CHAPTER 15

OUTSIDE PLANT FACILITIES

15.1 INTRODUCTION

The outside plant of a Telephone Company comprises, in general, all of the telephone facilities and supporting structures found between the main frame at the telephone central office and the station protector at subscribers' premises; it includes exchange and toll pole lines, both cable and open wire, and exchange and toll underground and buried cable systems.

The purpose of the outside plant is to furnish the physical paths over which communication signals are propagated. The outside plant problem in general is to fulfill the purpose of providing these physical paths in such a way as to satisfy the requirements of:

1. Safety to the public, the subscribers, and the Company's property.
2. To provide satisfactory paths from the standpoint of the subscribers.
3. It must be reliable under all conditions.
4. It must be flexible enough to meet the changing demands of the population growth and distribution.
5. Last, but by no means least, the arrangements should be such as to meet all of the above requirements in an optimum manner and at minimum cost.

In order to help realize the full importance of the outside plant, it should be noted that the total investment in the outside plant amounts to approximately 1/3 of the total worth of the Bell System. Another point of interest is that there are over 200 million conductor miles of exchange cable and over 35 million conductor miles of toll cable. Thus the total conductor mileage is more than triple the distance to the sun.

15.2 TOLL AND LOCAL FACILITIES

A distinction should be made between the facilities used for toll calls as compared with those used for local calls. This is necessary, even though every toll call requires the use of local facilities.

The local facilities include the greater part of the total telephone plant since local or short haul service is naturally used more frequently than long distance service. Accordingly, it is economically desirable to design these facilities primarily on the basis of providing satisfactory transmission within the exchange area. On longer local calls involving repeaters the same considerations described below would also apply to local facilities.

For toll or long distance connections, of which local facilities necessarily form a part in every case, more costly types of facilities are used for the long distance links in order that the transmission be satisfactory. This arrangement is in the interest of overall economy because the long distance facilities are relatively few as compared with the local facilities. It means in general that the latter facilities do not have to meet as exacting requirements as do the toll facilities with respect to attenuation per unit length, impedance regularity, or balance against noise and crosstalk. In exchange area cables, for example, wire conductors as fine as 22, 24, or 26-guage are widely used, whereas the minimum gauge in long toll cables is 19, or coaxial cable is used. Also, to keep crosstalk and noise within practical limits, quadded construction is used on the longer circuits. Generally, similar distinctions apply as between exchange and toll cables in the case of transmission over open wire. However, it may be noted that there is a certain middle ground where local trunks are of such lengths, or the service of such a type, that the transmission characteristics may approach those of the shorter toll circuits.

The development of the telephone art has involved the use of many types of facilities in the past. Changes will continue to be made as new methods come into use. At any given time the working plant will consist of facilities ranging from types on the verge of obsolescence to newly developed types barely out of the development stage.

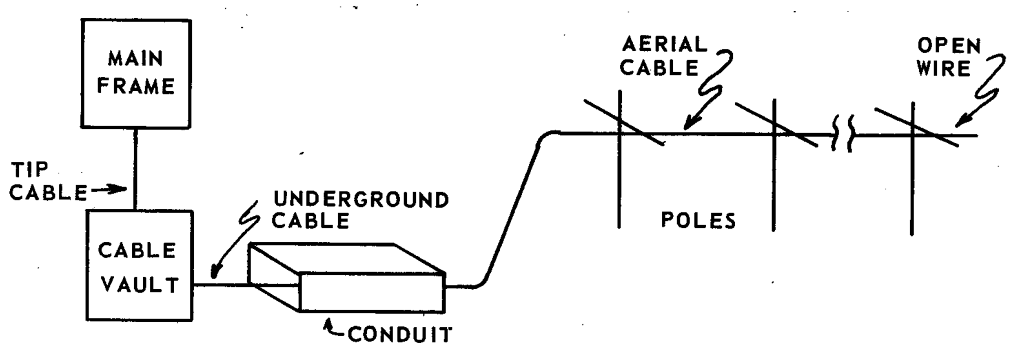
15.3 TERMINOLOGY OF COMPONENT SECTIONS

As mentioned earlier, the outside plant originates at the main frame in the central office and terminates at the station protector on the subscribers' premises. If we were to follow the pair for a typical subscriber from the central office to his telephone set, something similar to that presented in Figure 15-1 would be seen.

First of all, on leaving the main frame a "tip" cable or 300 connector with stub is found. This tip cable is spliced to the underground cable in the cable vault. The cable vault is generally located directly beneath the main frame. The underground cable is installed in conduit and generally serves densely populated routes in urban areas. At places where service requirements diminish, the underground cable may be spliced to aerial cable or perhaps buried cable. This aerial or buried cable divides and subdivides to serve the streets which intersect the cable run. Hence, the number of pairs in the cable diminishes with distance from the central office. Ultimately in suburban or rural areas a point may be reached beyond which the number of subscribers to be served is too small to justify continuation of cable, and open wire, B urban, B rural or some other form of line wire is used for further extension circuits.

There is an established nomenclature concerning the cable portions of the telephone circuits. If the cable on leaving the central office progresses for a considerable distance without dropping off circuits for subscribers, it is called a main feeder cable, or if a branch cable so extends it is called a branch feeder cable. In general, a feeder cable is an exchange cable containing a preponderance of pairs which are not terminated for service connection. Conversely, a distribution cable is one containing a preponderance of pairs which are terminated for service connectors along its length. At various poles along the cable route, selected pairs are made accessible in distribution terminals. A distribution terminal will be located near the subscriber's home. From the distribution terminal, a drop wire is used to reach the subscriber's home. The drop wire terminates on a station protector. This station protector consists of carbon block lightning arresters and in some cases, fuses which are designed to operate before the carbon blocks overheat on sustained discharges. From the station protector, inside wire leads to the telephone set. In congested areas, distribution to the subscribers may be made from a small branch cable, suspended by poles along an easement behind subscribers' homes, or attached to building walls. Such a cable, located within the confines of a municipal block, is called block cable. The wires leading from terminals of block cable are frequently supported in rings attached to building walls and need possess no strength for their own suspension. This type of wire is called block wire.

Where apartment houses are served, it is often desirable to run a branch cable into the building and terminate it in an inside distribution terminal. House cable leads from this terminal to small terminals on the various floors and then inside wire connects the individual telephone sets.



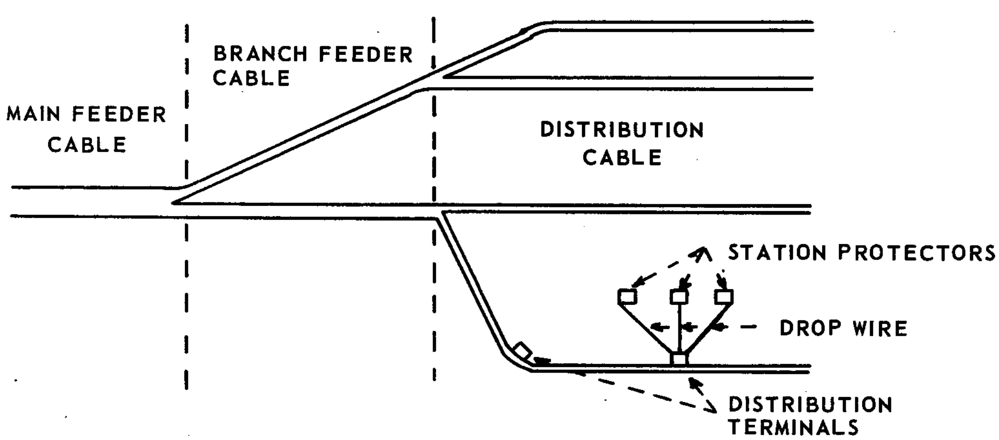


Figure 15-1 - Typical Cable Run -
Central Office To Subscribers

15.4 CROSSTALK

Crosstalk is a term widely used to mean unwanted coupling from one signal path onto another. Crosstalk may be due to direct inductive or capacitive coupling between conductors. When coupling paths give rise to intelligible (or nearly intelligible) interference, it is necessary to design the cable, open-wire line, antenna, repeater, or modulator so that the probability that a customer will hear a "foreign" conversation will be less than a prescribed value. In normal practice, a 1 per cent chance of having intelligible crosstalk is considered tolerable.

The effect of the magnetic field of one circuit on a second paralleling circuit is called magnetic induction. The effect of the electric field is called electric or electrostatic induction. Figure 15-2 shows how magnetic induction causes "crosstalk." At some particular instant in the alternating cycle, the current in wires 1 and 2 may be represented by I_a - equal and opposite vectors. As I_a increases or decreases in value, the magnetic lines of force will cut lines 3 and 4. With the relative spacing of the wires shown, more lines will cut wire 3 than wire 4. Therefore, the voltage induced by the magnetic field in wire 3 will be somewhat greater than that induced in wire 4. The voltages induced in both wires are in the same direction at any given instant, so that they tend to make currents circulate in circuit B in opposite directions. If they were equal, their net effect would be zero, however, since the voltage e_3 exceeds e_4, there is an unbalance voltage, $e_3 - e_4$, tending to make a current circulate in circuit B. It should be noted that although the current in circuit A is considered as being transmitted in one direction, the crosstalk current in circuit B appears in both ends of the circuit. The crosstalk at the left (toward the talker) is known as near-end crosstalk and that appearing at the right (toward the listener) end is known as far-end crosstalk.

If two long paralleling telephone circuits are not "balanced" against each other by some means or other, the crosstalk will seriously interfere with their practical use. The magnitude of crosstalk tends to increase with:

1. The length of the line

2. The energy level of transmitted currents

3. The frequency of the transmitted currents

Therefore, the use of telephone repeaters and carrier systems tends to increase the crosstalk level.

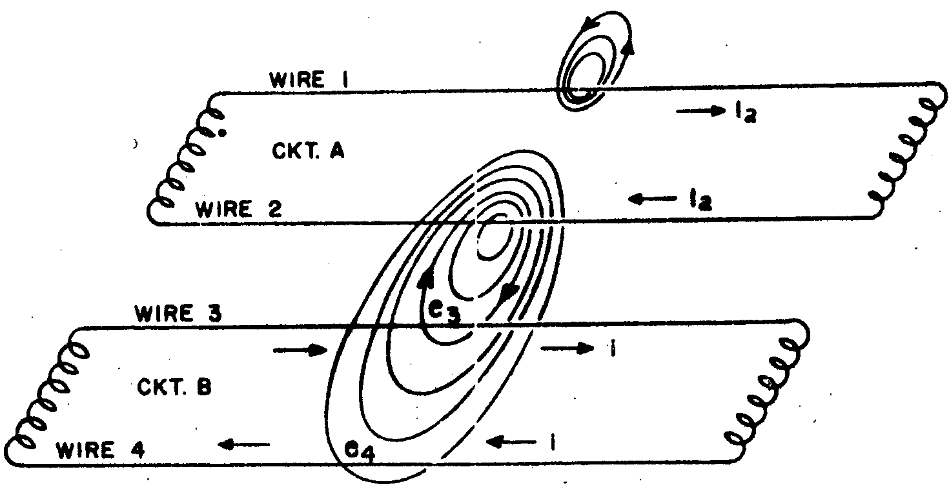


Figure 15-2 - Crosstalk On Transmission Line

There are several possible ways to eliminate, or at least substantially reduce, crosstalk induction. In an effort to keep the crosstalk in long toll circuits to a reasonable level, the effects of the basic design of long line circuits had to be taken into account. These design features will, in general, apply to both open wire and cable alike. One very important feature is the effect of the location of repeaters on crosstalk. Repeaters should be placed (i.e. spaced) on a line so that adjacent lines do not have such differences in energy level that crosstalk occurs. Methods of minimizing crosstalk will be discussed in the individual sections devoted to the various cable facilities.

15.5 OPEN WIRE

One of the first facilities to be used for the transmission of telephone signals was open wire pairs. This facility is still used today to reach outlying subscribers in rural districts and short haul toll lines containing only a few circuits.

Well before the turn of the century, the number of telephone circuits in large cities had increased to the point where open wire lines were becoming space consuming and difficult to maintain. This may be evidenced by observing a scene of Broadway in 1890 presented in Figure 15-3.

This mass of wiring had several objectional features. They were unsightly, had a high maintenance cost and very liable to storms and accidents. If the telephone plant was to be somewhere other than in the air and still be out of the public streets the only answer was to place it underground. By way of contrast, Figure 15-4 presents a picture of Broadway in 1920 after the move to underground plant was accomplished.

Figure 15-3

Figure 15-4

Open wire can be obtained in different sizes varying from 80 mils to 165 mils and is constructed of any of these three materials: (1) copper, (2) a combination of copper and steel, or (3) galvanized steel. A zinc coating is applied to the open wire to provide corrosion resistance.

In general, signaling limitations and transmission loss govern the choice of the conductor material. Steel wire is preferred for rural districts, provided it meets the transmission requirements, because its high strength permits economical long span construction. The spacing between wires for open wire exchange circuits is generally 10 to 12 inches. The larger spacing would generally be used with long spans to reduce the possibility of contact between the wires. When open wire lines encounter trees, leakage problems may result, especially during wet weather. Originally the only recourse was tree trimming. More recently an insulated wire is used when passing through trees. One such facility is called "tree wire." This wire employs a copper-steel conductor covered with rubber insulation followed by a heavy jacket of neoprene.

Before the development of the telephone repeater, the majority of long distance facilities were open wire and, to keep attenuation at a minimum, practically all open wire was loaded with relatively high inductance coils spaced at intervals of about 8 miles. Almost all of the conductors used were 165, 128 or 100 hard drawn copper wire, and each group of four wires was usually arranged to carry a phantom circuit. A phantom circuit uses repeating coils to obtain three circuits over two separate wire circuits by subjecting the third circuit on center taps of the coils of the two separate wire circuits.

The wires were carried on "ten pin" cross arms, with ten wires on each arm. These were numbered consecutively, starting at the left in the manner indicated in Figure 15-5.

The standard wire layout on the two cross arms shown in Figure 15-5 provides for ten "side" and five "phantom" circuits. Phantoms are derived from wires 1-4; 7-10; 11-14; 17-20; and 5-6, 15-16. The last is called the "pole pair" phantom. It has somewhat different electrical characteristics from the other phantoms because of different spacing and configuration of the wires. Similarly, the characteristics of the "nonpole pair" side circuits such as 1-2 or 9-10 (with 12 inch spacing between wires) are slightly different from those of the pole-pair circuits, 15-16, which are 16 inches apart. Many open wire lines of this type are still in use today in the long distance plant. Loading, however, has been generally discontinued because attenuation characteristics of open wire circuits change (particularly leakage) with varying weather conditions. For example, in dry weather, loading effectively reduces attenuation; but in wet weather, loading may actually increase the attenuation. Accordingly, to increase the overall transmission stability of such circuits, all loading was removed after the telephone repeater came into general use.

In the case of open wire lines, crosstalk reduction depends upon three main factors, namely: wire configuration on the poles, transpositions, and resistance balance. Resistance balance is primarily a question of maintenance and ordinarily presents little difficulty. The use of high-frequency carrier systems such as C, H, J or O, with their much greater crosstalk possibilities, had led to the development of configurations of open wire line in which the spacing of the individual conductors in a pair is closer together and the pairs are spaced further apart. This is illustrated in Figure 15-6 for one carrier system.

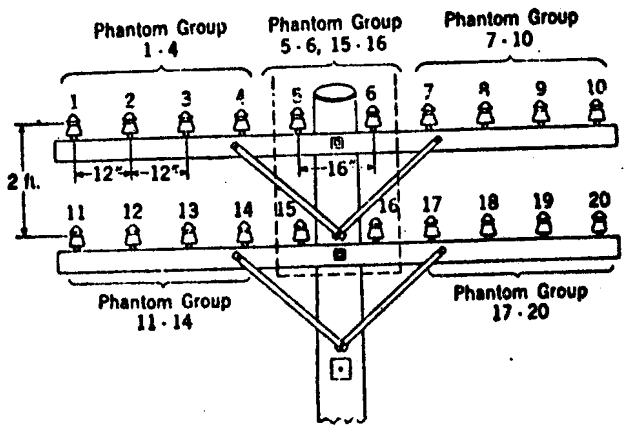


Figure 15-5 - Wire Configuration For Open Wire Line (Side and Phantom Circuits)

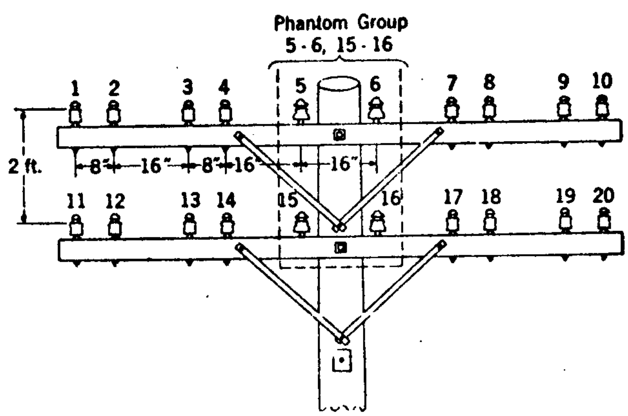


Figure 15-6 - Wire Configuration For Open Wire Line (Type-C Carrier Systems Superimposed)

This figure displays the arrangement which is generally used for "C" type carrier telephone systems (frequency up to 30 KH_z) in which the nonpole pairs have 8 inch spacing between wires and the separation between the nearest wires of the adjacent pairs is 16 inches. This configuration, which is designated 8-16-8, includes a pole-pair phantom group which is generally used for voice frequencies only. The change in spacing from 12 inches to 8 inches reduces the linear inductance of the pair and increases its linear capacitance by about 8%. The resistance and leakage remain the same and the attenuation is slightly increased. The characteristic impedance is reduced by about 50 ohms. Open wire facilities are subject to effects of leakage. This increases attenuation losses, particularly at carrier frequencies, and it must be adequately controlled to obtain satisfactory transmission.

There are two standard ways of placing transpositions along a pole line. They are most commonly known as the "point type" and the "drop-bracket", or "J-bracket", transpositions. Both types of transpositions are shown in Figures 15-7 and 15-8 respectively.

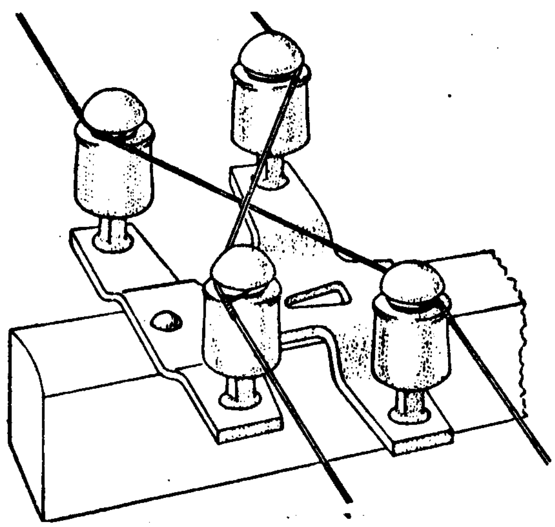


Figure 15-7 - Point-Type Transposition

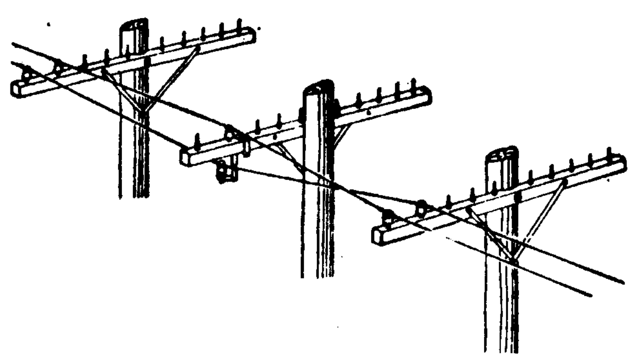


Figure 15-8 - Drop-Bracket Transposition

15.6 TOLL ENTRANCE CABLE

It is seldom practicable to bring open wire lines into the center of larger towns and cities; instead, the open wires are terminated at a pole on the outskirts of the city. These terminating cables are called "toll entrance cables." They vary in length from a few hundred feet to several miles. Many times intermediate cables are inserted in long open wire lines for river, rail or highway crossings. To meet the overall transmission requirements of long distance circuits, it is desirable to keep the attenuation of toll entrance and intermediate cable to a minimum. It is most important that the cable conductors be designed so that their impedance will closely match the impedance of the open wire to which they are connected. Loading of the proper inductance and spacing is used to obtain both low attenuation and impedance matching. The cables usually contain two guages of wire - that is 16 and 19 (previously 13 gauge was also used), - the larger gauge wires are connected to the larger gauges of open wire.

In certain instances the open wire carries frequencies which are so high that it is not desirable to load the entrance or intermediate cable at all. The resulting high attenuation is overcome by the application of high gain repeaters. However, in other cases, particularly in intermediate cables, a special type of conductor is used to handle these high frequencies. This consists of cable made up of individually shielded, 16 gauge, disc-insulated "spiral four" quads. Each such quad consists of four wires placed at the corners of a square, the two wires at the diagonals of the square forming a pair. These disc-insulated quads may also be loaded to improve still further their attenuation characteristics. However, this type of cable is used only in very small amounts and at infrequent intervals.

15.7 CABLE FACILITIES

Because of the rapid growth of telephony, the urban centers of our population soon became congested with a mass of overhead telephone wiring. Since the available space underground was limited it would be necessary to group the pairs much closer than was done with open wire, and the pairs would have to be protected from the moisture encountered underground.

Cable is comprised of two main segments; the cable core and the cable sheath. The core consists of the individually insulated conductors and the sheath is the outer shell which protects the conductors.

In first looking at the cable core, it is found that the individual pairs were twisted together for flexibility. The pairs are then stranded helically in concentric layers around a central pair or group of pairs. Thus, if we followed an individual wire we would find it following two helices; one around its mate in the pair and one around the other pairs in the cable. In the construction of the core it was mentioned that the pairs were twisted and stranded for flexibility. There is, however, another reason for the twisting. The pairs in a cable are much closer together than those in open wire lines, and the crosstalk problem is, therefore, more severe. By providing a number of different pair twist lengths the crosstalk problem is greatly reduced. This results from the fact that the signal induced in one pair from another varies continuously from adding in one direction to adding in the other, with the net pickup approaching zero.

Another element in circuit design in most of the longer voice frequency cable circuits and in all carrier circuits, is that the effect of near-end crosstalk is minimized by the use of separate paths for transmission in the two directions. In cable circuits, the pairs carrying the transmission in two directions are separated as much as possible by placing them in different layers in the cable; or, in the case of "K" carrier circuits in different cables. A similar separation is obtained in open wire carrier circuits by using different bands of frequencies for transmission in each direction.

At first conductors were insulated, to prevent physical contact between pairs, by wrapping them with strip paper. However instead of wrapping the paper on smoothly it was applied in such a way as to cause wrinkles in the paper. Thus a sort of tube of paper formed around the conductors with a good deal of air space between. The reason for allowing the paper to wrinkle is twofold: (1) for a given amount of paper the separation between conductors is greater than if the paper were wrapped smoothly thus reducing the likelihood of physical contacts between conductors and (2) air has a lower dielectric constant than paper and since attenuation is proportional to capacitance which is, in turn, proportional to the dielectric constant, we can reduce the attenuation by enclosing air gaps in the insulating material.

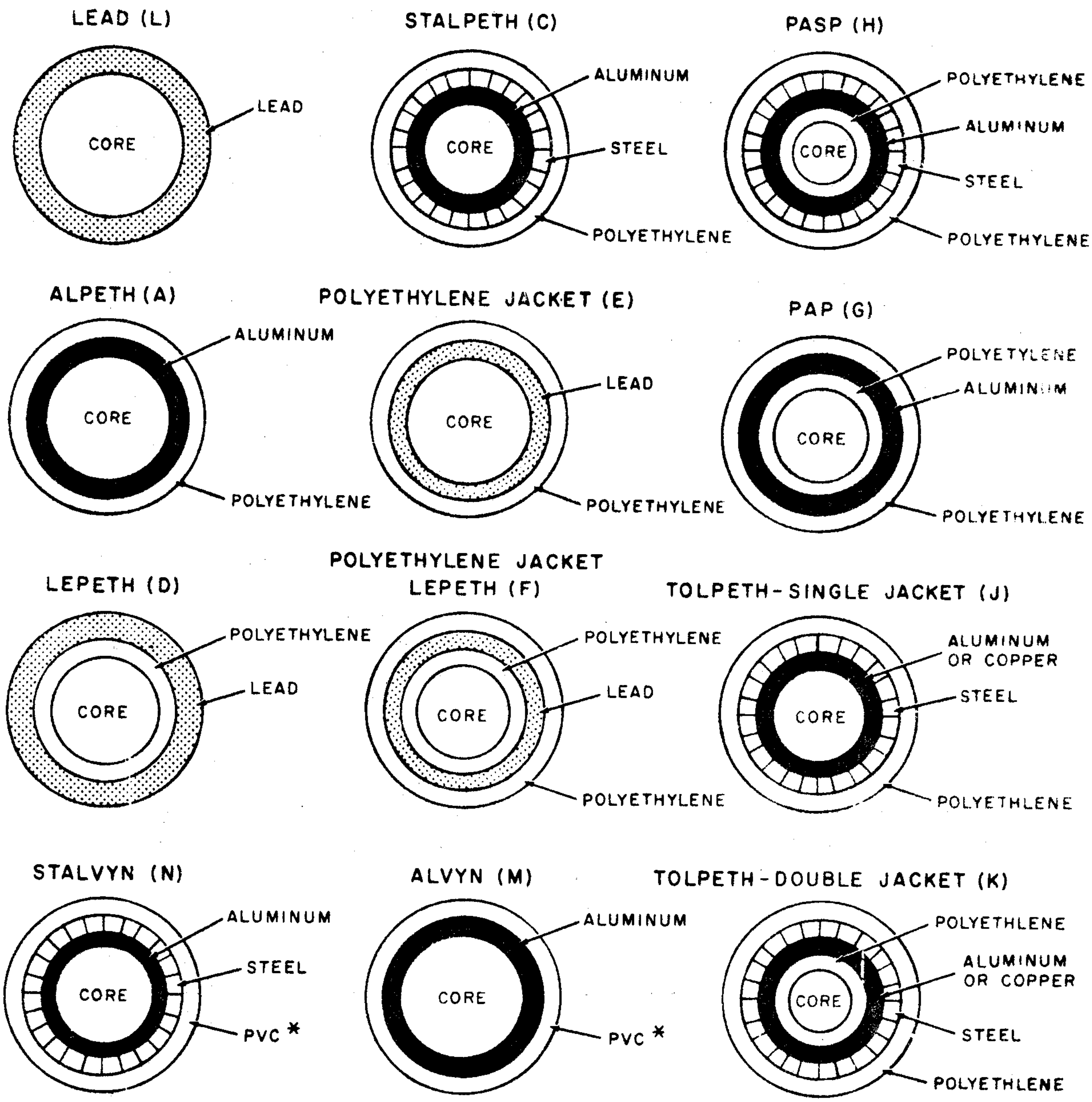
The next type of conductor insulation used was paper pulp. In this insulating process a tube of paper was formed around the conductor from a mixture of paper pulp and water, then the insulated wire was dried before the cable was formed.

Another effect of increasing demands was the introduction of mass production methods to cable manufacture. In order for mass production techniques to be effective, it was necessary to standardize cable sizes and conductor sizes.

Early in the development of cable, economic factors encouraged the use of cables of different attenuations for various conditions in the plant. For example, if a subscriber was located quite close to the central office we could provide him with adequate service with a cable pair having a much higher attenuation than we could if he was located at a considerable distance from the central office. In order that different cable lengths should match each other as well as their associated equipment it was necessary that the capacitance for cable be standardized. Two values were chosen; one for high grade transmission and another for local or exchange area transmission. These values are .062 and .083 mf/mile respectively. Since the capacitance has been fixed the only parameter left to vary the attenuation is the conductor gauge. In the exchange plant the four main gauges are 19, 22, 24 and 26. These gauges provide adequate increments of attenuation for various field conditions.

When cable was first used the sheath consisted of a lead or iron pipe and the cable core was pulled in by hand. By the turn of the century, however, methods were developed for extruding lead directly onto the cable core. The lead sheath held control of the field until the material shortages of World War II. This shortage led to the development of polyethylene as a sheath material. Polyethylene exposed to sunlight was subject to decomposition. Consequently, to shield the material from such effects, carbon back was dispersed in it to act as a light screen. It was also found that moisture would penetrate to the cable core in several years if it were immersed in water. To counteract this an overlapped aluminum tape was applied to the cable under the polyethylene. This structure is known as alpeth sheath. If still better protection against moisture is demanded, as in the case of paper or pulp insulated conductor, a soldered steel tube can be added between the aluminum and the polyethylene. This is called stalpeth sheath.

There are many other modifications to the basic types of sheath to protect the cable from such outside plant hazards as lightning, corrosion and abrasion. Various configurations and their designations are shown in Figure 15-9.



NOTE: FOR BREVITY THE SYMBOL SHOWN IN ( ) IS USED TO DESCRIBE THE DESIRED SHEATH AND IS ADDED TO THE CODE DESIGNATION AS A SUFFIX.

* POLYVINYL-CHLORIDE

Figure 15-9 - Available Types of Sheath Exchange and Toll Cable

The rapid success of polyethylene as a sheath material led to the investigation of polyethylene as a conductor insulation also. Polyethylene has two distinct advantages over paper or pulp insulation. It has a very low moisture absorption and it has very high dielectric breakdown properties. Because of its low rate of moisture absorption, sheath breaks do not require emergency maintenance as they do for paper insulated conductor cable. Cable terminals and splice closures could also be simplified if they were not required to be moisture tight. Because of the high dielectric break-down qualities, less protective measures had to be installed for lightning. The main shortcomings of polyethylene was its price and the fact that due to its higher dielectric constant a greater wall thickness was demanded to maintain the desired capacitance. The greater wall thickness added to the cost directly by requiring a greater amount of polyethylene and indirectly by increasing the core diameter thus requiring a larger sheath.

It is anticipated that these problems will be greatly reduced with the development of an expanded form of polyethylene. By mixing the polyethylene with air, economy is realized in two ways: (1) The polyethylene saved by the void spaces in the expanded poly and (2) The resulting structure has a lower dielectric constant thus requiring a thinner wall to obtain the required capacitance. Since the initial field trial in 1950 of polyethylene insulated conductor cable (which is called PIC cable) the use of this type of cable in place of cable insulated with strip paper of pulp has grown rapidly. Extra pairs are included in paper and pulp insulated cable to insure that a specified number of pairs will be usable.

The types of polyethylene insulated cable, commonly called PIC cables, which have been manufactured from 1954 to 1958 are generally termed as <u>ODD</u> count PIC because they include an extra pair with each 100 pairs or fraction thereof to conform with paper and pulp insulated cables. Polyethylene is much more reliable as an insulating material than strip paper and paper pulp. This together with improved manufacturing techniques makes it possible to guarantee that all pairs will be free from shorts, crosses, opens and grounds.

A new type of PIC cable was designed in the late 50's and is designated as EVEN count PIC cable. It is so designated because it does not have an extra pair for each 100 pairs or fraction thereof. Since all pairs in PIC cable are guaranteed to be free from opens, shorts, crosses and grounds, the extra pair is not needed as a substitute for defective pairs. It is obvious also that, without extra pairs, the pairs within the cable may be divided into uniform size groups. A 25 pair unit has been selected as the most suitable size for a standard group and all cable sizes except those smaller than 25 pairs, can be divided by this number. The pairs of the 25 pair group are identified by a simple code which uses 10 colors, 5 for the tip conductor and 5 for the ring conductor, with no duplication. The 25 pair groups are bound with bicolor binders made from thin strips of polyethylene. The colors of these binders follow the same color code as is used for the pairs. Such an arrangement permits fast and easy identification of any conductor or pair in the cable without the aid of translation charts. Self supporting PIC cable is now commonly used in aerial cable plant, where the support wire is built into the center of the PIC cable instead of lashing to a separate support wire.

It will be noted that unlike the development of inductance loading and repeaters, cable development received its initial impetus in the exchange area rather than in the toll plant. However, the development of better cables naturally resulted in their use over long distances. Toll cables between nearby centers of population, are placed on existing pole lines. These are called "aerial cables," as opposed to the "underground" cables in ducts below street level, or the more recently developed "buried" cables which are placed directly in ploughed trenches in the ground in open regions of the country.

When phantom circuits were introduced, their successful application to cable was contingent upon a method of reducing crosstalk by means similar to the phantom transpositions in open-wire lines. For this purpose "quadded" cable was introduced. A quad is two pairs of wires twisted around each other, in the same manner as the wires of each pair are twisted. A toll cable may contain a few unquadded pairs, such as those used for the transmission of broadcast programs; but in most cases, nearly all the units are quads.

One element of circuit design in most of the longer voice frequency cable circuits and in all carrier circuits, is that the effect of near-end crosstalk is minimized by the use of separate paths for transmission in the two directions. In cable circuits, the pairs carrying the transmission in two directions are separated as much as possible by placing them in different layers in the cable; or, in the case of "K" carrier circuits in different cables.

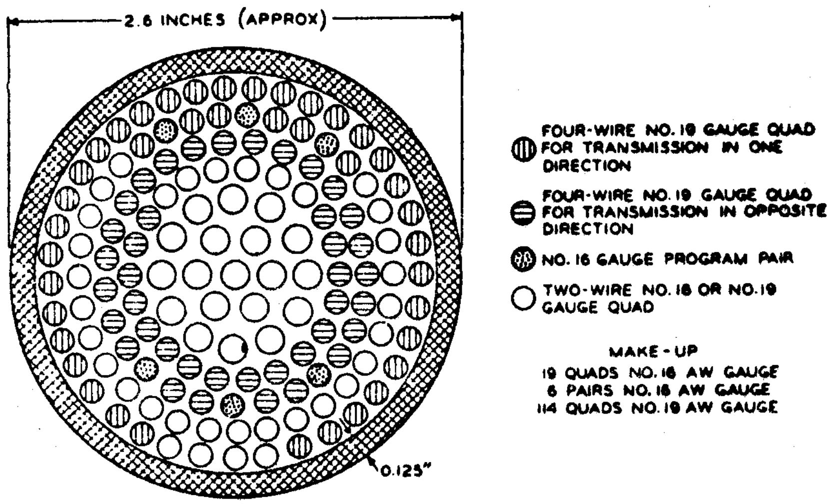


Figure 15-10 - Typical Toll Cable

15.8 COAXIAL CABLE

Coaxial cable was designed for broadband transmission, such as transmission of television signals or long-haul toll circuits where carrier systems may be economically employed. Coaxial cable is not a balanced transmission line like paired cable. It is completely unbalanced, one wire being used for transmission and a grounded cylindrical shield for the return conductor. Crosstalk, noise, or other interference cannot, therefore, be controlled by twisting the conductor. Interference is controlled entirely by the shielding action of the ground return conductor, which completely surrounds the center conductor. The efficiency of the shielding action increases with frequency and is therefore limited to use for transmission of high frequencies with a lower limit of approximately 50 KH_z. In actual use the coaxial lines are stranded into a cable along with paper insulated pairs. A typical cross-sectional view is shown in Figure 15-11.

Some of the paper insulated pairs are used for control of the repeaters needed on the coaxial system while others may be used for short-haul voice toll circuits between neighboring central offices where carrier systems are not economical.

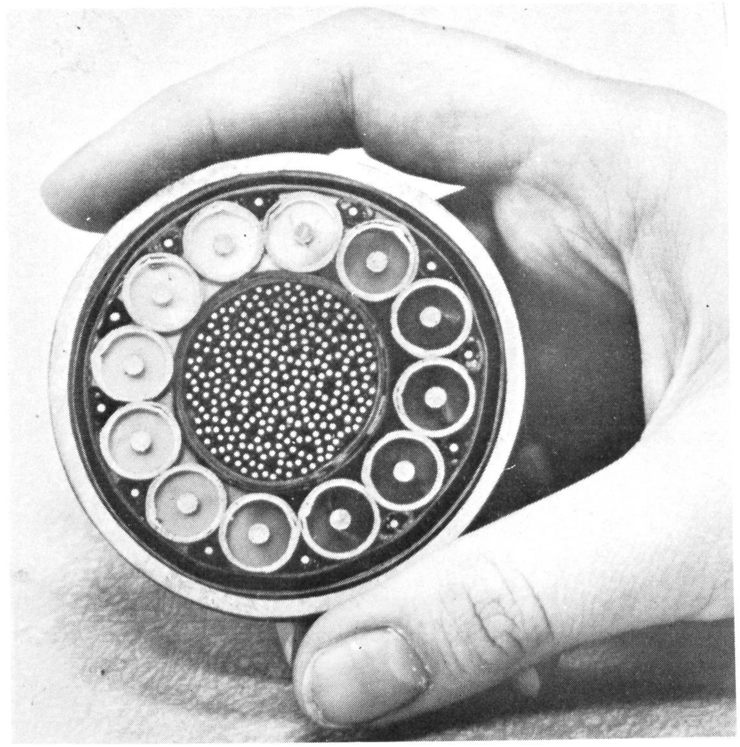
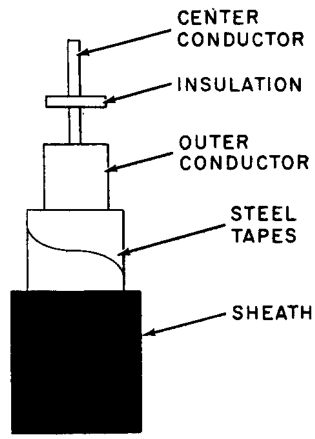


Figure 15-11 - Coaxial Cross-Section

A. ETV COAXIAL CABLE

Multichannel educational television, including color, is economically feasible for limited school budgets, mainly because of the availability of four coaxial types as shown in Figure 15-12. Basic coaxials for aerial or duct installations, CA-1878, and for plowing, CA-3002, are supplemented by coaxial cable with PIC pairs for intercity trunk use, CA-3015 and CA-3016, for buried and aerial applications respectively. Coaxial cables with PIC pairs are also available for use at airports, colleges or in other situations where there are heavy circuit requirements for exchange or centrex service, interoffice trunks in addition to broadband data and video grade circuits.

Aerial cables can be lashed on to an existing cable and support strand, or on a separate suspension strand. These aerial coaxials, CA-1875 and CA-3016, can also be installed conveniently in duct or conduit. For buried applications, the new C Cable Plow accommodates the CA-3002 and CA-3015 cables for plowing in most any terrain. Exacting tolerances and rigid quality control in the manufacture of these coaxials permit hi-quality transmission of six ETV broadcasts from 8 to 88MH$_z$.



CA-1878
ALPETH SHEATH
TV ONLY; AERIAL OR DUCT

Single coaxial tube where plowing is not possible or practical. Used extensively in early ETV installations, CA-1878 has been modified to include an aluminum shield preventing interference from nearby mobile radio or other transmitters in the 45 to 50 megacycle range.

CA-3002
PASP SHEATH
TV ONLY; BURIED

Single coaxial tube. A layer of corrugated steel stiffens the cable against deformation during the plowing operation; an aluminum shield provides lightning protection.

CA-3015
PASP SHEATH
(with PIC pairs)
TV PLUS MESSAGE OPTIONS; BURIED

A choice of 16, 37or 63 voice pairs around the coaxial tube is available for those applications where ETV can be combined with other services in the same sheath. Same PASP design as CA-3002.

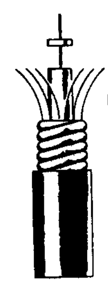
CA-3016
ALPETH SHEATH
(with PIC pairs)
TV PLUS MESSAGE OPTIONS; AERIAL OR DUCT

Identical to CA-3015; but has no corrugated steel layer or inner polyethylene jacket; same PIC options of 16, 37 or 63 pairs arranged around coaxial tube.

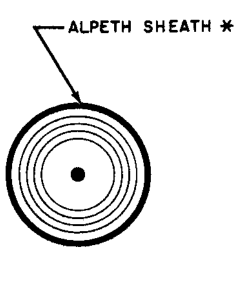
Dia over sheath:
0.61"
Wt.(lbs. per ft.)
0.2

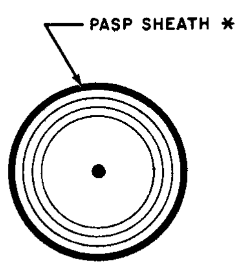
Dia over sheath:
0.81"
Wt.(lbs. per ft.)
0.32

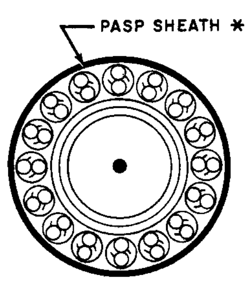
Dia. over sheath:
16 pr.: 1.16"
37 pr.: 1.37"
63 pr.: 1.56"
Wt.(lbs. per ft)
16 pr.: 0.66
37 pr.: 0.94
63 pr.: 1.25

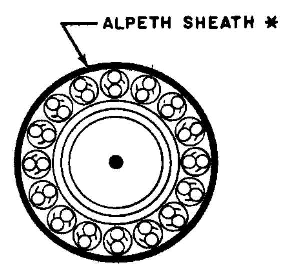


Dia. over sheath:
16 pr.: 0.99"
37 pr.: 1.19"
63 pr.: 1.38"
Wt.(lbs. per ft.)
16 pr.: 0.44
37 pr.: 0.66
63 pr.: 0.98









* SEE SHEATH CONSTRUCTION

Figure 15-12 - Mechanical Characteristics Coaxial Cables Specially Designed For Educational Television

Figure 15-13 provides a typical layout of part of a closed circuit television system. A brief explanation, omitting facility and equipment details, follows.

At the origin, video and sound base-band signals are accepted from the customer by a TRANSMITTING MODULATOR in which the appropriate video and sound intermediate frequency carriers are modulated for transmission to the subscribers' sets. This modulator is not required for community television antenna systems.

The modulated signals are transmitted from the origin over feeder cables. PRIMARY FEEDER cables differ from SECONDARY FEEDER cables only in that the latter provide connections for distributing the signals to subscribers. It is possible, in some routes or systems, that secondary feeders only will be provided. Other systems, such as Educational TV systems will be comprised almost entirely of primary feeders.

Branches of feeder cables are derived by the use of DIRECTIONAL COUPLERS which act as passive (no amplification) dividers.

A LINE AMPLIFIER is used at intervals along the feeder cables to compensate for attenuation of the signals. An EQUALIZER is required in each amplifier section to assist in compensating for transmission differences in the signal frequencies as temperatures vary. AUTOMATIC LEVEL CONTROL is applied at every third line amplifier to assure maintenance of signals at their proper strength.

BRIDGING AMPLIFIER, connected to the secondary feeder cable by a passive divider provides a means for connecting DISTRIBUTION CABLE to the feeder cable. Several (up to four) distribution cables may be connected at a bridging amplifier. Maximum length of a distribution cable should vary from about 1000 feet to 1500 feet, depending upon frequencies transmitted.

A TV TERMINAL is required at each service drop connection at the distribution cable.

A LINE EXTENSION AMPLIFIER may be used to permit the use of longer distribution cables. Only one such amplifier may be used in each distribution cable, as a greater number results in considerable signal distortion. Maximum length of distribution cable, with a line extention amplifier located near the center of the cable, is about 2000 feet to 3000 feet, depending upon the frequencies transmitted.

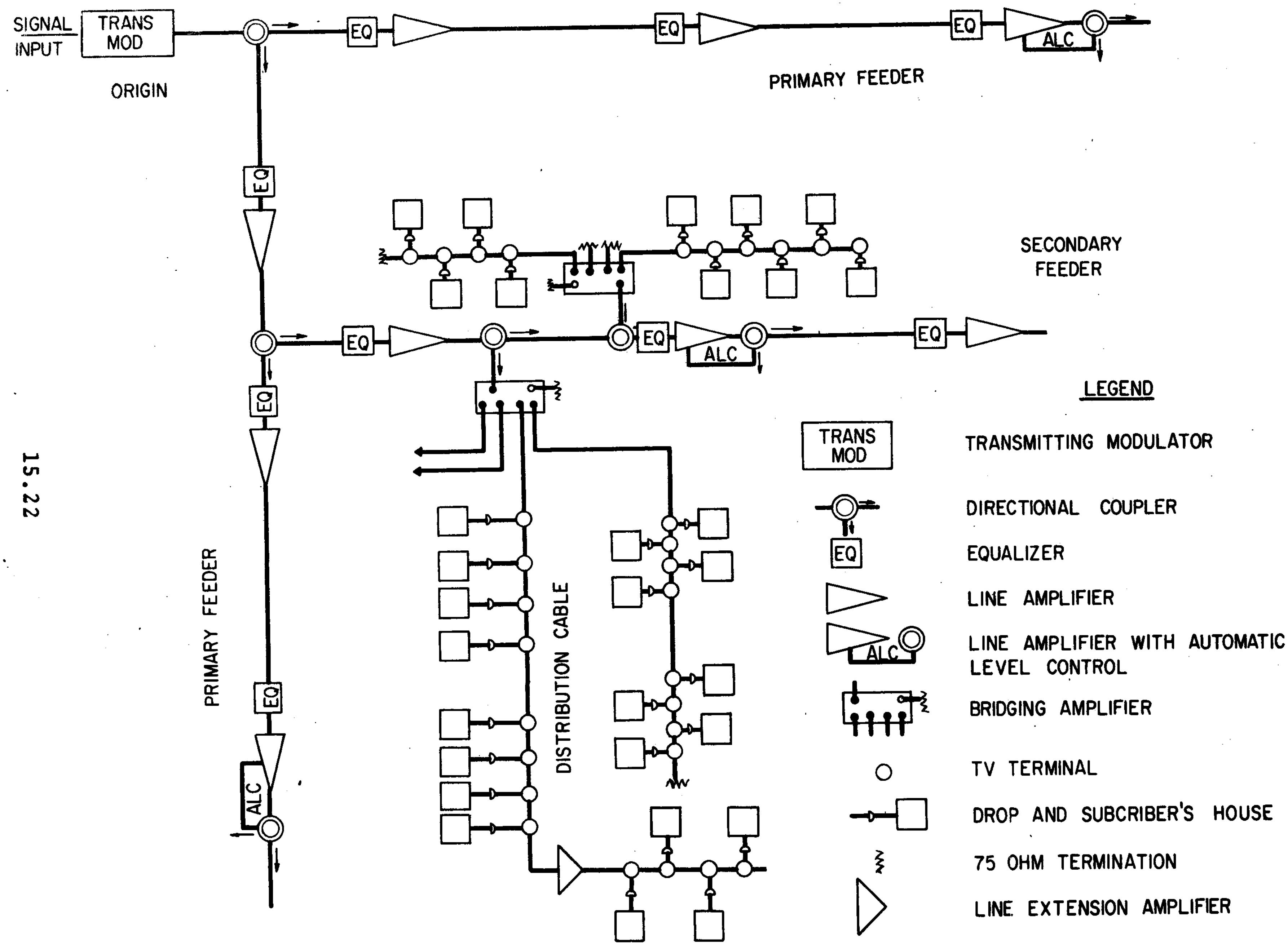


Figure 15-13 - Typical Layout - Closed Circuit TV System

Seventy-five (75) ohm TERMINATION is required at the end of each distribution cable or at each unused position on the bridging amplifiers to reduce echo effects in the system.

A grounded fitting for terminating the drop must be provided on the subscribers' premises. This fitting will generally provide the point of demarkation between Telephone Company plant and plant which is the responsibility of the user.

The foregoing description, being very general, applies equally whether the system is aerial or underground.

15.9 SUBMARINE CABLE

Another type of cable facility is submarine cable, such as the four transatlantic cables, the two cables to Hawaii with single continuation to Philippines and Japan, and the individual cables to Bermuda, Puerto Rico, Cuba, Jamaica - Canal Zone, and St. Thomas - Caracas.

The success of these cable runs, however, has been the result of over 90 years' work. The first successful wire communications systems across large bodies of water made use of a telegraph cable laid across the Atlantic Ocean in 1866. This cable, the first success after a decade of unsuccessful attempts, operated only one month before failing. Success on even such a limited scale, however, furnished the impetus for further work and by 1900 a number of telegraph cables were in operation beneath the Atlantic.

Although transoceanic voice communications have been established since 1927 by the use of radio systems, no attempt has been made to establish transoceanic wire communications for voice until recently. The need for wire communications is twofold. First, additional channels cannot be added to the radio system because of lack of space in the frequency spectrum. Secondly, radio systems are subject to varying periods of outage due to atmospheric conditions such as storms, sun spots, etc.

When engineers began to think in terms of voice communications on submarine wire, it was evident that the existing telegraph cables were inadequate. These were single conductor wires having high attenuations. The resulting bandwidth of the first transatlantic cables, using the best available techniques in terminal apparatus amounted to only 1-1/2 cycles per second. Bandwidths of some later cables were extended to about 100 cycles per second by the use of permalloy tape continuous loading to reduce the attenuation.

The first deep sea cables used for telephone use were laid between Key West and Havana in 1921. These were also the first deep sea cables using a coaxial return conductor; they were also continuously loaded with permalloy tape. Each of the three cables handled one telephone circuit and two telegraph circuits.

In the early 1930's it became apparent that any economical long underwater system would require repeaters. For the next 20 years, development was directed toward such a system. This resulted in 1950, in a submarine cable system between Key West and Havana with flexible submerged repeaters. By this means the attenuation was reduced to the point that 24 telephone circuits were derived from 2 cables, one for each direction of transmission. Similar systems were laid across the Atlantic with 36 telephone circuits.

The recent transatlantic cables had the appearance shown in Figure 15-14, and were used from 1950 to 1962.

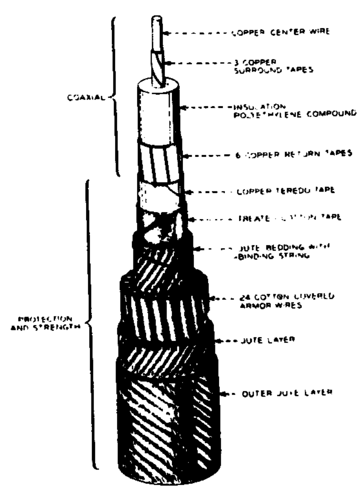


Figure 15-14 - Submarine Cable

The Key West to Havana cable system supplied 24 channels per pair and the transatlantic system supplied 36 channels per pair. These numbers correspond to bandwidths of one or two hundred KHz which were considered reasonable when the system was designed because of repeater limitations. In general, the economic balance between the cost of the transmission medium and the cost of the repeater requires that a system of higher bandwidth have a lower loss transmission line. A lower loss coaxial, in turn, means a larger coaxial with a larger center conductor. Because of skin effect, the large center conductor of a large coax is used inefficiently from a transmission standpoint.

The center of this conductor could be eliminated, or better still, it could be replaced with a strength member to help support the cable during laying and recovery. In fact, by changing the ratio of inner conductor diameter to outer conductor diameter slightly, all of the strength necessary to support the cable can be placed inside the center conductor. The construction of the present design can be seen in Figure 15-15, and in use since 1962.

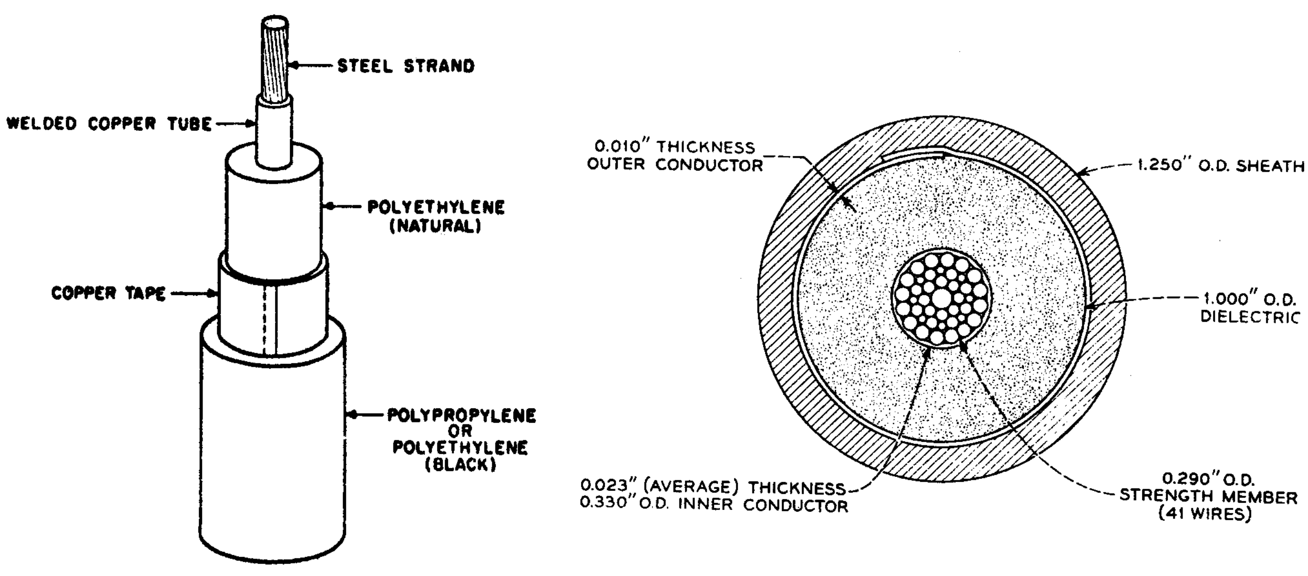


Figure 15-15 - Ocean Cable (Armorless-Lightweight)

The steel support wires can be observed inside the center conductor. The center conductor is insulated from the outer conductor by polyethylene. The outer conductor is made up of a copper tube. Another important design consideration in this new cable is that the torque under tension is considerably smaller with this design since the support wires are at the center of the cable. Because of this, twisting tendencies of the cable under tension are nearly eliminated. In the type of cable employed in the first transoceanic runs, the direction of spiral was the same for the inner tapes, return tapes and the armor wires. Thus the weight of the cable as it was lowered to the ocean floor was sufficient to put a torsion force on the cable. This torsional force was sufficient to put 16 complete turns in the cable per 100 feet during the laying process.

With this amount of untwisting during the laying process, the center conductor of the coaxial is stretched far beyond its elastic limit. When the cable reaches the floor of the ocean and the weight is removed, the cable again twists up. What then happens to the excessive length of the center conductor? It is believed that the hydrostatic pressure to which it is exposed molds it back into its original configuration. The new design, with its lower weight and smaller torque produces an untwisting of only one turn per 100 feet during the laying process which is well within the elastic limit.

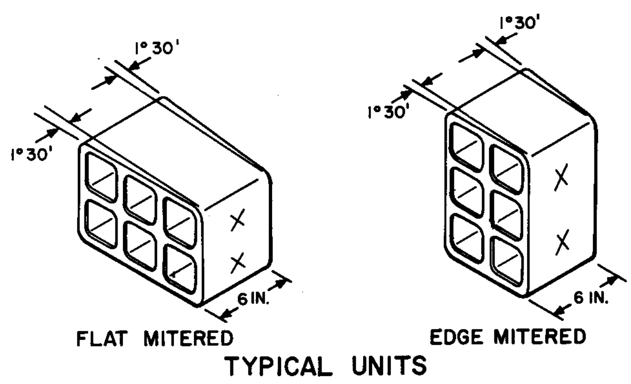
15.10 AERIAL CABLE PLANT

If a cable is placed aerially it must be supported. The size of the support wire is determined by the size of the cable which it is to support, anticipated storm loading conditions and the distance between poles, or span length. The support wire may be secured in place first and the cable may be lashed to the strand or the two operations may be combined as is done in the case of prelashing. Also available is an aerial cable that is self-supporting, which does away with lashing to a support wire.

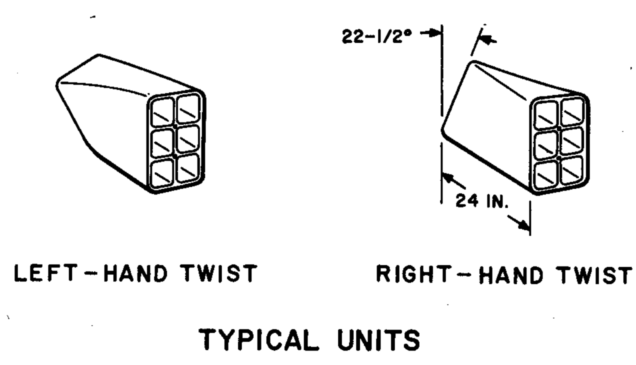
15.11 UNDERGROUND CABLE PLANT

Underground plant proves in economically in congested areas where right-of-way for aerial construction is difficult and expensive to obtain, or city ordinances prohibit the placement of aerial cable. Underground cable is much less susceptible to accidents and storm damage than aerial cable, and when large cables are involved this results in substantial maintenance savings which can offset part of the high first cost of an underground conduit system. The conduit itself has been made of such things as asbestos fibre, wood or paper fibre impregnated with coal tar, soapstone, and fiberglass. The most commonly used material, however, is a vitrified clay. It is formed in straight sections of single duct or 2, 3, 6 and 8 duct multiple units. In addition to the straight sections it can be obtained in curved sections called mitered duct, for use when it is necessary to change the horizontal direction or vertical depth of the subway, or when it is necessary to grade the conduit up or down to avoid an obstruction. Transposition conduit having an angular twist of 22-1/2 degrees between its ends is used to change from a construction in which the conduit is laid on its longer side to one laid on its shorter side. Several of these special purpose configurations are shown in Figure 15-16.

Each kind of clay conduit is available also in a special form having longitudinal scorings midway along the walls of the ducts. This scoring permits the units to be separated into several pieces and reassembled. In this way, scored conduit is used to restore existing subways that may be broken during street excavations, or to replace conduit removed by telephone men while clearing trouble in the cable.



Mitered Clay Conduit



Transposition Clay Conduit

Figure 15-16 - Conduits

When two sections of conduit are to be joined, dowel pins are placed in the dowel holes at the end of one section and the next section is guided into place so that the dowel pins engage its dowel holes. The two sections are then sealed by means of a mortar bandage. Figure 15-17 shows the appearance of a mortar bandage. The mortar bandage is simply a piece of folded cheesecloth enclosing a ribbon of cement. The bandage is prepared on location and wrapped around the joint and tied in place.

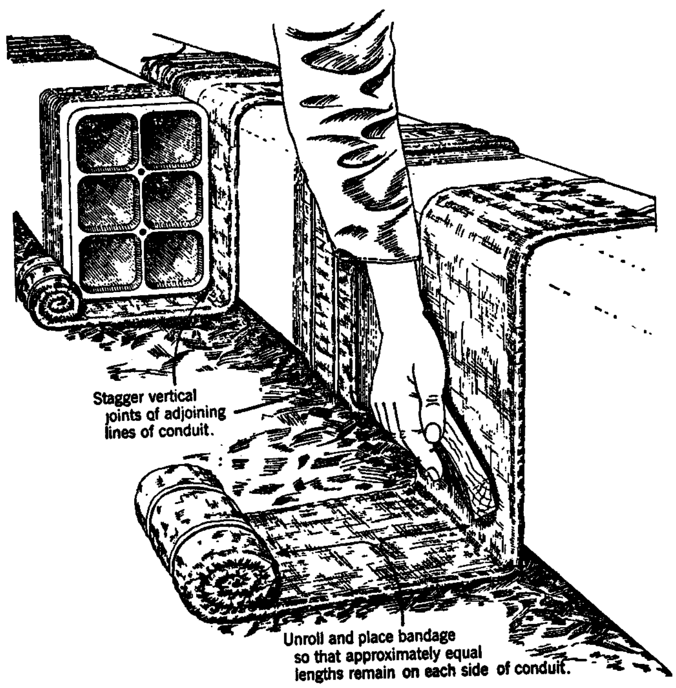


Figure 15-17 - Underground Mortar Bandage

The cost of installing a duct system is quite high. Since the cost of tearing up the road and digging the duct trench is the major cost of a duct system, care is taken to make a good estimate of the future requirements so that an adequate duct structure can be installed initially.

15.12 BURIED CABLE PLANT

A buried system differs from an underground system in that the cable is placed directly into ground without the use of conduit. Buried cables have been used to an increasing extent in recent years with the advent of moisture resistant plastic insulations. As compared to underground cable in conduit, buried cable is cheaper to install. As compared to aerial cable, it is subject to fewer hazards to service continuity. It is subjected to smaller and slower swings in temperature which makes transmission regulation less of a problem. It is also usually easier to obtain right-of-way for buried plant than for aerial plant. In the past, the chief use of buried exchange plant was in locations where aerial lines were not suitable from an appearance standpoint, as in high grade residential sections or where clearance was a problem, such as near airports.

Buried cable has the disadvantage that an additional cable installation is just as expensive as the first installation while an additional aerial cable can be placed on the existing pole line. It is also more costly to locate a fault in the buried plant than it is in the aerial plant. New techniques in the art of fault location are, however, continually being developed to improve this situation.

The procedure for burying distribution plant involves opening a trench for the cable and a series of connecting lateral trenches for the service wires to houses. The cable and service wires are then placed in the trenches. A loop of cable, about 5 feet in length is left above ground at each terminal location and the trenches are then refilled and tamped. A terminal such as shown in Figure 15-18 consists essentially of a pointed metal post, which is driven in the ground, and a cable closure. The cable is looped in the closure through the bottom, after which a section of cable sheath is removed so that any pair in the core will be accessible for making a connection to a subscriber at that point. Service wires to a number of subscribers are usually provided from each terminal point. At the house end, the service wires are brought through a small opening in the building wall, either above or below ground level.

15.13 DISTRIBUTION WIRES

With the advent of polyethylene with its high dielectric breakdown and nonhygroscopic properties it became feasible to use unsheathed cables. These unsheathed cables are called distribution wires and they have distinct advantages over sheathed cables in the smaller size ranges. Their transmission characteristics, when dry, closely resemble those of pairs in sheathed cables, but when wet they change considerably in transmission characteristics. Used with discretion and in moderate lengths, they have a very definite field of use.

One of these is the B Rural Wire. It is intended primarily as a distribution facility in rural areas. It consists of six twisted pairs of 19-gauge copper conductors around a polyethylene insulated 109E support wire. Each conductor is insulated with polyethylene followed by a second layer of polyvinyl chloride or PVC for short. PVC is somewhat more abrasion-resistant than polyethylene and the pairs are completely color-coded. Each pair has a different twist length to minimize crosstalk.

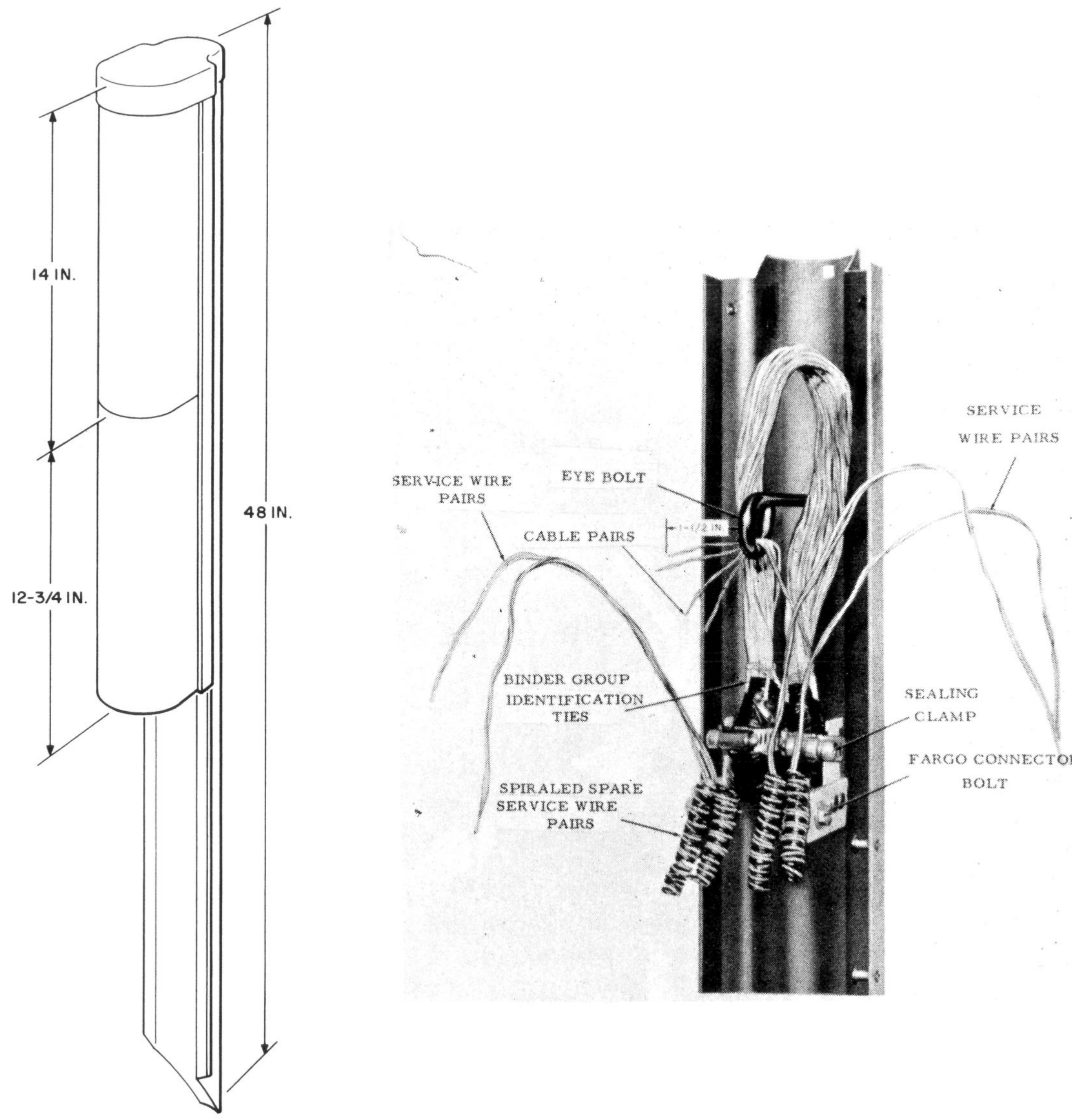


Figure 15-18 - Terminal Location

Since this wire has become available it has found use in a variety of ways. It is being used for extension of subscriber plant into new areas and for branches off existing main lines of cable in locations where circuits are needed for only a few customers. It is sometimes used to defer placement of cable particularly where there is immediate need for a few additional circuits on an existing route and future circuit requirements are uncertain. It might be preferable to place a B Rural Wire if this would take care of immediate requirements and probable growth over the next two or three years, at which time a better forecast of long-range requirements could perhaps be made. B Rural Wire is also used to supplement existing runs of small distribution cables by taking over part of the local distribution and thus freeing several pairs of the distribution cable for new customers located further out.

Another type of distribution wire is the B Urban Wire. This wire is similar to the B Rural Wire in construction but it is designed for use in heavily populated areas as a replacement for lead sheath block cable. Its sheathless construction furnishes access to all pairs at all poles. This makes possible quick connection of drop wires to subscribers without costly splicing. B Urban Wire has 16 twisted pairs of polyvinyl chloride-insulated #24 gauge copper conductors spiraled around a polyethylene insulated 109E support wire. Eight different twists are used to minimize crosstalk and each pair is distinctly color coded.

The transmission disadvantages associated with B Rural Wire, due to wet-dry changes in attenuation, apply to B Urban Wire also, but they are not so bothersome since urban wire is used in relatively short lengths, (typically 1000 to 2000 feet), while rural wire is used in long runs - sometimes up to 10 miles.

It is not difficult to see why the Operating Telephone Companies like these wires. They are easier and cheaper to install than open wire or cable, and drop wire connections are easier too, since there is no sheath to remove. The drop wires are connected to the B Rural and B Urban Wire by means of a clever terminal known as the "watch case" terminals. This terminal is clamped onto the support wire and furnishes access to one pair.

These extension facilities which have briefly been investigated are used in the aerial portion of the outside plant. As progress from these facilities toward the central office is made the number of circuits required increases and cable will be employed. This cable may be in the aerial plant, underground plant, buried plant or some combination of these three. How is it decided which type of plant to use in a given situation? This is determined mainly on a basis of economics, but there may be other factors which contribute to the decision such as community regulations, customer good will, or appearances.

15.14 PROTECTION EQUIPMENT

Protection is employed in the telephone plant for two reasons: (1) To limit the voltage to prevent breakdown of insulation or hazard to the subscriber or Company personnel. (2) To limit the duration of high current to prevent overheating or fire hazard. Limitation of voltages is accomplished by means of protector blocks which are air gaps connected across the dielectric which they are to protect and these air gaps spark over when their rated voltage is exceeded. Limitation of high current duration is accomplished by the use of fuses, heat coils, and fuse cable.

A. PROTECTOR BLOCKS

The protector blocks used to limit excessive voltages consist of two carbon blocks andhave the configuration shown in Figure 15-19.

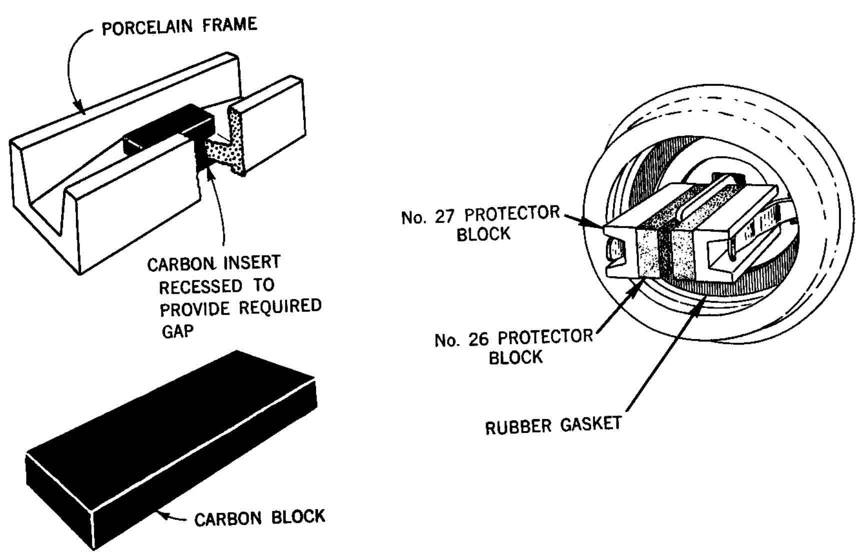
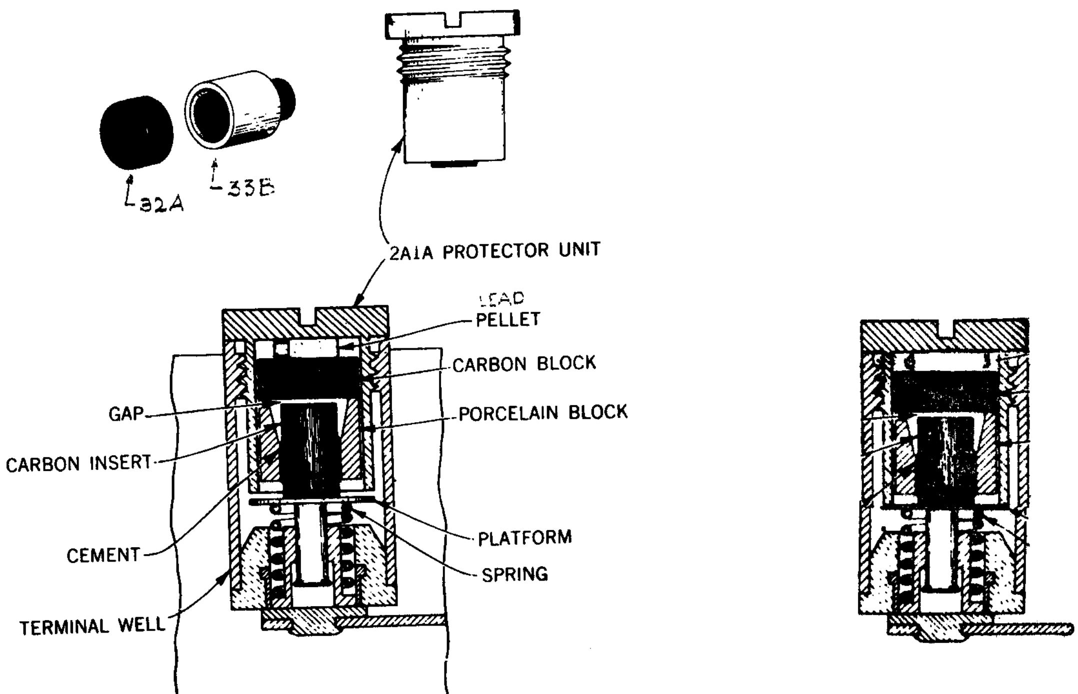


Figure 15-19 - Protector Blocks

When these two blocks are placed in their protector mounting a small air gap is provided between them. When the voltage across these blocks is high enough, sparkover occurs between them, providing a low impedance path around the protected facility. These blocks are currently produced in three sizes. One with a 3 mil spacing which will break down with a peak voltage in the neighborhood of 500 volts, another with a 6 mil spacing which will break down with a peak voltage in the neighborhood of 800 volts, and another with a 10 mil gap which will sparkover with a peak voltage of approximately 1250 volts. The 3 mil blocks are generally used at subscribers' premises and at the main frame at the central office. The 6 mil blocks are used at junctions between cable and open wire. The necessity of applying protector blocks at the junction of open wire and cable results from the exposure of open wire to lightning surges and the low dielectric breakdown of paper insulated conductor cable. Since the open wire has no sheath to shield it from lightning strokes it is capable of developing high voltages, but due to the wide spacing and heavy conductors used, it in itself, is not too vulnerable to damage. If, however, the open wire is connected to a pair in a cable, this cable pair is then subjected to surge voltages which may be sufficiently high to break down the conductor insulation if paper is used. Therefore, protectors must be used to prevent excessive voltages from appearing on the pairs in a cable. In localities where lightning is particularly severe, such as over a high mountain it may be necessary to use an auxiliary protection scheme. In such a case the 10 mil blocks are used as backup protection for the 6 mil blocks. These 10 mil blocks would be located 8 or 10 pole spans away from the junction of the open wire and cable. At this distance there would be sufficient impedance between the two sets of blocks to allow operation of the 10 mil blocks thus relieving a good portion of the load from the 6 mil blocks. The lightning problem at such junctions is of much less concern in the PIC cables where the dielectric strength of the conductor insulation is considerably higher than it is for paper insulated conductor cable.

Protector blocks have the advantage over fusible types of protectors in that they will clear themselves when the surge has passed. Thus, it is not required to dispatch maintenance men for this job. If a surge is continuous, such as a power cross, the blocks can develop sufficient heat and present a fire hazard. To prevent this from happening, a fuse had to be associated with the protector blocks at the subscribers' premises. Elimination of this fuse, by increasing the current carrying capacity of the protector blocks, was possible by the development of a new type cylindrical shaped protector block. Essentially the construction is the same; the gap being provided between two carbon blocks; but in this type of protector a low melting point alloy slug is provided behind one of the carbon blocks. When the blocks sparkover, the ground path is established through this slug and if arcing continues the slug melts establishing a metal-to-metal path which bypasses the carbon blocks before sufficient heating of the blocks occurs; thus avoiding a possible fire hazard. In this case, of course, the cable circuit will be grounded until a new protector block is installed. This type of protector is shown in Figure 15-20 along with a schematic showing its operation.



Before Operation

After Operation

Figure 15-20 - Cylindrical Protector

B. SNEAK CURRENT PROTECTION

When foreign voltages are not high enough to operate the protector blocks the currents produced by these voltages must flow through the terminal equipment. These "sneak currents" although small may be high enough to produce a fire hazard if they are allowed to persist. To protect against this possibility either heat coils or fuses must be used. The heat coil is used to protect central office wiring by providing a low impedance to ground in the event of a persisting current. Physically, the heat coil has the appearance shown in Figure 15-21.

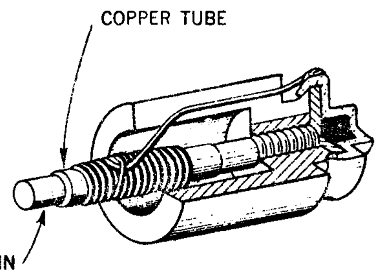


Figure 15-21 - 76A Heat Coil

The heat coil consists of a coil of fine wire wrapped around a copper tube in which a pin is soldered. The heat coil in its mounting is in series with the telephone conductor. When the current in the coil heats the copper tube sufficiently to melt the solder, the pin, which is connected with the line side of the coil of wire, moves under the pressure of the mounting spring and grounds the conductor. Grounding rather than opening serves two functions; it provides a signal announcing that the line is in trouble, thus reducing out-of-service time; and it also prevents the appearance of unwanted voltages on the main frame.

At the subscribers' premises protection is also provided against sustained currents. The protection generally applied here consists of 7 ampere fuses in conjunction with the rectangular 3 mil protector blocks already mentioned. 3 mil circular blocks with a fusible element are also used. The 7 ampere fuse is capable of interrupting excessive currents at voltages up to approximately 3000 volts, above which arcing will occur. Therefore, in high voltage joint use areas where the power voltages may exceed 3000 volts, additional protection is needed to insure a maximum of 3000 volts at the subscribers' station. For this purpose a 118A protector shown in Figure 15-22 is utilized.

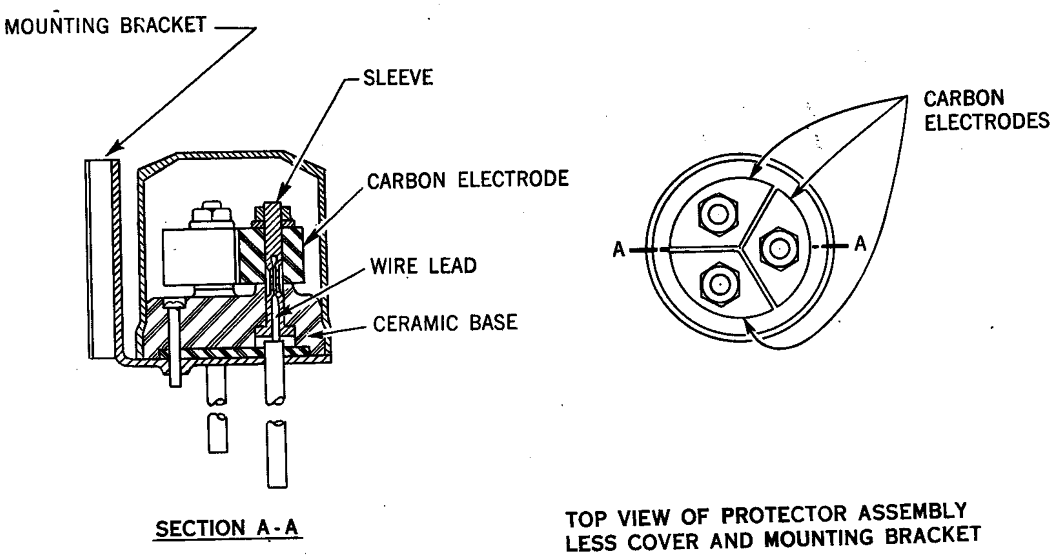


Figure 15-22 - Heavy Duty Protector In Weatherproof Mounting

This protector consists of three pie-shaped symmetrically arranged carbon sections separated by air gaps. The breakdown between them occurs at voltages lower than the 3000 volts required for sustained arcing of the station fuses. It finds its field of application in joint use areas involving open wire where a power cross can get directly onto the cable pair. The protector is connected from each side of the open wire to the grounded neutral of the power circuit.

C. LIGHTNING PROTECTION

Lightning may appear on exchange cable in three ways:

1. By direct strokes

2. By induction

3. By conduction

No concern is needed with direct strokes since large aerial cables and properly engineered buried cables can take most direct strokes. Small aerial cables can usually take small direct strokes. Induced lightning surges are the most frequent type, but they are usually of quite low magnitude. The major use of protection devices is to limit the effects of conduction surges. There are several methods of reducing the likelihood of dielectric breakdown between conductors. Cable can be made to withstand higher magnitude surges by increasing the dielectric strength of the conductor insulation, increasing the dielectric strength of the core wrap, reducing the magnitude of the surge reaching the conductors by adding additional protector blocks at interval along the cable, or increasing the sheath conductivity thereby limiting the voltage buildup between the sheath and conductors.

These basic factors involved in exchange cable troubles due to lightning can be applied to toll cables also, but their importance may be quite different. A toll cable has few, if any, subscriber connections. Furthermore, if surge voltages are induced in the cable pairs from the cable sheath there is a much smaller possibility of high potential differences developing between adjacent cable pairs. These potential differences on other than toll cables are caused by subscriber connections of various positions and types existing along the cable permitting surge buildup between pairs. Since, it is difficult for surges to enter an individual cable pair, there are fewer conductor-to-conductor faults in toll cable than in the exchange cable. One type of fault experienced in the toll plant and not in the exchange plant is crushing where coaxial cable is involved. This crushing occurs in buried plant where the ground is wet. When the surge hits the ground in the vicinity of the cable, the moisture is converted to steam and the force of the steam pressure crushes the cable. An over-all quick glance at the typical outside plant protection scheme can be seen in Figure 15-23. Thus far those facilities which have been in use for years and have until recently proved themselves quite adequate, have been stressed. However, with the advent of the semiconductor, new problems have to be dealt with in the telephone plant. The 500 volt protection provided by the protector blocks was no longer adequate in the many applications involving semiconductors. In some cases, metallic voltages (voltage between the wires of a pair) as low as 10 volts can cause failure. Since protector blocks cannot be made to function properly with an air gap of less than 3 mils, which provide 500 volt protection, it was necessary to take a new approach to provide protection for semiconductor devices. A rather natural philosophy evolved - why not use semiconductor devices to protect semiconductor equipment? An arrangement of two voltage limiting semiconductor diodes connected back-to-back in parallel with

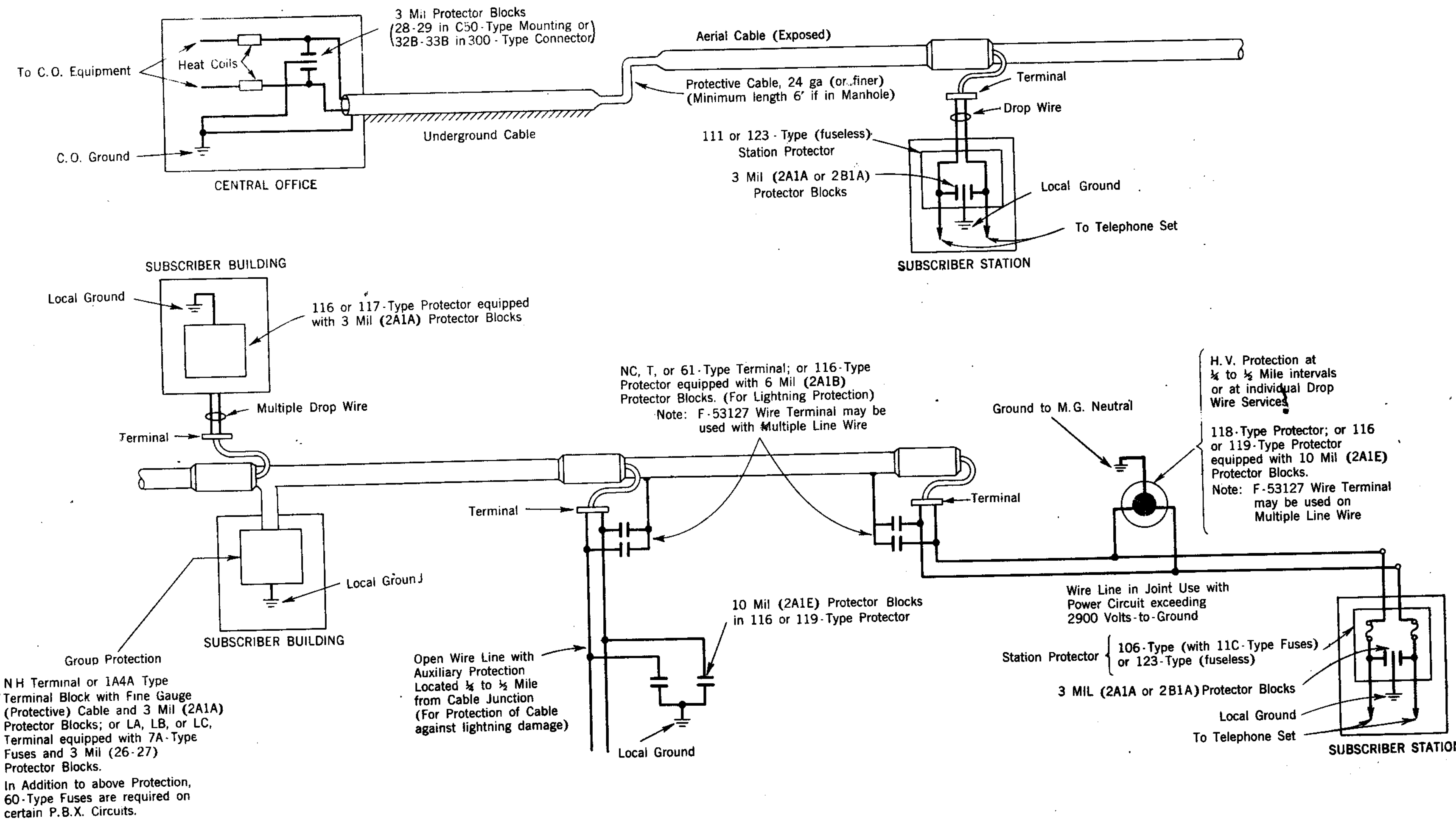


Figure 15-23 - Typical Protection Scheme the equipment to be protected has proved to be an effective means of providing low voltage protection. This method of protection uses the zener breakdown region of a diode as a means of limiting the voltage. The method of operation may be explained briefly as follows. The voltage current relationship for a diode is shown in Figure 15-24.

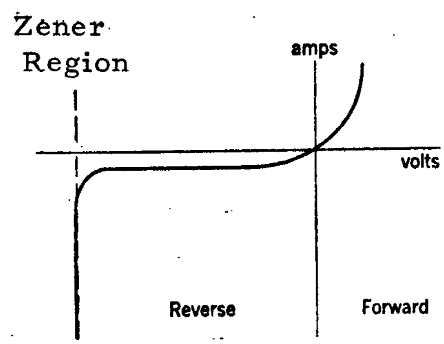


Figure 15-24 - Diode Characteristic

As the reverse voltage on the diode is increased, the current increases only slightly until the zener breakdown region is reached; at this point a slight increase of reverse voltage causes the current to increase rapidly to a high value.

A lightning surge in the telephone plant is usually a unidirectional impulse with a rapid rise and an exponential decay, but can be of either polarity, therefore, it is necessary to use two diodes, back-to-back to provide protection. At the present time silicon-alloy diodes can be produced having breakdown values within the range of 4-1/2 volts to 500 volts. Their main fault at present is that their current-carrying ability is very much less than the magnitudes of surge current presented to the plant. Consequently, diode protection can only be used in combination with some form of heavier duty primary protection, such as protector blocks.

15.15 GAS PRESSURE FOR TOLL CABLES

In 1926, the idea of making the cables gastight and maintaining them under continuous internal pressure was conceived along with the plan of providing some form of mechanical device which could be connected permanently to the cable and so arranged that a decrease of pressure would operate an electric alarm. The first work done in the field employing these principles was in the early part of 1927, using dry nitrogen gas. From that date to the present time, there has been a continued development in the technique of employing gas under pressure for the purpose of keeping moisture out of the cables and as a means of locating small openings in the sheath.

In utility work, service is the commodity offered to the customer and reliability of service is a prime consideration in marketing service.

With the advent of carrier development, the number of circuits carried in a cable increased tremendously and the importance of avoiding interruptions to service increased proportionately. This is exemplified by the 225 voice frequency circuits afforded by a full size cable, which compares with a circuit possibility of over 2,000 for a cable of the same size containing coaxials and paper insulated conductors operated on a carrier basis.

To protect this concentration of circuits from interruption, all of the long toll cable plant is maintained under gas pressure. In order to apply gas under pressure to the practical maintenance job, it has been found desirable to install gastight plugs, at intervals, which will confine the gas to a limited length of cable.

The length of cable included in one gas section will depend upon the resistance to the flow of gas in the cable and the degree of protection required. In general, this length is between 50,000 and 60,000 feet, but sections as short as 25,000 feet, or as long as 34 miles have been employed in actual practice.

Because the gas is placed in the cable so as to prevent moisture from entering through small openings in the sheath, it is essential that a certain limited pressure range be maintained. In order to determine when this pressure has reached the minimum limit, a low pressure warning device, called a contactor, is provided at regular intervals. This unit consists of a Bourdon tube and electric contact with associated mechanical features, arranged in such a way that the electric contacts normally are held open by the pressure of the gas. When the pressure falls below a certain predetermined value, the contacts close and place a short circuit across a pair of conductors, called the "alarm pair," which operates an alarm in an adjacent attended office. Assuming a normal underground or buried gas section of 60,000 feet, one such contactor usually is placed about 5,000 feet from each end of the gas section and four others are spaced uniformly along the cable at 10,000-foot intervals.

To provide a means of measuring the pressure of the gas, valves similar to those used in automobile tires are spaced fairly uniformly along the cable about 3,000 feet apart. Some deviation from this spacing, however, is permitted if the location of the valves can be made more accessible to the maintenance personnel. Such valves also are provided at the location of each contactor and on each side of the gastight plugs.

In addition to contactors and valves, there also is provided at each contactor location a means whereby the maintenance forces can connect a telephone to a pair of conductors and establish communication between these points and an attended telephone office. The pair of wires in the cable for this communication is commonly referred to as a "talking pair," which is stubbed out of the cable and connected to a terminal in a watertight housing.

15.16 LINE CONCENTRATOR

In telephone systems, the instruments of the telephone users have always been connected to the central switching point over individual paths (except in the case of party lines). Since 1908, and probably earlier, development engineers have been trying to devise a method of utilizing the accepted principles of concentration and expansion, which form the basis of all switching systems, for reduction of the number of paths required between the users and the switching point, without affecting service.

Not until fairly recently (1960) has the state of the art advanced to the point where such a "concentrator-expander" (now generally called a "Line Concentrator") could be designed to be practical and economically attractive as compared with individual metallic conductors between the customer's premises and the central office. Some of the new developments which have contributed to this success are: magnetically latching switches and relays which use no power during the period a connection is held, but only during the setup and disconnect intervals; new power stores, such as large capacitors or nickel-cadmium batteries, which can be used at the remote concentrator to provide power for performing the setup and disconnect functions, and which can be replenished by power from the central office during the periods where there is at least one idle trunk; better metal finishes which permit electromechanical apparatus to be used in outside environments, in weatherproofed housings without undue corrosion.

There are two major fields of use for line concentrators: (1) temporary use to defer outside plant construction and (2) permanent use. They may also be used in emergencies to provide service in areas requiring extensive short-term service.

Temporary use of concentrators is economical in areas where deferment of cable reinforcement is desirable or necessary because of slow, unpredictable or unstable growth, because of seasonable fluctuation in the demand for service, or where large capital expenditures can be deferred. The length of time that cable reinforcement can be deferred depends, of course, on the relative annual charge rates of cable and whatever concentrator arrangements are substituted, and also on the length of time before the cable reinforcement becomes absolutely necessary. The recent trend toward higher investment per line for outside plant than for central office equipment tends to make concentrator installations more attractive than they would have been a few years ago. Figure 15-25 shows a typical situation where concentrators can be used on a temporary basis.

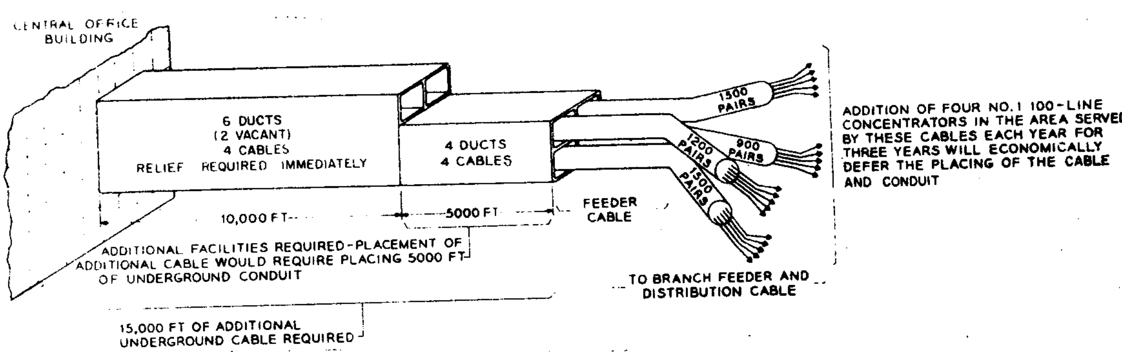


Figure 15-25 - Temporary Use of Concentrators

Concentrators can also be used economically on a permanent basis where the distance from the central office is such that annual charges for cable facilities are greater than annual charges on facilities developed through application of concentrators. Figure 15-26 illustrates such a case. Here, two 50-line and one 100-line remote units installed initially, will defer cable reinforcement for 2 years; proper concentrator additions will eliminate the need for more cable indefinitely.

In areas where customers are located beyond the normal operating range of the central office, it is customary to use "long-line" circuits. It is obvious that wherever there is a concentration of such customers sufficient to load a concentrator, great savings in long-lines equipments could be realized if they could be connected into the concentrator trunks instead of being provided on a per-line basis. Information is available which permits any Telephone Company to modify their 1A Line Concentrators so as to be usable in this manner.

Special situations arising in connection with a proposed program for modernization of the nation-wide teletypewriter switching network have resulted in the design of a-c signaling circuits which can be inserted in the control channels of the 1A Line Concentrator to extend the range, by means of multifrequency signaling techniques, to several hundred miles. In this case, of course, carrier channels will probably be used in the talking trunks.

15.17 MULTIPLING

Before examining the latest method of cable distribution to main stations, called Dedicated Outside Plant, the method of Multipling, used until recently, should be explained. Since the telephone industry is continuously changing and growing the plant must be flexible enough to handle this growth. When a new cable is installed perhaps the initial pair utilization will only be 20 to 30% and will slowly increase to 80 or 85% during the life of the cable as new subscribers are added. To obtain a pair utilization of 80 or 90% requires careful planning and growth rate estimates at the time the cable is installed. As an example refer to the 51 pair distribution cable with its associated distribution terminals presented in Figure 15-27 (a).

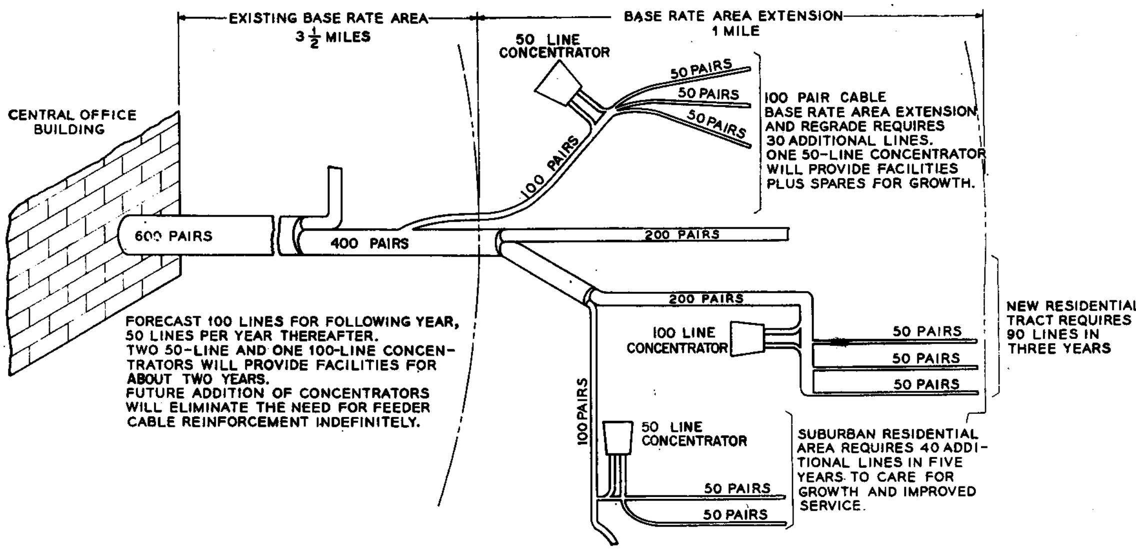


Figure 15-26 - Permanent Use of Concentrators

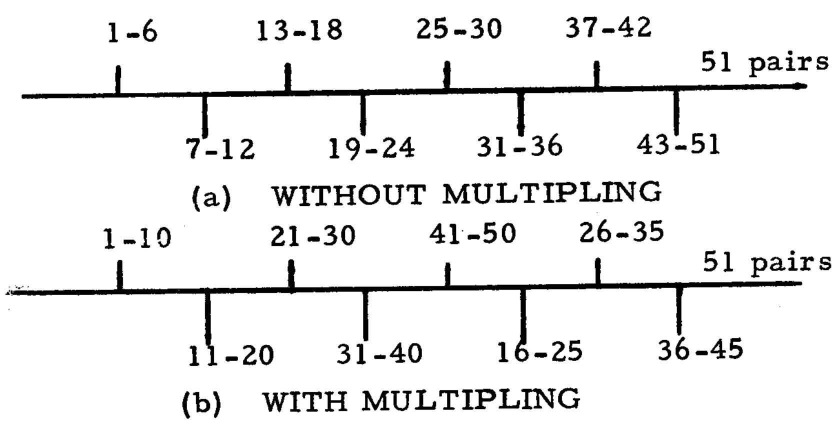


Figure 15-27 - Distribution Cable

Now suppose the growth rate on the cable is not evenly distributed and the first two terminals would like to serve eight houses each but the last six terminals are only serving three houses each. In this case there is an inflexible, inefficient cable plant. All the pairs available in the cable are not being used and some subscribers cannot be served. This problem can be circumvented by multipling. Multipling is a term used in the cable plant to indicate the repeated or multiple termination of the same cable pairs at more than one location. Multipling is shown in Figure 15-27 (b).

If the growth pattern varies from one area to another, pairs can be borrowed from the slow growth area to fill the needs of the fast growth area. Thus, we have the flexibility to handle eight pairs in the first two terminals and three each in the other terminals.

Multipling serves five general purposes:

1. To make all pairs available for termination where and when they will be needed, thereby minimizing unavailable cable pairs, as these tend to prevent high cable pair utilization.

2. To make the same cable pairs available at a sufficient number of points to:

   a. Provide for possible variations in growth rate with a minimum amount of rearrangement.

   b. Permit a satisfactory party line fill, with party line stations conveniently located geographically.

3. To distribute ultimate loads as evenly as possible throughout the cable.

4. To avoid early congestion of any one terminal.

5. To facilitate splicing, fault location and the clearing of trouble.

15.18 DEDICATED OUTSIDE PLANT

The objective in the design of an exchange cable network is to provide facilities to meet demand, with a minimum of capital investment and future rearrangement and change cost. High party line development, a low percentage of households with service, the relative inflexibility of pulp type cable with hermetically sealed terminals and the difficulty of correctly forecasting the distribution pattern of line demand led originally to the adoption of a highly multipled form of outside plant design.

In recent years the factors enumerated have undergone radical changes.

1. Demand for party line service has been decreasing steadily. As a result of this trend, bridging of party line customers in the field is becoming more difficult and we are gradually approaching the need for a cable pair per main station in the present plant.

2. The percentage of households with service has been rising steadily during the post war period. In many new developments one hundred percent usage is frequently forcast.

3. Color-coded polyethylene insulated conductor (PIC) distribution cable and ready access terminals are now being used in lieu of pulp cable and hermetically sealed terminals. All cable pairs are therefore available for use at every terminal location. Terminal multipling is no longer necessary and the flexibility of the distribution portion of the network is greatly increased.

4. Outside plant forecasts of lines should improve as a result of the decrease in party line demand and the increase in the number of households with service.

Rearrangements and changes are also necessary under a multipled form of design as information regarding the detailed location of growth becomes known. This major item of expense has been rising consistently in the post war period as it is directly related to System growth. Because of customer demand for better grades of service, the high percentage of households with service, recent technological innovations such as "PIC" cable and the rising expense associated with the administration and operation of multipled plant, it now appears to be economically and technically feasible to design plant initially on a more permanent basis.

A. DEDICATED PLANT PLAN

This plan provides for the permanent assignment (dedication) of a cable pair from the central office main frame to a residential or non-key business location, as demand develops, regardless of the class of service. Once dedicated, the pair remains permanently assigned to the location whether working or idle. The Plan applies to main stations located within a radius of approximately 32,000 feet from the central office. This area contains about 97 percent of the total System main stations. Beyond this point, the added investment in outside plant necessary to provide a separate pair per residential or non-key business location, would probably exceed the operating savings resulting from dedication.

Party line customers, two- and four-party, will be bridged at the central office main frame using bridge lifters (1574A and B Inductors). Two- and four-party line fills of substantially 2.0 and 4.0 respectively are possible under this plan. Fills of this order make maximum use of central office line equipments. They also provide a stimulus for any upgrading program, as all customers will receive grades of service for which they are paying. <u>Fills</u> are defined as the ability to obtain subscribers who want either 2 or 4 party service, and connecting these subscribers to wire pairs so that 2 or 4 parties will utilize that wire pair instead of a lesser amount. This plan also provides for the use of a new approach to the design of new subscriber cable plant, the "Spare Pair Concept." It also recommends the gradual conversion of existing plant to a dedicated status.

This plan provides for the virtual elimination of line and station transfers, essentially all cable pair transfers and central office and drop wire or terminal jumper transfers associated with such activities. Service order assignment will be simplified. Man-made troubles and service order completion intervals will be reduced. Loop transmission will be improved and the installed first cost of new cable plant will also be less in many cases.

1. <u>Line and Station Transfers</u> - Under present operational methods, working party line customers are bridged in the field to minimize the use of feeder facilities. Line and station transfers are made to clear cable pairs to meet new demand or to improve party line fills and line equipment usage. Working main stations are also moved from one cable pair to another to permit transfers between cable complements. Under dedicated plant each party main station will be assigned a separate cable pair and bridging will be done at the central office main frame. A cable pair, once assigned to an address, will remain dedicated to that address and will not be made available for

use at another location even though service may be disconnected at the initial address. Therefore, line and station transfers will be virtually eliminated. Some reassociation of party line customers at the main frame will be required periodically to maintain high party line fills.

2. Cable Pair Transfers are usually made for one of three reasons:

   a. To redistribute existing idle facilities or to distribute new facilities to areas where demand is being experienced.

   b. To transfer customers from one central office area to another or, in the case of large PBX's, from one location to another.

   c. To clear coarse gauge cable for use on longer loops.

It is for (a) that the bulk of the expenditures for cable pair transfers is made and it is in this area that large savings will be derived. Under present design method, cable pairs are multipled over an area to increase the probability of their use. When a cable complement becomes congested, new facilities are made available at a demand location by transferring one of the multipled cable legs to a less congested or new cable complement.

Under the dedicated plant approach, assigned cable pairs, whether working or idle, are not subject to transfer except for reasons cited in (b) and (c) above. Initially only a portion of available cable pairs are spliced through to demand areas, and these on a non-multipled basis. As additional demand becomes apparent, existing unassigned or new cable pairs are made available at demand locations through the use of control points and access points. Thus, cable pairs transfers for normal growth are eliminated.

Spare Pair Concept - This concept suggests a method of designing the customer portion of the exchange cable network which will result in increased flexibility and improved utilization. Essentially, it proposes the allocation of a certain percentage of the pairs available at the central office to demand locations. The remainder are retained as spares in the feeder network and distributed when demand becomes evident. This concept recommends the use of control points and access points to improve plant availability. Control Points provide a means of distributing spare facilities in main feeders to branch feeders and, between branch feeder cables. Access Points provide a means of connecting pairs in distribution cables to spare pairs in branch feeder cables.

In applying the Spare Pair Concept in the design of cable in a main feeder route, the route is first divided into allocation areas. Pairs are then allocated to each area in proportion to the amount of growth generated in the area. Within each area 70 per cent of the allocated pairs are connected to branch feeders while 30 per cent are retained as common spares. The latter would be connected to branch feeders later as demand, in excess of the initial dedication, is experienced. The percentage allocations shown above for main branch feeders are based on average growth conditions. In rapidly growing routes it may be desirable to increase the percentage connected while in slow growing routes it may be desirable to decrease it. A basic guide in determining the percentage of the allocated pairs to be distributed involves a fundamental rule of the Spare Pair Concept. "Only enough pairs should be allocated to distribution areas to meet clearly indicated demand."

Establishment of Allocation Areas in Main Feeder Cables - The maximum number of branch feeder and direct distribution legs should be included in each allocation area, consistent with bridge tap limitations and loading considerations, so as to make common spares available to the greatest practical number of cable legs. To facilitate the administration of spare pairs, it would appear that the size of the area might be selected so that the maximum allocation will not exceed 1000 pairs. The typical layout shown in Figure 15-28 is divided into three allocation areas. In this case the controlling factor in determining the size of the area is bridged tap.

Allocation of Pairs to Each Allocation Area - The allocation of pairs to each area is made on the basis of the proportionate average rate of growth in pairs per year generated within the area, to the total average rate of growth for the route, as determined at the central office. The number of pairs to be allocated is the total number of new cable pairs and unassigned pairs originating at the central office.

1. Allocations to each area are determined in the following manner:

$\frac{A \times C}{B}$ = Area allocation in pairs (area allocations should be made to the nearest 50 pairs in main feeder cables of 900 pairs or more and 25 pairs in smaller size cables or branch feeder cables).

A = Average rate of growth generated in the area in pairs per year.

B = Average rate of growth for the entire route in pairs per year.

C = Total number of pairs to be allocated at the central office.

Pairs to be allocated to Area #1 $= \frac{100}{300} \times 1800 = 600$ pairs

(see Figure 15-28 for source data).

Although the total pair allocation to each allocation area may be made on the basis of proportionate rates of growth, the number of pairs to be connected to each branch feeder or distribution cable within the area should be based on the actual growth pattern of the branch feeder or distribution cable. This will result in the most efficient administration of spare facilities and maximum cable fills before relief.

For the sample problem it was determined that 600 pairs would be allocated to Allocation Area #1. Seventy per cent (70%) would be connected to branch feeders and thirty per cent (30%) would be retained as spares in the main feeder cable.

Pairs to be connected = 600 x .70 = 420 pairs = 400 pairs (rounded to nearest 50 pairs).

Common spares = 600 - 400 = 200 pairs.

For the sample problem it is assumed that for Allocation Area #1, the forecast of lines indicates that 400 pairs will meet growth requirements for four (4) years. Therefore, a sufficient number of cable pairs should be

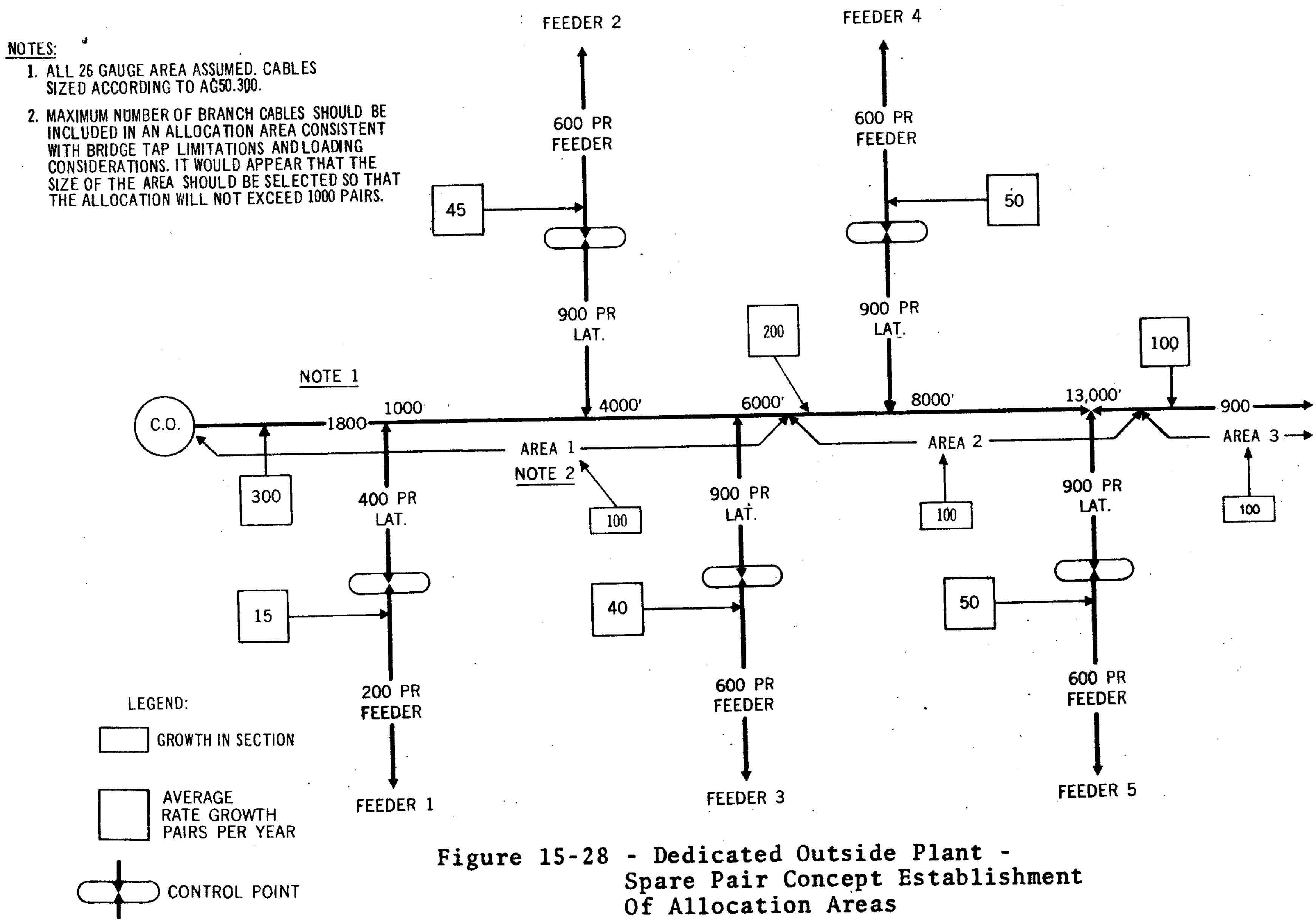


Figure 15-28 - Dedicated Outside Plant - Spare Pair Concept Establishment Of Allocation Areas connected to each branch feeder cable to meet forecast line growth for a period of four (4) years. In Allocation Area #1, the following allocations are made for illustrative purposes (see Figure 15-29).

	Forecast Requirement 4.0 Years - Pairs	Round to Nearest 50 Pairs
Feeder Cable #1	60	50
Feeder Cable #2	180	200
Feeder Cable #3	160	150
Total	400	400

In Allocation Area #1 200 pairs have been designated as spares in the main feeder. These pairs are made available in control points through the lateral cables. To minimize the number of spare pairs spliced initially and on subsequent relief it is recommended that they be multipled over the lateral cables so that the number made available in any control point will not exceed twice the number of pairs initially connected through the point. For the sample problem:

	Number of Pairs Initially Connected	Number of Spares Made Available
Feeder Cable #1	50	100
Feeder Cable #2	200	200 *
Feeder Cable #3	150	200 *

* Maximum available in Allocation Area #1

Figure 15-29 shows the allocations to each allocation area and a schematic layout of the distribution of the pairs within Allocation Area #1.

15.19 UNIGAUGE CUSTOMER LOOP PLANT

The latest development called the Unigauge Plan, is to provide customer loops with a single, fine-gauge cable and to provide modern electronic equipment when required to maintain good transmission and signaling.

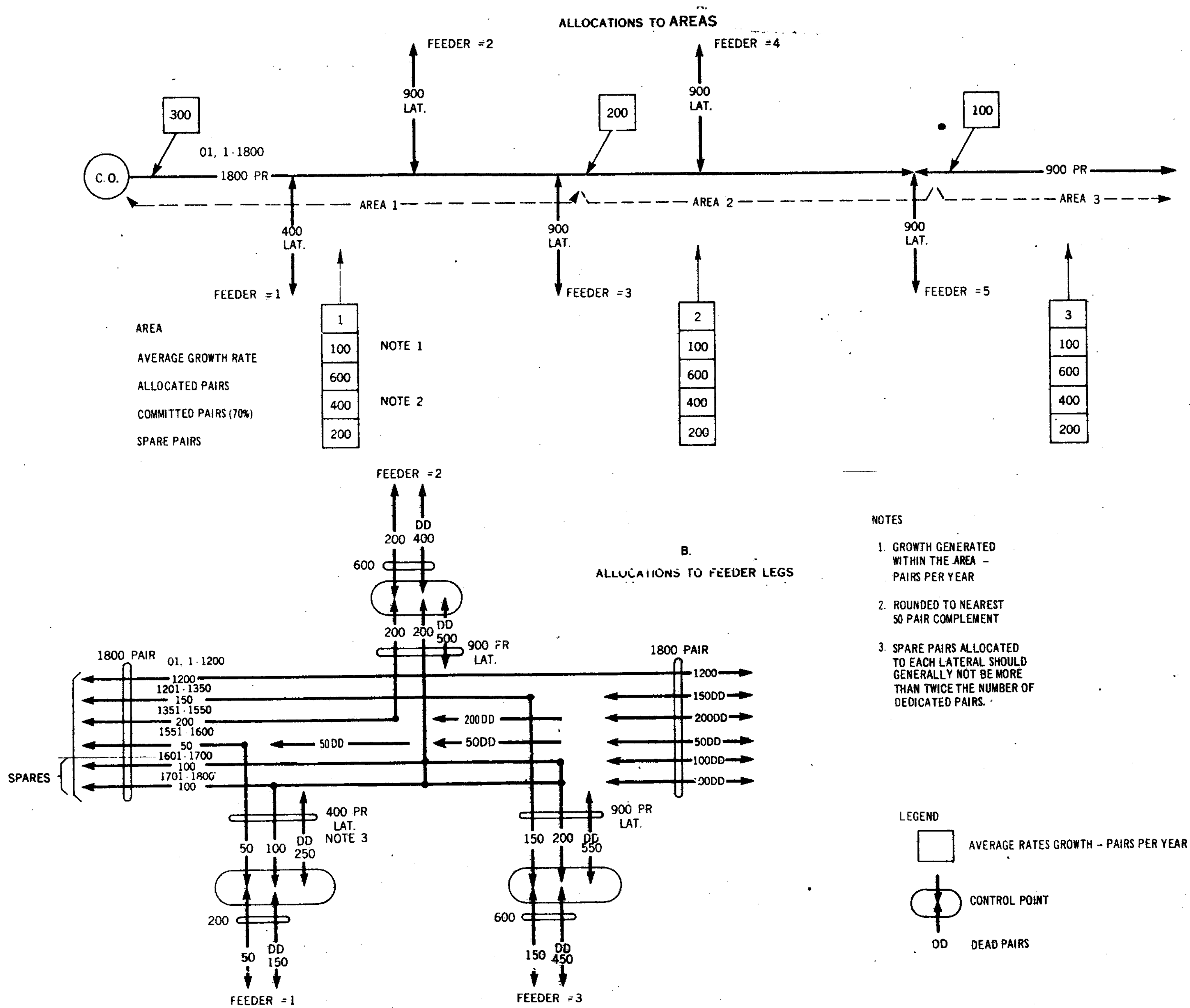


Figure 15-29 - Pair Allocations To Areas and Feeder Legs

Briefly, new loops as long as 30,000 feet will be entirely 26 gauge, the amount of inductive loading will be drastically reduced and the resulting increased resistance and transmission impairment of the longer loops will be compensated for by repeaters and signaling range extenders in the central office. Transmission is estimated to be comparable to that in the present plant and capital savings for the 1970-75 periods are estimated to be $44 million per year. These savings are based on the assumption that all growth of loops over 15,000 feet in No. 5 Crossbar and ESS wire centers will be developed by Unigauge plant.

Most of the present plant has been developed under the loop resistance design rules. The important resistance design rules are that customer loops are developed with a maximum conductor resistance of 1,300 ohms and that all loops over 18,000 feet are equipped with 88 mh loading coils at 6,000 foot intervals (H88 loading). Three gauges of cable (22, 24 and 26) are used for nearly all loops within the 30,000 feet range, but the cable may occasionally be extended by 19-gauge cable or various open or buried wires. The gauges are chosen to use the minimum copper while keeping within the 1,300 ohm limit.

The chart in Figure 15-30 illustrates how the various gauges of cable are combined theoretically to provide good transmission with minimum plant investment. Customers within 15,000 feet of the office can be served with all 26-gauge nonloaded cable. Those between 15 and 18,000 feet can be served with loops made up partly of 26 gauge and partly of 24 gauge. Beyond 18,000 feet inductive loading must be added. The longer the loop the coarser the gauge so that customers between 40 and 50,000 feet for instance, must be served with combinations of 19 and 22 gauge. The width of the lines in Figure 15-30 indicates the relative copper content of the various gauges. For example, a unit length of 19 gauge contains five times as much copper as the same length of 26 gauge.

The Unigauge plan is designed primarily for single-party and 2-party lines, and initially for No. 5 Crossbar and on a 1970 basis for ESS central offices. Coin, PBX, 4 and 8 party, and special service lines can be handled, however, the loop resistance limit will be reached in a shorter geographical distance on 26 gauge than on coarser gauge facilities. When this resistance limit is exceeded, modifications may be required; these will be discussed later. Standard station sets are used on all lines.

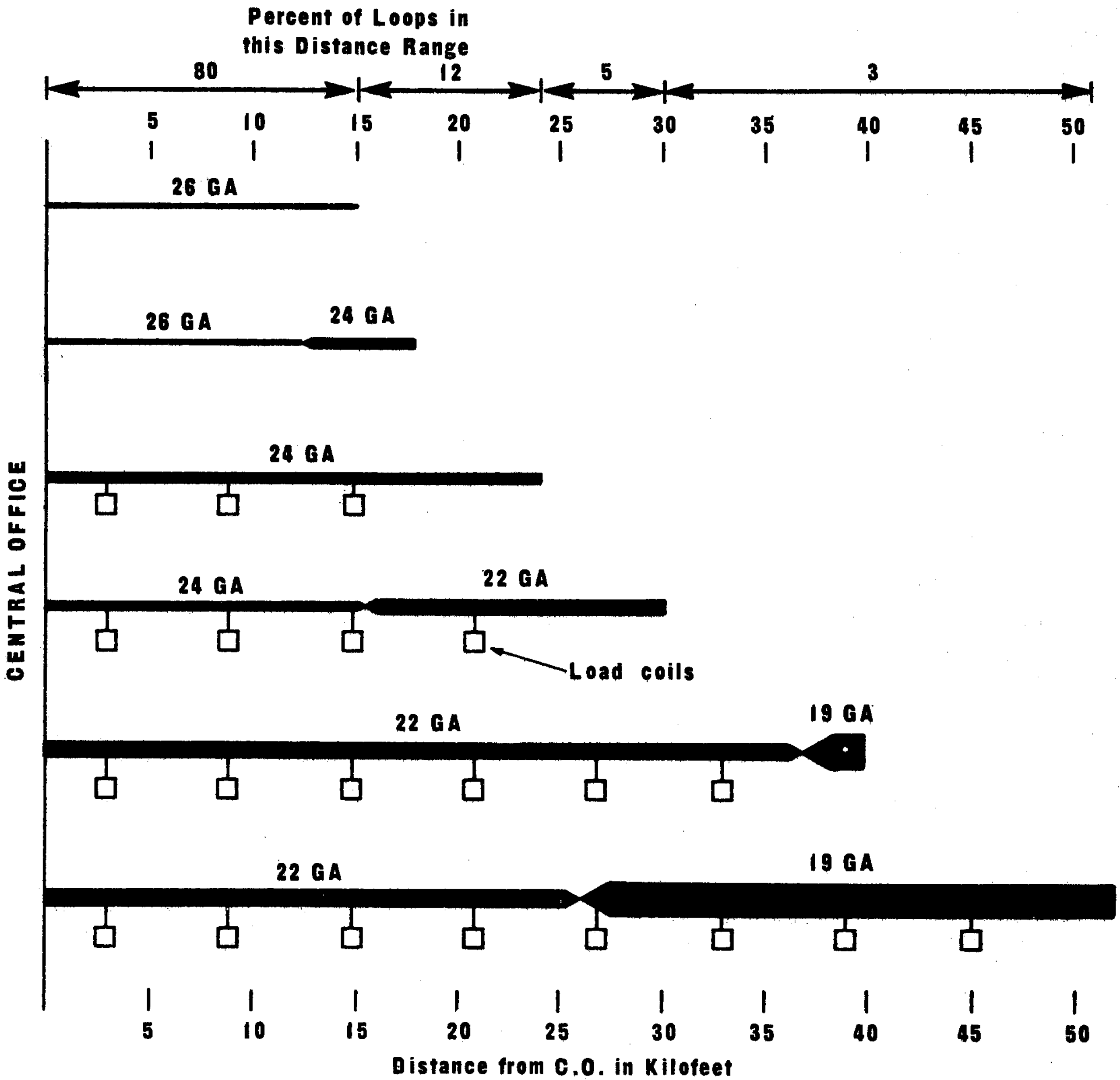


Figure 15-30 - Cable Plant Gauge Composition
Resistance Design

Line diagrams of loops developed under the plan are shown in Figure 15-31. Stations within 15,000 feet of the office are served over loops of 26-gauge non-loaded cable with 48 volt battery and conventional equipment in the central office. This is identical with their treatment under theoretical resistance design rules. This length range includes 79.5 per cent of all main stations. Stations in the 15 to 24,000 feet range are also served over 26-gauge non-loaded cable but they require a range extender and amplifier in the central office. This range extender provides 72 volts for signaling and talking and 5 db midband gain for speech. Higher gain is provided at the higher frequencies to compensate for the frequency distortion in the long non-loaded loops. This gain is not sufficient for NL loops longer than 24,000 feet but satisfactory transmission is obtained on loops as long as 30,000 feet by adding 88 mh load coils at the 15 and 21,000 feet points. No loading coils are permitted closer to the office than 1,500 feet. All Unigauge loops, thus, have at least 1,500 feet of 26-gauge non-loaded cable adjacent to the office. This makes their input impedance uniform and allows all Unigauge repeaters to be alike and non-adjustable without degrading the office balance. They therefore, do not need to be provided on a one-per-line basis but may be switched in when needed. A four-or five-to-one concentration ratio of lines to range extenders is practical. This is of vital importance to Unigauge economics.

Thirty thousand feet is the limit of the strictly Unigauge (i.e., all 26 gauge) loop plant but many of the Unigauge features may be applied to many of the loops serving the 3.25 per cent of the main stations that are more than 30,000 feet from the office. This is illustrated by the bottom line diagram in Figure 15-31 Central office equipment and the adjacent 15,000 feet of loop are identical with Unigauge loops. Beyond 15,000 feet, 22 gauge H88 loaded cable is used. Using this method, loops as long as 52,000 feet may be handled in the central office as though they were Unigauge loops. Remote Message and Signal Repeaters may be used to further extend these ranges. Under this combined standard and Extended Uniguage plan, about 65 per cent of the load coils required for resistance design are eliminated and among these are 85 per cent of the coils located in manholes where they are becoming difficult to install and service.

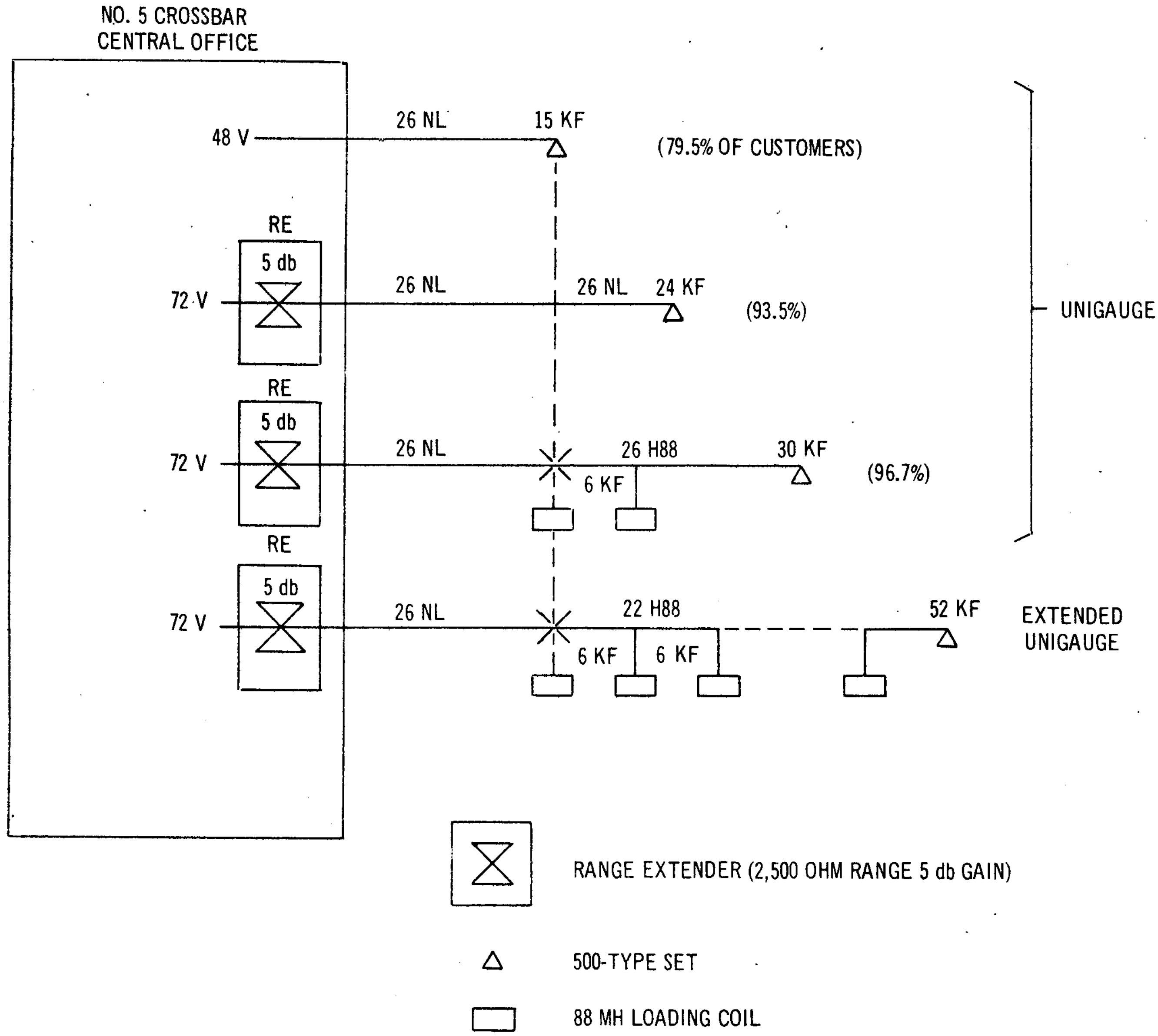


Figure 15-31 - Uniform Gauge Loop Plant Layout

Savings in the cost of outside plant are thus obtained from a number of factors. These include:

1. Reduced cable costs - less copper
2. Fewer load coils
3. Higher average route fills - only one type of facility
4. Reduced expense for rearrangement and changes for gauge recovery
5. More efficient use of underground conduit systems
6. Less cable maintenance - fewer sheaths - less sheath footage
7. Simplified outside plant engineering
8. Reduced inventory and supply expense

Two-party lines require extra attention. The central office equipment must be capable of selective ringing and party identification. On any one line, both parties must be in the 0-15,000 foot range or in the 15-30,000 foot range. Under 15,000 feet loop stations cannot be paired with longer loop stations. This is not a serious restriction because, with dedicated plant, the parties will be bridged at the central office and may therefore be located on any of the cable routes running out of the office. Central office bridging radically changes the input impedance of the loop and, if not corrected, will cause the Unigauge repeater to sing. Conventional bridge lifters (1574-type inductors), that will continue to be used on the short loops, are not adequate for repeated loops because, even when saturated, they will have enough residual inductance to upset the balance. There may be occasions when both parties are off-hook with both inductors in their low impedance state. A satisfactory solution to this problem is to bridge a shunt negative impedance converter on the long lines at the main frame. The circuit is shown in the upper line diagram of Figure 15-32. This converter neutralizes the impedance of one of the loops and makes the impedance of the bridged line substantially the same as that of a single-party loop. The converters are all alike and are not adjustable.

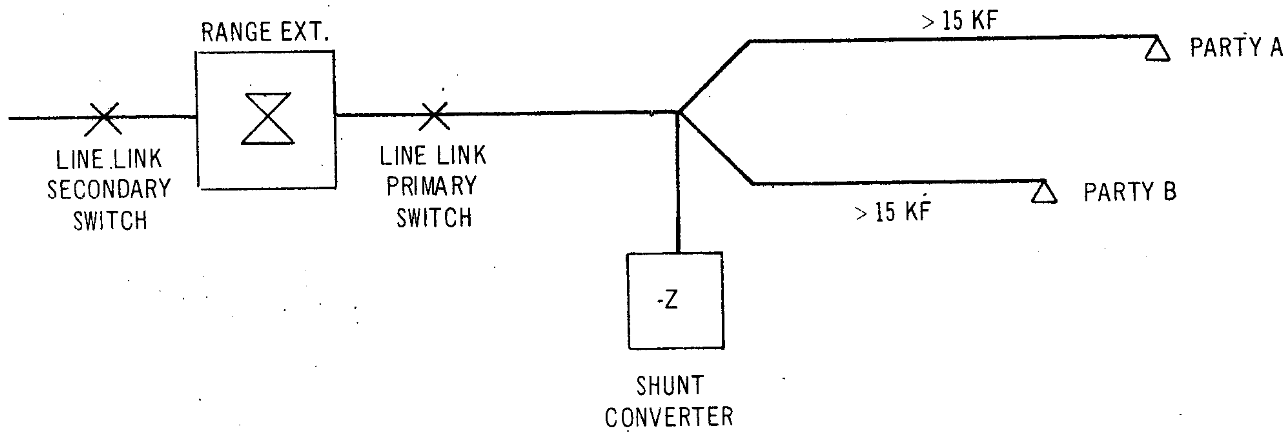


Figure 15-32 - 2-Party Lines

During reverting calls the transmission loss between stations on long 2-party loops will be greater than normal since the bridge at the main frame bypasses the two Unigauge repeaters that would be connected in series on an intraoffice call between these locations. However, the shunt converter compensates for some of this extra loss. Transmission will be acceptable in most cases and if not, some reassignment of parties may be required to avoid community of interest and consequent reverting calls.

Coin lines and 4 or 8-party lines cannot be served at present by the Unigauge range extenders. If they are beyond limits with the Unigauge plant available, they must be handled by standard E-type repeaters and dial long line circuits on a one-per-line basis unless coarse gauge cable is available.

Many of the special services will fall within ranges in the Unigauge plan in which they will meet the objectives specified in Bell System Practices. In fact, assignment of some PBX and other special service lines to Unigauge equipment will provide a more convenient and economical method for meeting objectives than is available today. Longer special service line and PBX trunks will require individual design and treatment. In general, non-switched lines to 24,000 feet and switched lines to 15,000 feet can be cared for with Unigauge equipment. Beyond these distances individual design and treatment is required. In some cases four wire techniques will be required.

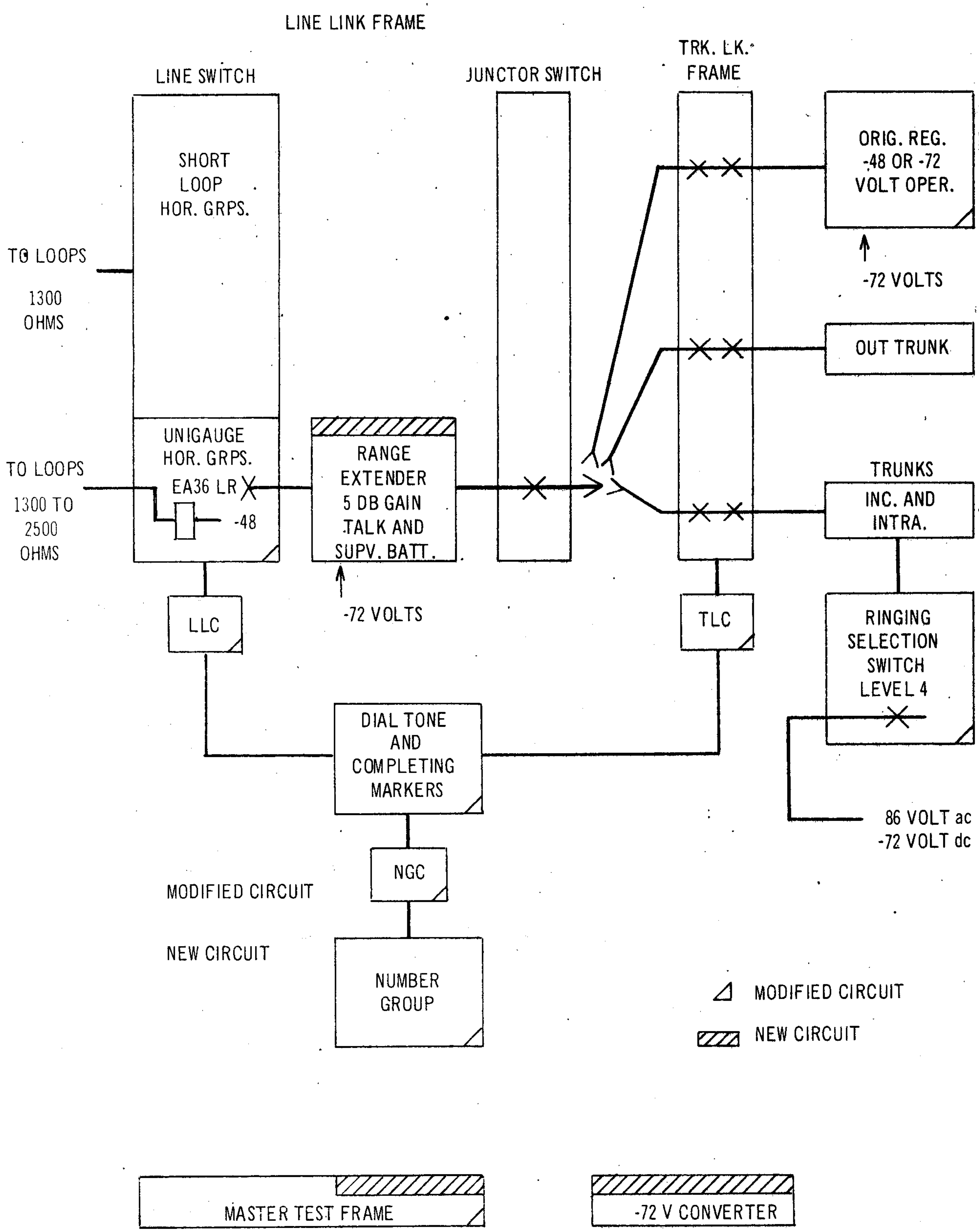


Figure 15-33 - Unigauge No. 5 Crossbar Switching Plan

Although Figure 15-33 is not involved with outside plant it is presented to show the modifications of No. 5 Crossbar office for Unigauge.

Arrangements for serving Unigauge loops from No. 1 ESS offices are not as far advanced as they are for No. 5 Crossbar but are developing along similar lines. It is expected that range extenders will cut into the B links when needed by command from the stored program control. The repeaters will probably be electrically identical with those developed for crossbar offices but their equipment design may differ.

Less work has been done on No. 2 ESS offices but it is expected that they will handle Unigauge loops in a manner quite similar to No. 1 ESS.

Satisfactory arrangements have not yet been found for step-by-step offices. It appears that Unigauge equipment costs will be higher than in crossbar or ESS offices because separate originating and terminating switch trains are used in step-by-step offices.

There is no intention of adapting panel or No. 1 Crossbar offices to Unigauge since no new offices of these types are being built and the existing ones are located in cities where few loops exceed 15,000 feet.