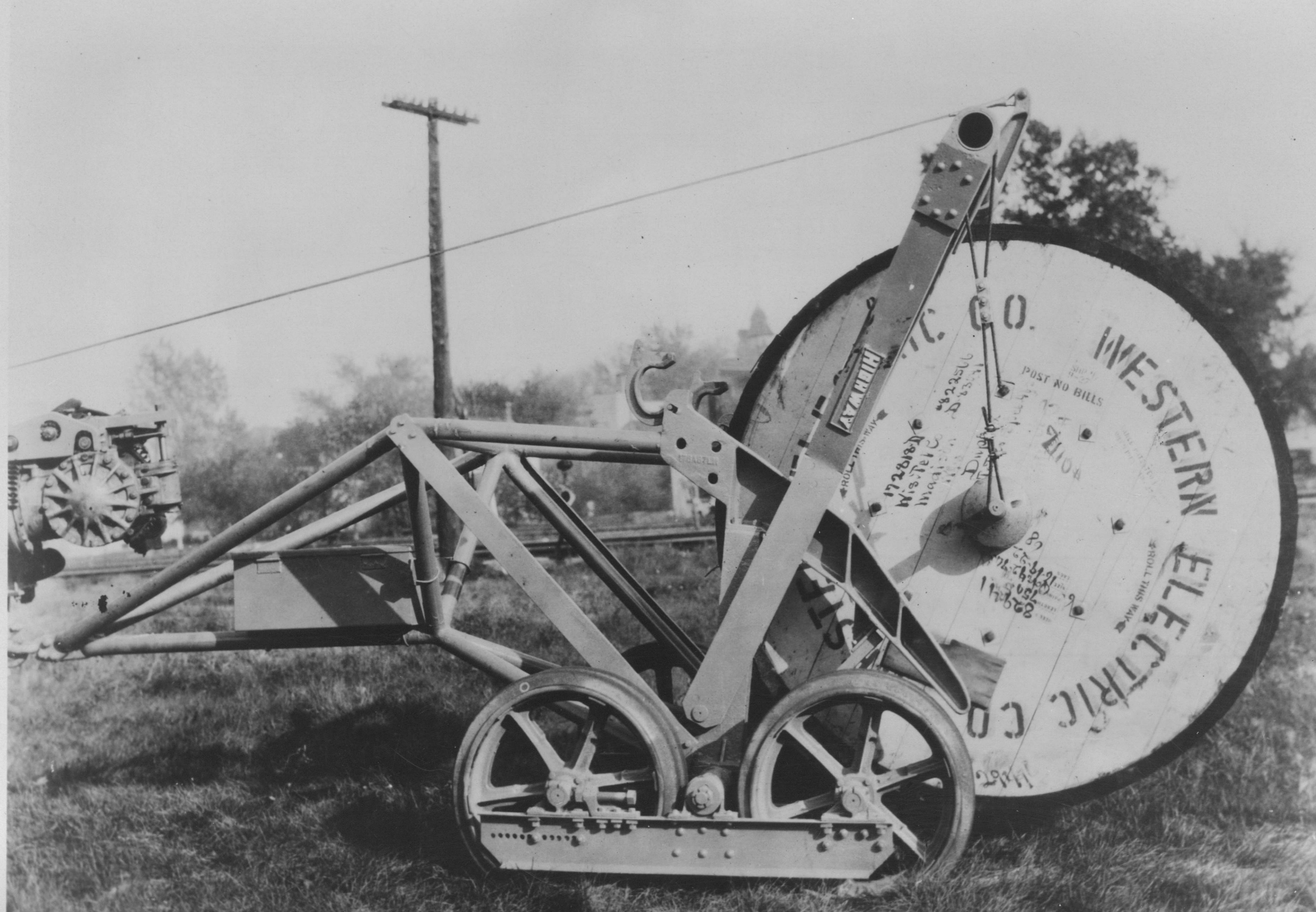

Figure 28. A Special Cable Reel Loading Device.

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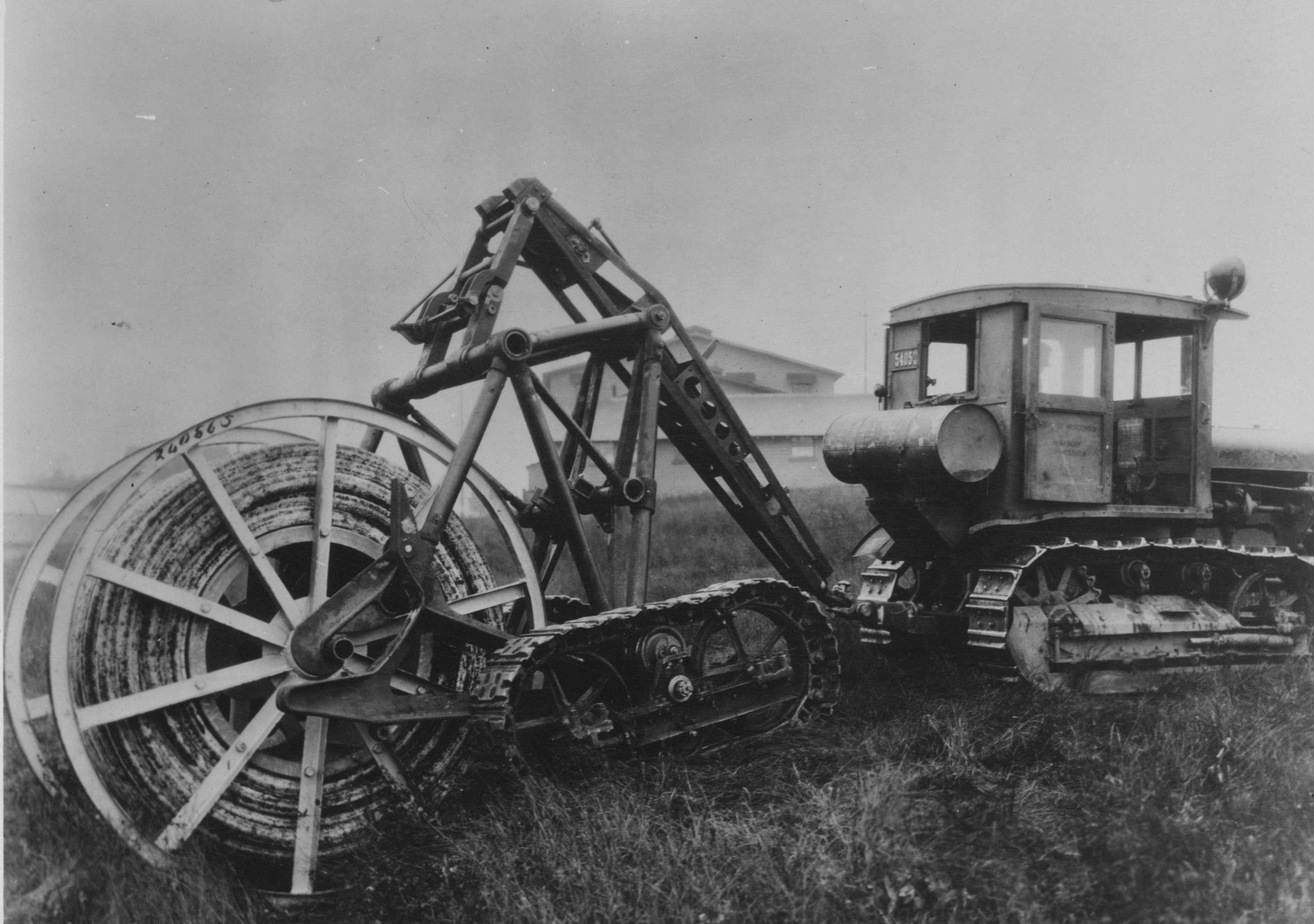

Figure 29. Traction Loading Cable Reel Trailer. Starting to Load.

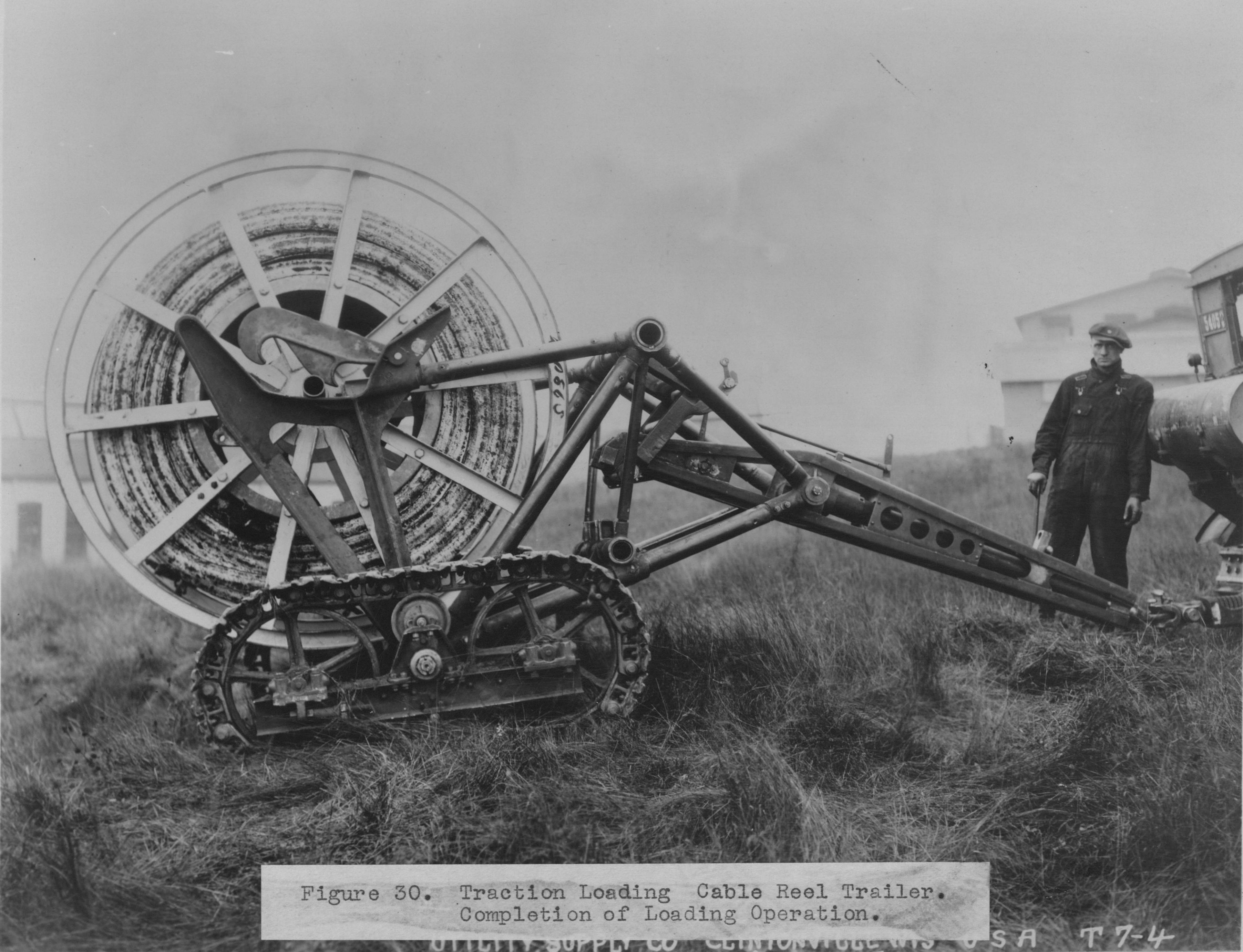

Figure 30. Traction Loading Cable Reel Trailer.
Completion of Loading Operation.

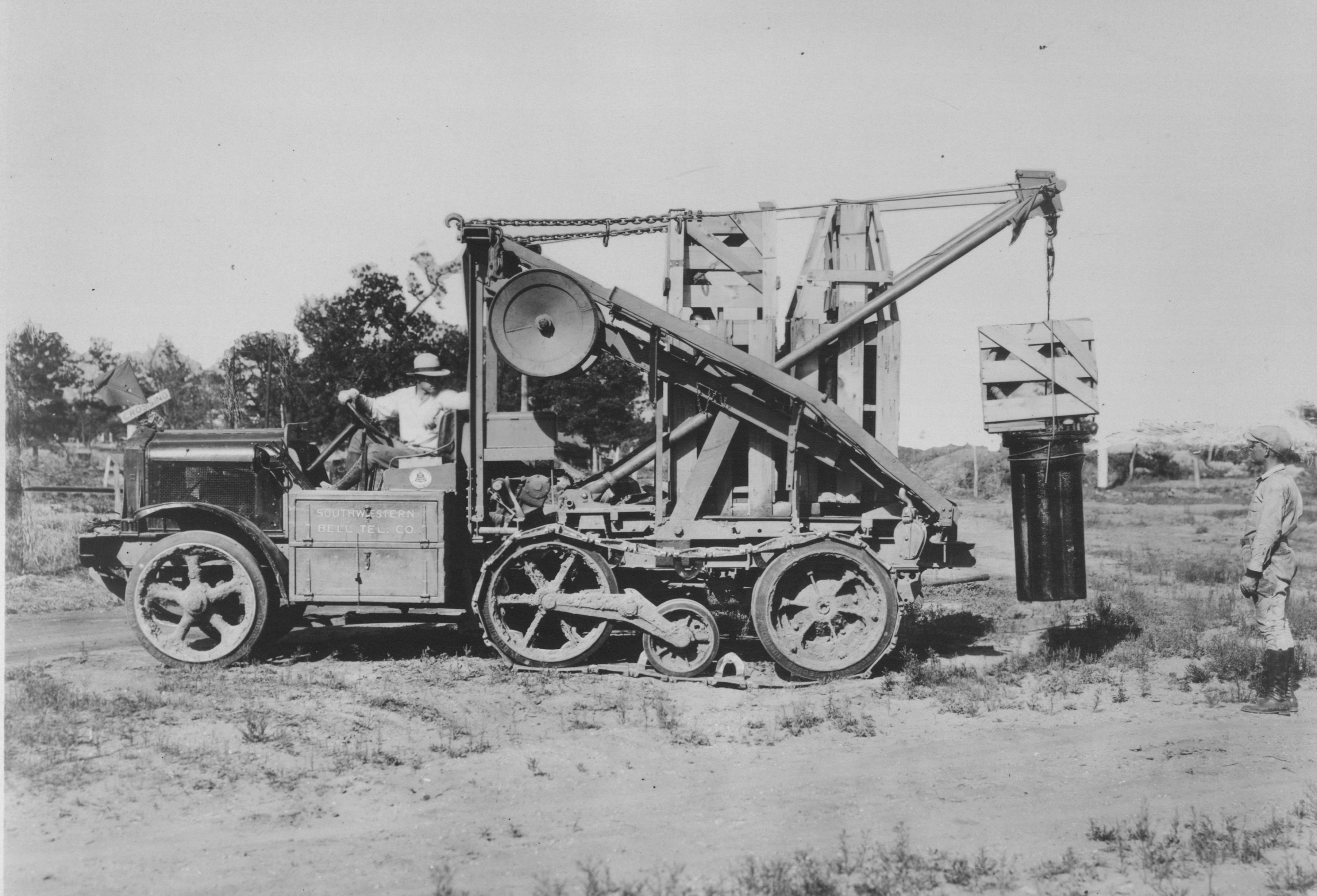

Figure 31. Truck Equipped with Caterpillar Tracks, Derrick and Winch.

Figure 32. Excavating for Manhole.

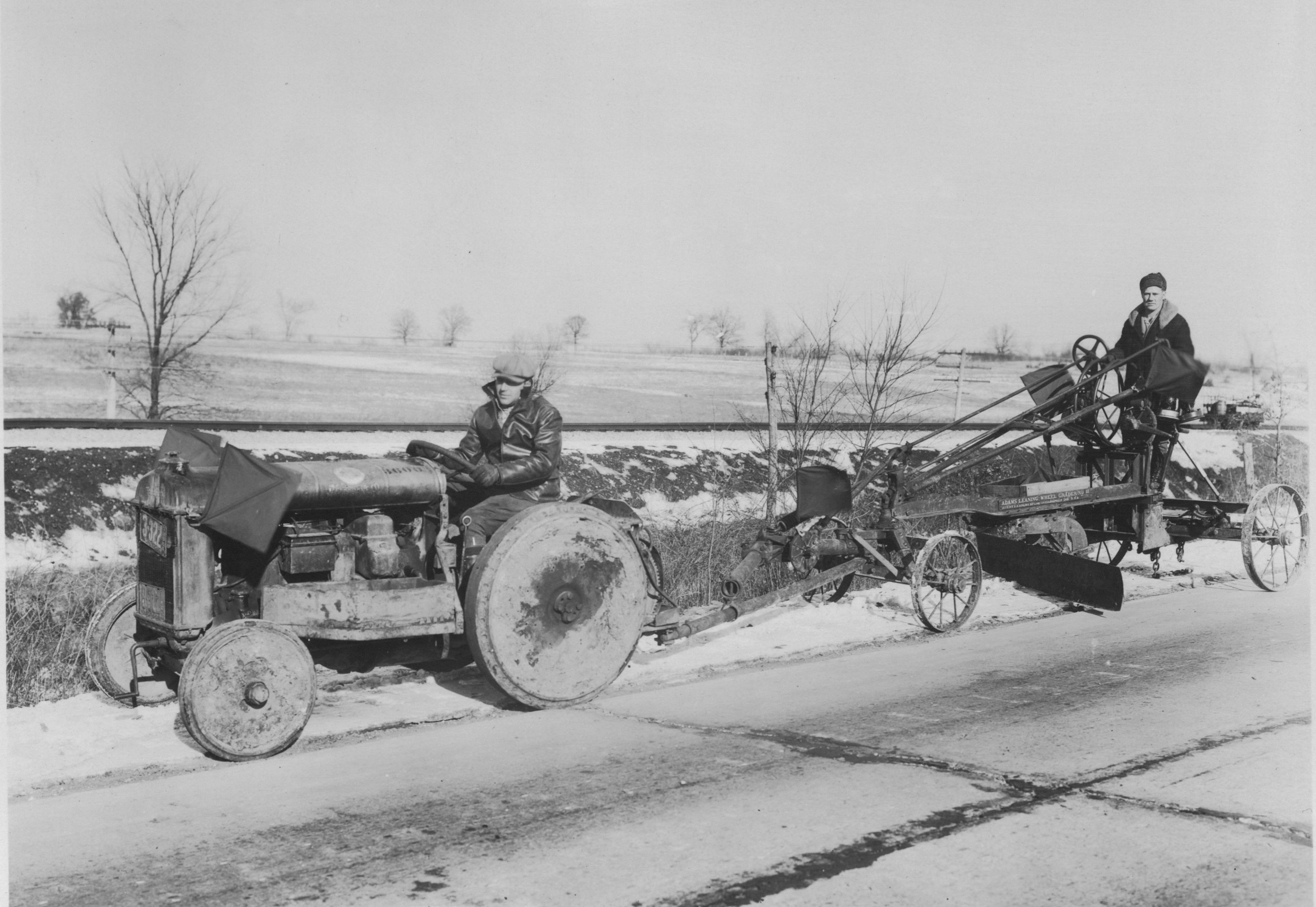

Figure 33. Road Scraper.

Figure 34. Road Roller.

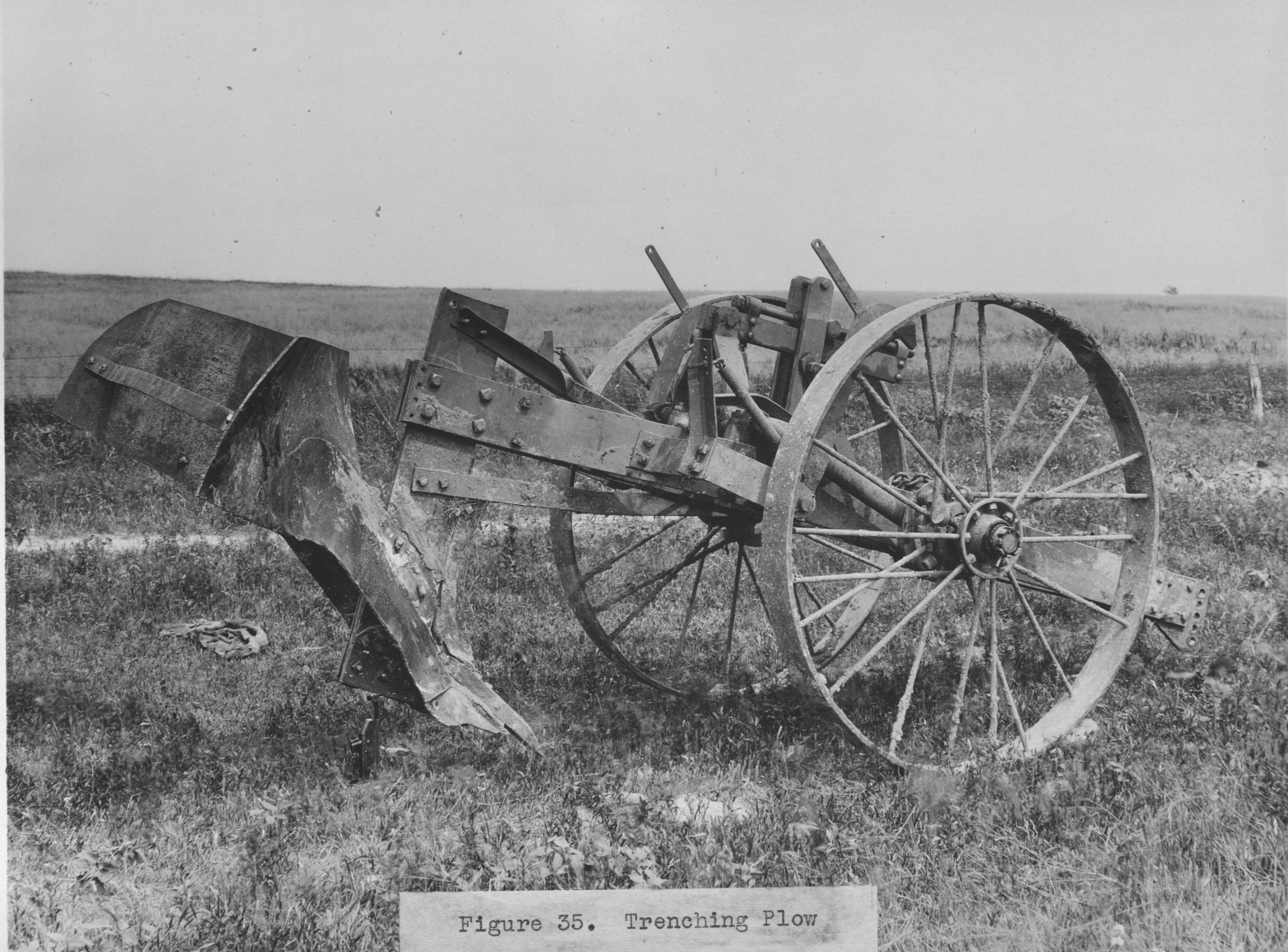

Figure 35. Trenching Plow

Figure 36. Trenching Plow in Operation.

Figure 37. Plow Excavated Trench.

Figure 38. Laying Tape Armored Cable - One Trailer.

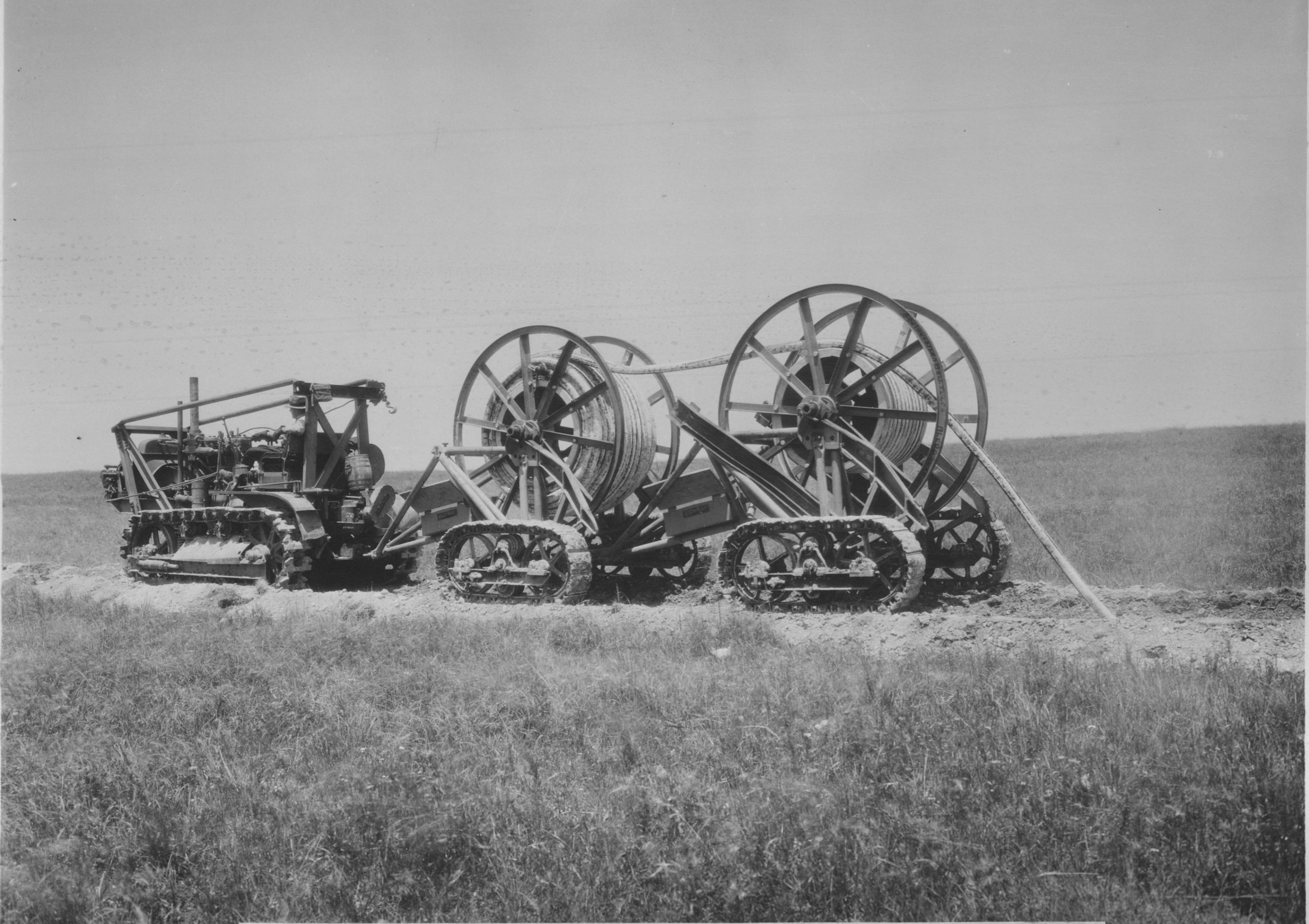

Figure 39. Laying Tape Armored Cable - Two Trailers.

Figure 40. Cable Laying Plow - First Design.

Figure 41. Cable Laying Plow in Operation.

Figure 42. Backfiller - I-Beam Type.

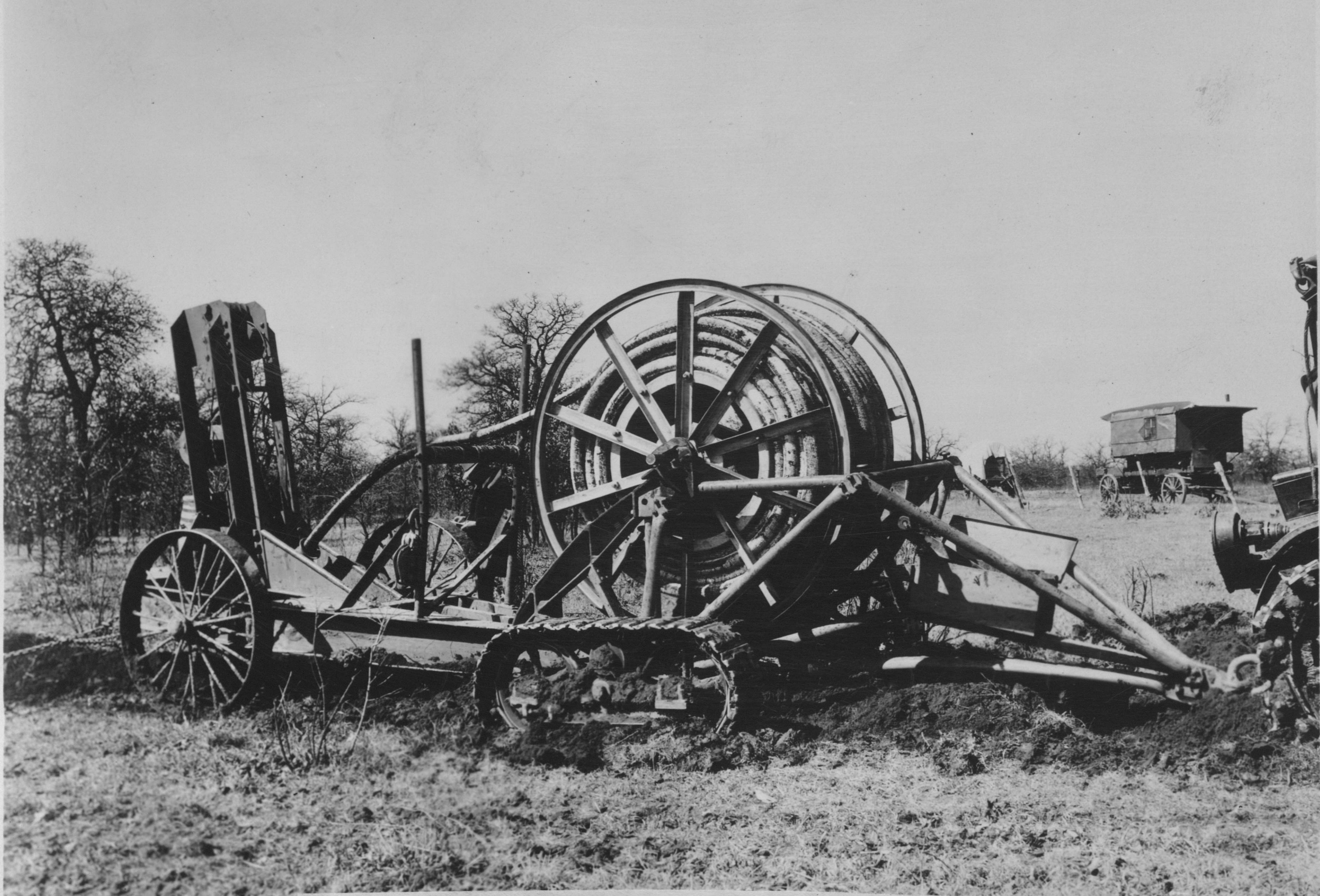

Figure 43. Cable Laying Plow - Second Design.

Figure 44. Gas Valve in End of Length of Tape Armored Cable.