April 1983
Section 644
Issue No. 3

Rural Electrification Administration
Telecommunications Engineering and Standards Division

DESIGN AND CONSTRUCTION OF UNDERGROUND CABLE (PHYSICAL PLANT)

CONTENTS

1. GENERAL

1.1 This section is intended to provide REA Borrowers, Consulting Engineers, Contractors, and other interested parties with technical information in the design and construction of REA Borrower's telephone systems. It includes considerations for the design and installation of underground cable plant (cable to be placed in conduit and manholes).

1.2 Additional information for the design and construction of underground cable (physical plant) is contained in REA Form 515 entitled, "Telephone Systems Construction Contract", and REA Form 515d entitled, "Specification and Drawings for Underground Cable Installation" and other REA specifications and construction practices.

1.3 Underground cable plant for REA Borrowers usually will be installed by contract from plans and specifications prepared by a Consulting Engineer. The engineer should detail the following information on the Construction Drawings as shown in Figure 1.

1.3.1 The position of manholes, and building and/or pole riser in relation to streets, roads, buildings, poles, and other obstructions.

1.3.2 The distance between manholes (wall-to-wall measurement), manhole to riser pole (wall-to-pole measurement) and manhole to building (wall-to-building measurement).

1.3.3 The conduit configuration, size and type between manholes, manholes to riser poles and manholes to buildings. In addition, the drawings should reflect all existing and proposed cables and the particular duct in which they either exist or are to be placed.

1.3.4 Manhole, cable vault and building cable racking diagrams should be provided to show the positioning of all existing and proposed cables, cable stubs, and load coil cases. The racking diagrams should also show the rack position at which each particular splice is to be placed, the conduit configurations with the particular cable assignments, cable bonding arrangement and any supporting structures that are necessary.

1.3.5 The Plan should show exact cable (splice-to-splice) cut lengths for all proposed cables to be placed in conduit.

1.3.6 Pole and building cable riser should be detailed to show the splice locations, supporting structures, method of cable attachment and physical protection, if required.

1.3.7 Cable identification, cable type, size, conductor gauge, and pair count should be shown on all existing and proposed cable where there is a change in size, gauge or pair count.

1.3.8 Detailed information should be provided for specialized equipment, such as pressurization blocks, valves, flow meters, compressors alarms, etc.

1.4 The Engineer should keep in mind during the design of underground cable plant that flexibility of the plant depends to a great extent on the physical arrangement of the cables and associated equipment in the underground conduit and manhole system. Correct assignments and arrangements of the underground cable will provide economical advantages by decreasing future costly rearrangements.

2. DESIGN CONSIDERATION

2.1 The underground cables placed in conduit and manhole systems are considered the backbone of the outside plant facilities. The sizing of cables and the selection of the conductor gauge are determined in accordance with the design principles as detailed in REA TE & CM Sections 204, 210 and 231. It is of utmost importance that cable placed in the underground system be sized to economically justify the use of each conduit due to the high cost of a conduit and manhole system. Normally, cables that are considered for placement in the conduit system are exchange feeder cables, trunk exchange cables, toll cables, and special cables such as video, coaxial, and optical. The larger size manholes and the greatest number of ducts start at the central office and decrease in manhole size and duct number as the distance increases from the central office. The sizing of exchange feeder cables will normally follow this same pattern.

2.2 Prior to the design layout of underground cable plant, it is necessary for the Engineer to make an on-site field survey of all manholes, pole risers, building conduits, etc.

2.3 A cable racking diagram should be made for the central office vault, cable trough, central office building wall (See Figures 7, 8, 9 and 10) showing the location of all existing cables, stubs, load coil cases and ducts in use. Using this information a vacant duct should be selected that will allow new cable to be placed without crossing over existing cable or blocking other vacant ducts. Generally, it is desirable to assign the lower conduits to trunk and loaded cables which usually will not require replacement, and also to special cables, which require protection. The cable duct assignment should be the same in each manhole, whenever possible. However, each duct should be selected section-by-section, since the same relative position in each manhole may not always provide the best cable arrangement.

2.4 Where cables are pulled through a manhole without a splice, the duct selection should be the same at both ends of the manhole. Changes in duct selection, especially in elevation, should be considered carefully to avoid damage to the cable sheath and to keep the pulling tension as low as possible.

2.5 On the manhole cable racking diagram (Figure 7) all necessary additional cable supporting hardware within a manhole should be indicated as should additional work such as drilling holes, etc.

2.6 Actual lengths of the conduit runs are necessary. These measurements can be obtained from the plant-in-place records of the conduit systems. But these measurements should be verified so that cable lengths will be correct. The distance, manhole wall-to-wall, manhole-to-riser pole, or manhole to building, should be added to the amount of cable required in each manhole for pulling-in, setting-up, testing, and splicing. These measurements when added together are to be indicated on the Construction Drawing as cable "cut length. The amount of excess cable normally required for splicing, testing and pulling usually amounts to one meter (3 ft) per cable or 2 m (6 ft) per section.

2.7 For pull-through manholes (no splice), the length of cable necessary for racking should be added to the wall-to-wall lengths of the conduit sections on both sides of the manhole.

2.8 Cables and stubs should be arranged in the manhole to allow accessibility to the cable splices. In general, limit the number of branch cables from the end of mainline splices to two (2). To maintain this arrangement, stubs may be necessary. At locations requiring stubs, the size, gauge, and intended use of the stub usually will determine the racking position. Where stubs are used to connect branch feeder or distribution cables entering the manhole from branch conduits, the terminal end of the stub should be racked on the manhole wall opposite the branch conduit.

2.9 At each splice in central office vaults, troughs or on building walls; as well as in manholes the shields of all cables should be bonded together. Detailed information and methods should be shown on the detailed drawings.

2.10 The construction layout drawing should be prepared in detail to show all work activity and information necessary to install the underground cable plant. The layout drawings will also provide the borrower with plant-in-place records upon completion of plant installation.

3. SAFETY PRECAUTIONS

3.1 Open manholes should be guarded at all times with a manhole guard or barricade. These and other warning devices should be set up at the manhole before removal of cover.

3.2 Approved local, state, or federal, warning lights should be displaced between sunset and sunrise and when vision is impaired by fog, haze, etc, in accordance with local, state and/or federal ordinances.

3.3 Open flames, torches, lighted cigars, cigarettes, or pipes should not be brought near an open manhole, into a cover or tent over a manhole opening, or into a manhole even though tests indicate that combustible gases are not present.

3.3.1 Only lighting and heating equipment of the type recommended by a manufacturer of this type equipment should be used.

3.3.2 Connection and disconnection of electric lighting equipment should not be permitted in the manhole.

3.4 Every manhole opened for the first time during the day or reopened after having been closed for any length of time shall be tested to determine whether combustible gases are present. Additional tests should be performed at the start of each work shift change and at intervals not to exceed two (2) hours during a particular work shift. When a manhole is covered with a tent or tarpaulin it should be tested at intervals not to exceed one (1) hour. Manholes should be also be tested after the removal of water or duct plugs which could possibly have permitted the flow of gas into a manhole. Where gases are detected or suspected, ventilation of the manhole should be employed by forced fresh air equipment in accordance with the manufacturer's instructions.

3.5 Establish adequate communications between the cable feeding location and other pulling equipment prior to starting any pulling operation.

3.6 Arrange material and tools in the vicinity of the manhole so it will not fall into the manhole or unnecessarily interfere with pedestrian or vehicular traffic.

3.7 Exercise caution when entering and leaving a manhole, particularly those located on traveled thoroughfares. Always use a ladder when entering or leaving a manhole. When descending or ascending into or from a manhole, always face oncoming traffic. Keep hands free of materials or tools when ascending or descending a ladder.

4. CABLE PROTECTION

4.1 When working in manholes care should be exercised to prevent damage to cables in setting up the pulling apparatus or while using tools of any kind. Never use a cable, load coil case, or splice case as a step when ascending or descending a manhole. Special care should be taken when working with filled cables especially when the temperature is below 2^{o} C (35^{o} F). This type cable becomes more difficult to bend and work as the temperature decreases, and there is a possibility of cable damage at temperatures near -18^{o} C (0^{o} F).

4.2 Cable reels which are delivered to the work location, but are not to be set up immediately for placing operations, should be securely blocked or secured to a pole or other substantial support to prevent rolling or movement. Do not leave them on a grade or in a traffic lane if this can be avoided. When it is necessary to leave the reels on a grade, turn the reels against the curb and block them so that they will not roll.

4.3 Cable reels left along streets or highways overnight should be marked in accordance with local and state regulations. Otherwise, barricade and light with flasher lights or red lanterns not later than one-half (1/2) hour before sunset.

5. CABLE LOCATION AND SELECTION OF DUCTS

5.1 Care should be exercised so that the cable is placed relative to cable number, count, size, cutting length and gauge in strict accordance with the construction drawings.

5.2 The cut ends of nonfilled cable remaining on a reel after a length of cable has been removed should be sealed with an approved end cap equipped with a pressure testing valve and pressurized with dry air or nitrogen between 55 and 69 KPa (8 and 10 psi). Filled cable cut ends should also be sealed with suitable end caps.

5.3 The contractor should maintain a record of the cable placed and of the cable remaining on any reel after a cutting length has been removed.

5.4 Each reel should have a suitable tag fixed to the outside of each flange indicating the number of feet remaining on the reel. The tag should be updated immediately after a length of cable is removed from the reel.

5.5 The duct assignment for each individual cable for any duct section relative to cable number, count, size, gauge, and cutting length should be specified on the construction drawing. Cable should not be placed in ducts other than those which have been specified nor should the cable be racked in any other manner than is shown on the contract drawings without prior approval of the engineer.

6. RODDING AND CLEANING DUCTS

6.1 It is the contractor's responsibility to determine whether ducts designated for occupancy should be rodded and cleaned. The contractor should assume complete responsibility for any difficulties or damage to the cable in placing cable in ducts as indicated in the applicable REA Construction Contract Form 515 specifications.

6.2 In the event there is any question as to whether a duct is satisfactory for use, the contractor should perform the following test prior to placing the cable: A test mandrel or short cable length equal to, or slightly larger in diameter than the cable to be placed should be inserted between two wired lines and pulled through the duct. If the mandrel does not pass through satisfactorily the duct should be rodded and cleaned.

6.3 Ducts suspected or found to contain particles of earth, sand, gravel or other obstructions should be cleaned by pulling a stiff bristled wire brush through each conduit as required.

6.4 Ducts which are found to be obstructed by foreign material which cannot be removed should be reported to the engineer without delay. The engineer will determine what action must be taken.

7. CHECKING REEL AND CABLE MARKINGS

7.1 Prior to setting up a cable reel the contractor should check the reel number, cable pair size, gauge and the cutting length with the information contained on the construction drawings, against the verified distance of the manhole to manhole center-to-center distance.

7.2 Cable for placing in underground conduit runs should be ordered by cut lengths (manhole to manhole center-to-center distances plus additional length required for racking and splicing) with factory equipped pulling eyes. All cables of 32 mm (1.25 in.) diameter and larger to be pulled into conduit runs should use factory eyes. These are available from the cable manufacturer. All cables of smaller diameters than 32 mm (1.25 in.) to be pulled into conduit runs should have heat shrinkable end caps placed on the cable ends and use cable grips.

8. SETTING UP CABLE REELS AND APPARATUS

8.1 The contractor should inspect cable reels for flange protrusions which could damage the cable sheath. Also the contractor should inspect for any obstructions that could interfere with proper unwinding of the cable.

8.2 Careful control should be exercised in the movement of cable reels. Where it is necessary to roll a reel to a desired location it should be rolled in the direction indicated by the arrows painted on the reel flanges. The reel should not be permitted to tilt. A substantial runway of heavy planks should be employed where uneven ground conditions exists that may cause the reel to tilt. Where it is necessary to move a reel of cable with a construction trunk, a CT cable reel sling or equalivalent should be used.

8.3 In conduit sections containing curves the cable reel should be set up at the manhole near the curve unless traffic or other conditions do not permit.

8.4 Cable reels should be set up on the same side of the manhole as the conduit section in which the cable is to be placed. The reel should be made level and brought into proper alignment with the conduit section so that the cable may be passed from the top of the reel in a long smooth bend into the duct without twisting. This is of utmost importance in handling the filled type cable in temperature ranges of 2° C (35° F) and lower. Under no circumstances should the cable be pulled from the bottom of a reel.

8.5 It is essential that the cable reel be in proper alignment and level during the placing operation, as incorrect locating of the reel will cause unnecessary binding which will result in uneven cable feed.

8.6 Adjacent turns of cable on the reel should not be permitted to stick together and cause binding as the cable is payed off the reel. Feed the cable by rotating the reel manually.

9. PULLING LINES

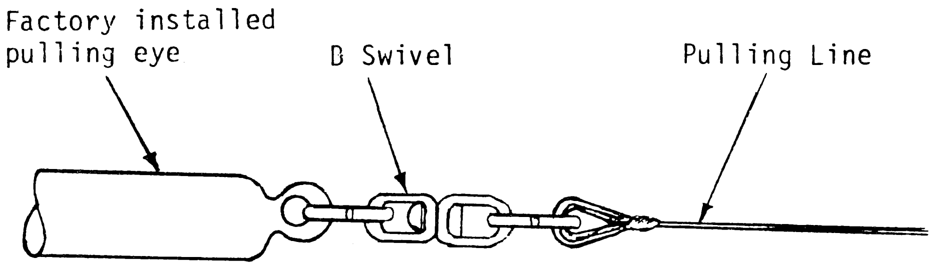
9.1 Use pulling lines in good condition in connection with cable placing operations.

9.2 Place a marker on the pulling line, 6 m (20 ft) from the cable end of the line. This marker is used to indicate when the cable is about to enter the manhole.

10. ATTACHING PULLING LINE

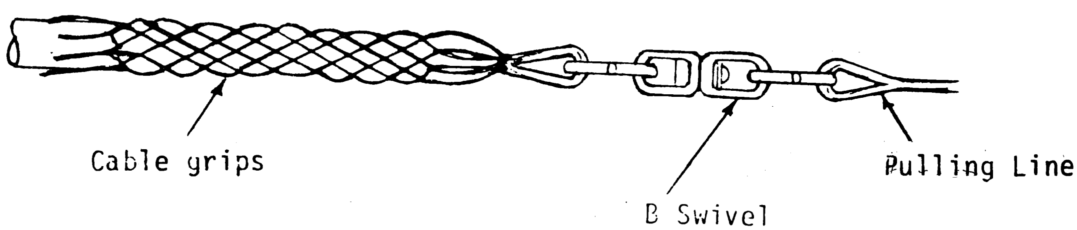
10.1 When cable is equipped with a factory installed pulling eye, the pulling line is attached as shown in Figure 2.

Figure 2
Factory Installed Pulling Eye



10.2 When the cable is not equipped a pulling eye, a cable grip may be used on the pulling line and is attached as shown in Figure 3. Rings to prevent the grip from slipping should not be beaten into the cable sheath.

Figure 3
Cable Grip Installation



10.3 When installing cable either with pulling eyes or with cable grips, a "B" swivel of 19 mm (0.75 in.) links will be used between the pulling eye and/or cable grip and the pulling line.

Note: The above methods of pulling cable into conduit runs applies to both air core and filled cables.

11. INSPECTION OF CABLE

11.1 All nonfilled cables to be placed in a conduit section should be pressurized to a static pressure of 83 ± 14 KPa (12 ± 2 psig) prior to placement. If the cable does not hold the pressure for a period of 6 hours the cable should not be placed. Each cable should be jointly inspected by the contractor and the engineer at least 2 hours after placement to determine that the cable has retained its pressure. If there is a loss of pressure, the contractor should recharge the cable to 83 ± 14 KPa (12 ± 2 psig). Unless the cable holds the recharged pressure for 6 hours, the contractor should replace the cable.

12. FEEDING AND PULLING CABLES

12.1 A cable feeder guide of suitable dimensions (the cable may not bend at any location to a radius less than 10 times the diameter of the cable outside dimensions) should be used between the cable reel and the face of the duct to protect the cable and guide it into the duct as it is payed off the reel.

12.2 Before starting to pull, check the equipment carefully to make sure that it is properly set up in order to minimize the chance of interruption once pulling has started. Tension should be kept on both the cable reel and the pulling line at the start of the pull. Excessive slack and the twist of the pulling line may cause the connecting links to turn and catch in the duct. As far as possible, the cable should be pulled in without stopping until the required amount of cable is in each manhole. A pulling speed of 24 to 30 m/min (80 to 100 ft/min) is desirable.

12.3 As the cable is payed off the reel it should be carefully watched and inspected for sheath defects. If defects are noticed, the pulling operation should be stopped immediately and the engineer promptly notified of the defect. Kinks and/or other irregularities in the cable sheath should be removed or corrected as directed by the engineer.

12.4 The mechanical stress placed upon a cable during installation should not be such that the cable is excessively twisted, stretched or flexed. Such treatment not only weakens the cable but has an unfavorable effect on its electrical properties. It is therefore of utmost importance that the Engineer determine before cables are pulled into ducts or conduits the maximum tensions that will be allowed to make the installation. One of the most important factors to consider is the coefficient of friction values between the various types of duct material and the cable pulling tensions which in turn is the deciding factor for selecting of maximum cable lengths to be placed.

Table I outlines the coefficient of friction values when using either high or low density cable jacketing material with the various types of conduit. Low density cable jacketing is the more commonly used. The data reflected in Table I is based upon conduit with clean surfaces. The coefficient of friction increases significantly if the conduit material is dirty. It is therefore of utmost importance that conduit must be cleaned prior to the installation of cable.

TABLE I

TYPE OF CONDUIT	Coefficient of Friction (Sliding): High Den. Poly. Jacket — Dry	High Den. Poly. Jacket — Lubricated	Low Den. Poly. Jacket — Dry	Low Den. Poly. Jacket — Lubricated
Polyvinyl Chloride (PVC)	0.312	0.131	0.363	0.155
Vitrious Tile	0.244	0.175	0.368	0.186
Black Fiber	0.282	0.175	0.449	0.220
Concrete Asbestos	0.422	0.220	0.479	0.209
Concrete	0.483	0.367	0.571	0.410
Corrugated Plastic	0.220	0.130	0.396	0.130
Wood (Creosote)	0.571	0.280	0.543	0.220

Values are given for dry and lubricated cable as would be encountered in the field. The figures show that lubricated coefficient of friction values are generally one half (1/2) or less of those for a dry cable, allowing lower tensions to be developed and longer cable lengths to be pulled. For purposes of safety regarding pulling tensions of the cable, the dry coefficient of friction value should be used to do preliminary tension and length calculations. The effectiveness of a lubricant is dependent to a large extent on the thoroughness of application. In addition, the surface condition of the conduit relative to being dirt free, as previously mentioned, contributes significantly to the actual coefficient of friction.

12.5 The length of cable that may be safely pulled into a duct system depends on the following factors:

1. Size and type of conductor, e.g., copper or aluminum.
2. Maximum pulling strain allowed on conductors.
3. Method of pulling cable (pulling eye or basket weave grip).
4. Number of bends in conduit.
5. Radius of bends.
6. Bend angle.
7. Coefficient of friction.
8. Cable pulled dry or lubricated.

12.6 Once a cable route has been tentatively determined and the size and type of cable selected, preliminary calculations of cable length and tensions can be made to aid in the placement of manholes and other termination points. Often the termination or distribution points of the cable are predetermined because of service needs and territorial boundaries. Prior planning and preliminary figuring can often arrange these points by using longer lengths resulting in the following cost savings: 1. Reduced splicing costs; 2. Fewer manholes; 3. Reduced reel handling charges and set-up costs; 4. Fewer pulling eye charges; 5. Fewer reel length pressurization charges in the case of air core cable.

12.7 In order to pull a length of cable into a duct system without injury or strain to it, the maximum allowable pulling tension must be determined. To find this value for cable equipped with factory applied pulling eyes, the following equation is used:

T = ANK (equation 1)

where: T = Maximum allowable pulling tensions (lbs)
A = Cross-sectional area of conductors (cir. mils)
N = No. of conductors terminated in pulling eye
Note: Only 1/2 of the total conductors in a cable are terminated in a factory installed pulling eye.
K = Constant - Depending on conductor material
where: K = 0.008 lbs/cir. mil for copper or 3/4 hard aluminum.

To determine A:

Conductor Size (AWG)	Area (Cir. Mils)
19	1290
22	642
24	404
26	254

This equation is used to determine the absolute value of maximum allowable pulling tension for any type of communications cable regardless of shield and jacket design.

Example 1: Determine the maximum allowable pulling tension for a 900 pair, 24 gauge cable with copper or 3/4 hard aluminum conductors.

T = ANK
T = 404 x 900 x 0.008
T = 2909 lbs.

12.8 Having determined the maximum cable pulling tension from Example 1, the maximum allowable pulling length for the same type of cable can be calculated utilizing the maximum pulling tension from the following equation:

$$L = \frac{T}{Wf} \quad \text{(equation 2)}$$

Where L = Maximum allowable pulling length (ft.)
T = Maximum allowable pulling tension (lbs.)
W = Weight of cable (lbs/ft)
f - Coefficient of friction (for duct type)

Example 2: What length of 900 pair, 24 gauge PIC cable can be pulled into PVC conduit with no conduit bends and the cable equipped with a factory applied pulling eye?

$$L = \frac{T}{Wf}$$

T = 2909 (lbs.)
W = 3.34 (lbs/ft)
f = 0.363

$$L = \frac{2909}{3.34\ (0.363)} \qquad L = 2399 \text{ ft.}$$

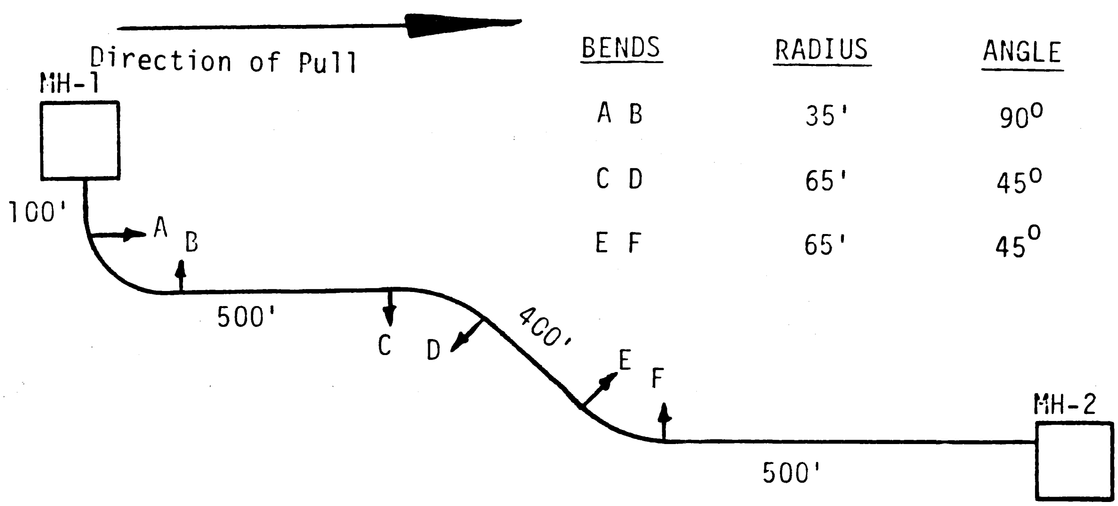
If the same pull were made using cable lubricant, the value "f" would be 0.155 and the solution would be:

$$L = \frac{T}{Wf} \qquad L = \frac{2909}{3.34\ (0.155)} \qquad L = 5619 \text{ ft.}$$

The use of lubricant more than doubled the maximum allowable pulling length.

12.9 The effect of bends in duct systems on the pulling tensions of cable is substantial and should be so considered in the design of conduit and manhole systems. A hypothetical solution which will give a general knowledge of the effect of conduit bends on pulling tensions is as follows: (Refer to Figure 4 below).

Figure 4
Effects Of Conduit Bends On Pulling Tensions



BENDS	RADIUS	ANGLE
A B	35'	90^0
C D	65'	45^0
E F	65'	45^0

12.9.1 The cable to be considered is a 900 pair 24 gauge PIC. The standard reel length is 1500 ft. The cable has a low density outer jacket and the conduit is PVC. The cable is being pulled from manhole 1 to manhole 2. Pulling tensions for a duct system with bends are calculated on a cumulative basis using the following equations:

$T = lwf$ (equation 3) $T = T_1e^{fa}$ (equation 4)

Where: T = Pulling Tension (lbs)
l = Length of cable (ft)
W = Weight of cable (lb/ft)
T_1 = Accumulated tension to start of bend.
e = Base of natural or Naperian logarithms (constant = 2.718)
f = Coefficient of friction between duct and cable.
a = Bend angle in radians (1 radian = 57.3 degrees)

The tension at point MH-2 is found by beginning at the opposite end of the conduit, MH-1 and calculating the accumulated tension at each point. Equation (3) is used to find the tension at point A.

Manhole 1 to point A

$$T = lWf = 100 \times 3.34 \times 0.363 = 121 \text{ lbs.}$$

The tension from Manhole 1 to Point B is found by using equation (4).

$$T = T_1e^{fa} = 121e^{(0.363 \times 1.57)} = 214 \text{ lbs.}$$

The tension of the 500 foot section is then added to find the tension to Point C:

$$T = T_1e^{fa} + lWf = 214 + (500 \times 3.34 \times 0.363) = 820 \text{ lbs}$$

Tension at Point D:

$$T = 820\, e^{(0.363 \times 0.79)} = 1092 \text{ lbs.}$$

Tension of the 400 foot section is then added to the tension at Point D to find the tension at Point E:

$$T = 1092 + (400 \times 3.34 \times 0.363) = 1577 \text{ lbs.}$$

The tension at Point F:

$$T = 1577\, e^{(0.363 \times 0.79)} = 2101 \text{ lbs.}$$

The tension of the 500 foot section is then added to the tension at Point F to determine the tension at manhole no. 2.

$$T = 2101 + (500 \times 3.34 \times 0.363) = 2707 \text{ lbs.}$$

12.9.2 It is therefore determined that it requires 2707 lbs of pulling tension to pull a 900 pair, 24 gauge PIC cable from MH-1 to MH-2. Paragraph 12.7 indicated the maximum allowable pulling tension for this cable using a factory installed pulling eye was 2909 lbs. The cable can therefore be pulled from MH-1 to MH-2 without exceeding the maximum allowable pulling tension (caution, sidewall pressure requirements in section 12.10.1 must also be met). Since the pulling calculation was made for unlubricated cable, use of lubrication will provide a substantial safety margin.

12.10 Another factor to be considered and never exceeded is the maximum allowable sidewall pressure. Sidewall pressure is the radial force exerted on the sheath of a cable at a bend point when the cable is under tension. The sidewall pressure acting upon a cable at any bend may be estimated from the following equation:

$$P = T/R \quad \text{(equation 5)}$$

Where: P = Sidewall pressure (lbs/ft)
T = Pulling tension (lbs)
R = Radius of bend (ft)

12.10.1 The maximum allowable sidewall pressure for telephone cable should not exceed 100 lbs/ft. In such cases of multiple bends, the greatest tension will be developed through the last bend, as will the greatest sidewall pressure. For this reason, during the layout of a duct route, the most severe bends should be planned at the start of a cable pull. The following calculations display the sidewall pressure developed for the conduit system diagrammed in Figure 4.

Bend A B, P = T/R = 214/35 = 6.1 lbs/ft
Bdnd C D, P = T/R 1092/65 = 16.8 lbs/ft
Bend E F, P = T/R 2101/65 = 32.3 lbs/ft

These calculations indicate that the sidewall pressures at all bends in the conduit system of Figure "4" are below the maximum allowable value of 100 lbs/ft.

12.11 Cables should be lubricated with a lubricant that is compatible with the cable jacket material as they are payed off the reel into the cable feeder. A cable lubricator (funnel) should be placed around the cable just ahead of the cable feeder to facilitate proper lubrication of the cable.

WARNING

SOAP LUBRICANTS OR LUBRICANTS CONTAINING SOAP ARE DEFINITELY HARMFUL TO POLYETHYLENE SHEATHED CABLE.

12.11.1 The quantities of cable lubricant which should be used in cable placing operations should be in accordance with the manufacturer's instructions. Lubrication of the polyethylene sheath is not required in lengths shorter than 90 m (300 ft) provided the conduit section is free from sharp bends.

12.11.2 After the cable has been placed, the exposed cable in the manholes should be wiped clean of cable lubricant with a cloth before leaving the manhole.

12.12 Careful attention should be paid to signals from the installation crew as the cable is being pulled so that pulling may be stopped instantly whenever necessary to avoid damage to the cable.

12.13 If for any reason the pulling operation is halted between manholes, the winch operator should not release the tension on the winch unless directed to do so. In restarting the pulling operation, the inertia of the cable should be overcome by gradually increasing the tension in steps a few seconds apart until the cable once again is in motion.

12.14 The leading end of the cable at intermediate manholes should be guided into the duct and a feeder tube nozzle placed around the cable to prevent the cable from rubbing on the edge of the duct. To maintain pressure on the sealing gasket of the pulling eye of polyethylene cables, so equipped, the pulling eye nut should be retightened at each intermediate manhole.

12.15 Sufficient cable should be left in each manhole to properly rack and splice the cables as shown in the contract drawings. All pulled ends should be examined for evidence of damage due to the pulling operation. The cable sheath should not be pulled beyond the cable core. Notification to the Engineer should be made for inspection, and repair action that should be taken where cracks or openings are found in the cable sheath following the pulling operations. Repairs should be made in accordance with REA Splicing Standard PC-2.

Note: Cable ends should be kept sealed at all times. Only REA approved cable end caps may be used for this purpose.

12.16 After the cables have been placed, the cable ends in all manholes should be temporarily secured to the cable racks to prevent damage. Any bending of the cable sheath should be accomplished in such a manner as to avoid possible injury to the cable sheath. Excessive lengths of cable in the manhole should be looped around the manhole in long sweeping bends and tied securely in a location where it will not obstruct the working space in the manhole. The cable ends should be so placed that they are high, close to the manhole roof.

12.17 Duct seals acceptable to REA, should be placed around the cable in the ends of each duct section when the ends of the duct are broken or are in such condition that sheath damage appears likely where cables are installed in metal pipe conduit.

12.18 After the cables are placed, each cable should be identified on each end of a splice with identification tags indicating the cable number, pair count, size, and gauge, and also the cut length.

12.19 Splices should not be placed or pulled into the duct (duct splices) but should be positioned within the manholes.

12.20 Where filled cables are to be spliced to a pressurized cable, a cable stub with an installed in-line pressure block should be placed between the filled cable and the pressurized cable.

13. PULLING CABLE INTO SUBSIDIARY DUCTS

13.1 When placing cable in a subsidiary duct extending from a manhole, service manhole or vault to a pole riser, or to a building, the cable reel should be located at the end of the duct nearest the bend. The cable should be fed in a long smooth curve rather than be pulled upward around the bend from the opposite end.

13.2 Due to the number of bends usually encountered in subsidiary conduits, cable lubricant that is compatible with cable jacket material should be used to facilitate placement of the cable regardless of the conduit lengths.

13.3 Sufficient cable should be left at each end of the duct to permit setting-up and splicing. The cable should be lashed temporarily to the pole or wall with houseline to insure that it does not interfere with other activities, become a safety hazard in work areas or come into contact with electrical power service.

14. SEALING DUCTS

14.1 The ends of all ducts whether specified for occupancy or to remain vacant should be sealed to prevent the entrance of foreign materials and to protect against gas and water entering buildings. The type of duct seal to be used is shown in the "List of Materials Acceptable for Use on Telephone Systems of REA Borrowers."

15. ELECTRICAL PROTECTION AND BONDING

15.1 In general all underground cable shields should be bonded together at each manhole, cable vault, underground dips, underground to aerial junctions and at other locations as may be specified on the construction drawing.

15.1.1 Central Office: The shields of all cables entering the central office should be bonded together and connected to the central office ground with a No. 6 AWG copper insulated or larger ground wire. The bonds should be connected to the cable shields in the cable vault or trough as near the cable entrance as is practicable and/or as specified on the construction drawings. Where a suitable ground cannot be reached conveniently, it may be desirable to establish a ground by running a strip of bonding ribbon the length of the vault frame above the top horizontal support. The bonding ribbon can be secured with wire ties spaced approximately one meter (3 ft) apart. This bonding ribbon should be mechanically fastened to the central office ground lead which is terminated in the vault. As each cable is installed, the ground connections can then be made conveniently by bonding the splice enclosure to the above bonding ribbon where they cross.

15.1.2 Manholes: The shields of all cables in each manhole should be bonded together by placing a bonding wire or ribbon as described in section

15.1.1. At intermediate manholes where the cable is pulled through without a sheath opening, bonds are not required.

15.1.3 Building Entrances: All cable should be bonded and/or grounded as close to the building entrance as possible. Generally a No. 6 AWG copper insulated or larger ground wire is run from the cable shield, or splice enclosure to a permanent and convenient pipe in the cold water system. A bond should be placed between the metallic conduit and/or cast iron bend and the metallic shield of the cable or aerial cable suspension strand at each end of an underground dip and at underground aerial cable junctions.

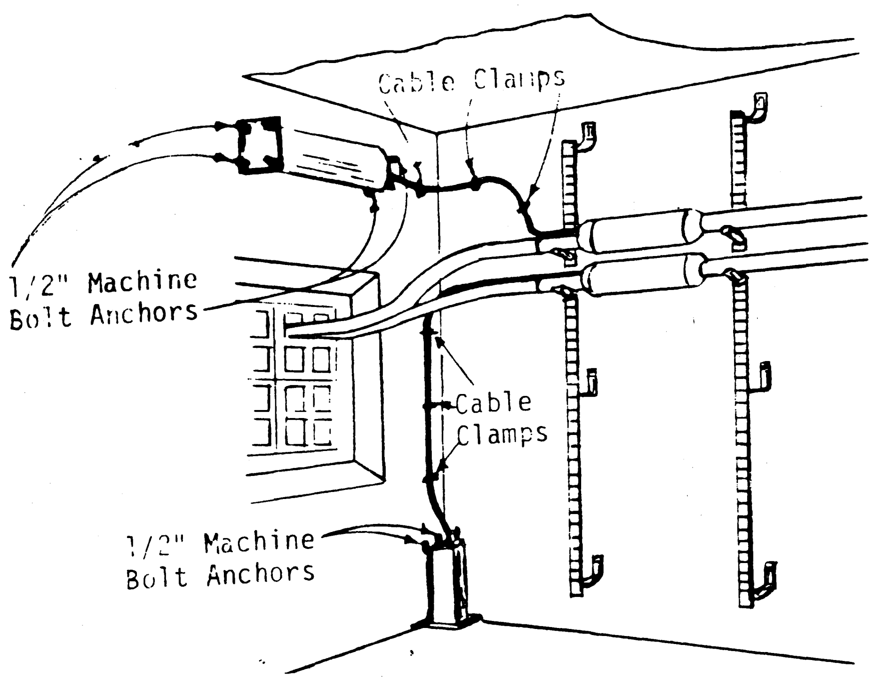
16. PLACING UNDERGROUND LOAD COIL CASES

16.1 The construction drawings should indicate where the case should be located:

a. placed on the floor of the manhole in a vertical position
b. placed on its side
c. attached to the wall

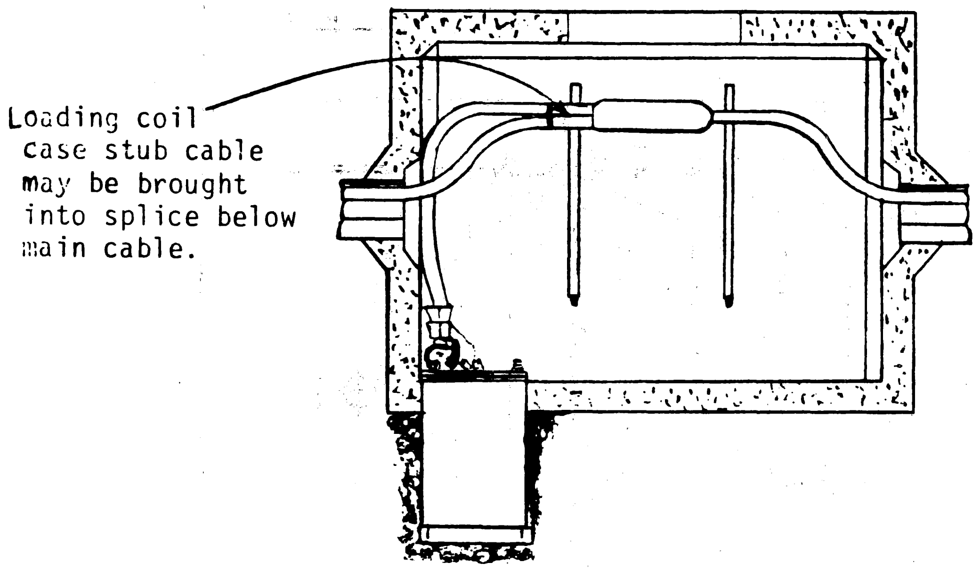
16.1.1 In line manholes the cases will generally be attached to the end wall or stood on the floor as shown in Figure 5.

Figure 5
Load Coil Case Location (In-Line Manhole)



At some locations where the available wall space is completely occupied, it may be necessary to place the case on its side at one end of the manhole. If the loading case must be installed in the manhole floor, the stub should be arranged as indicated in Figure 6.

Figure 6
Load Coil Case Location (Manhole Floor)



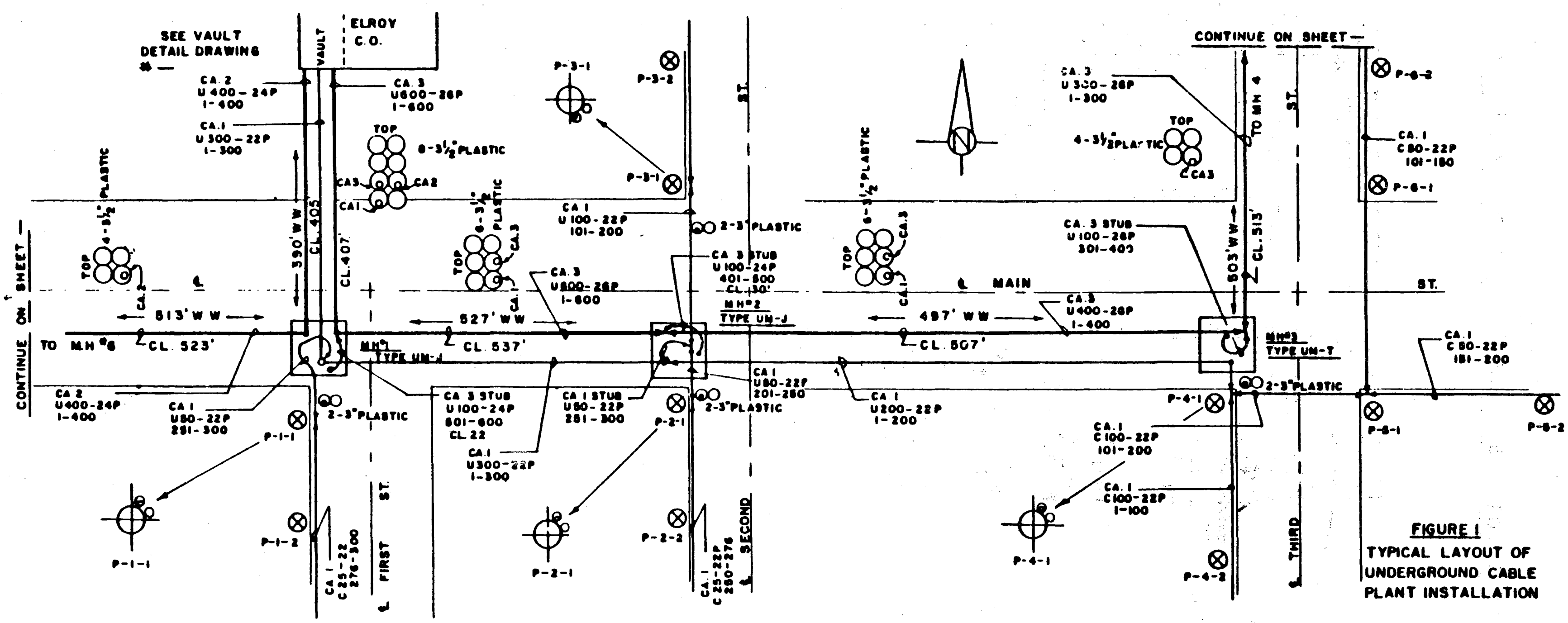


FIGURE I
TYPICAL LAYOUT OF
UNDERGROUND CABLE
PLANT INSTALLATION

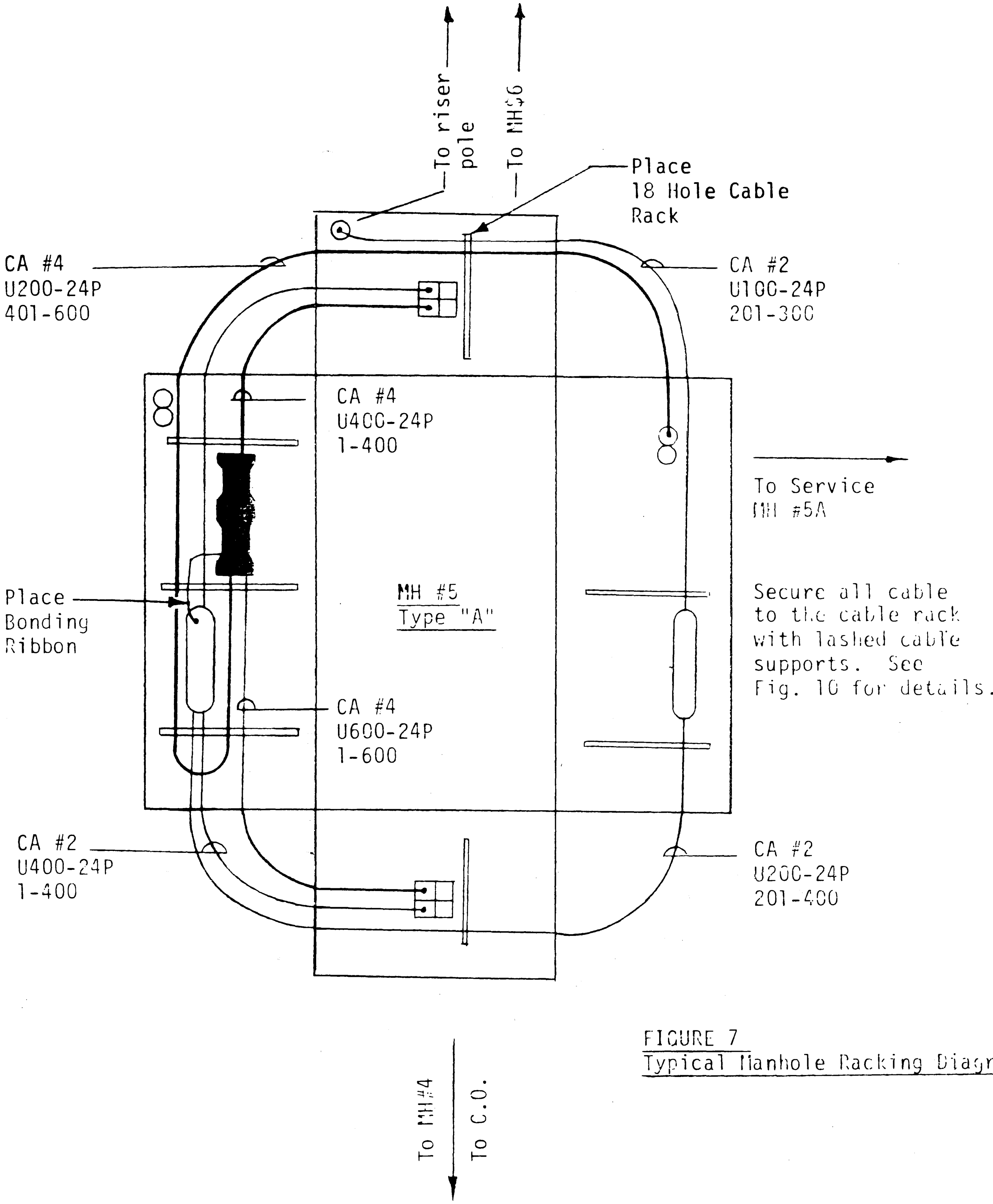
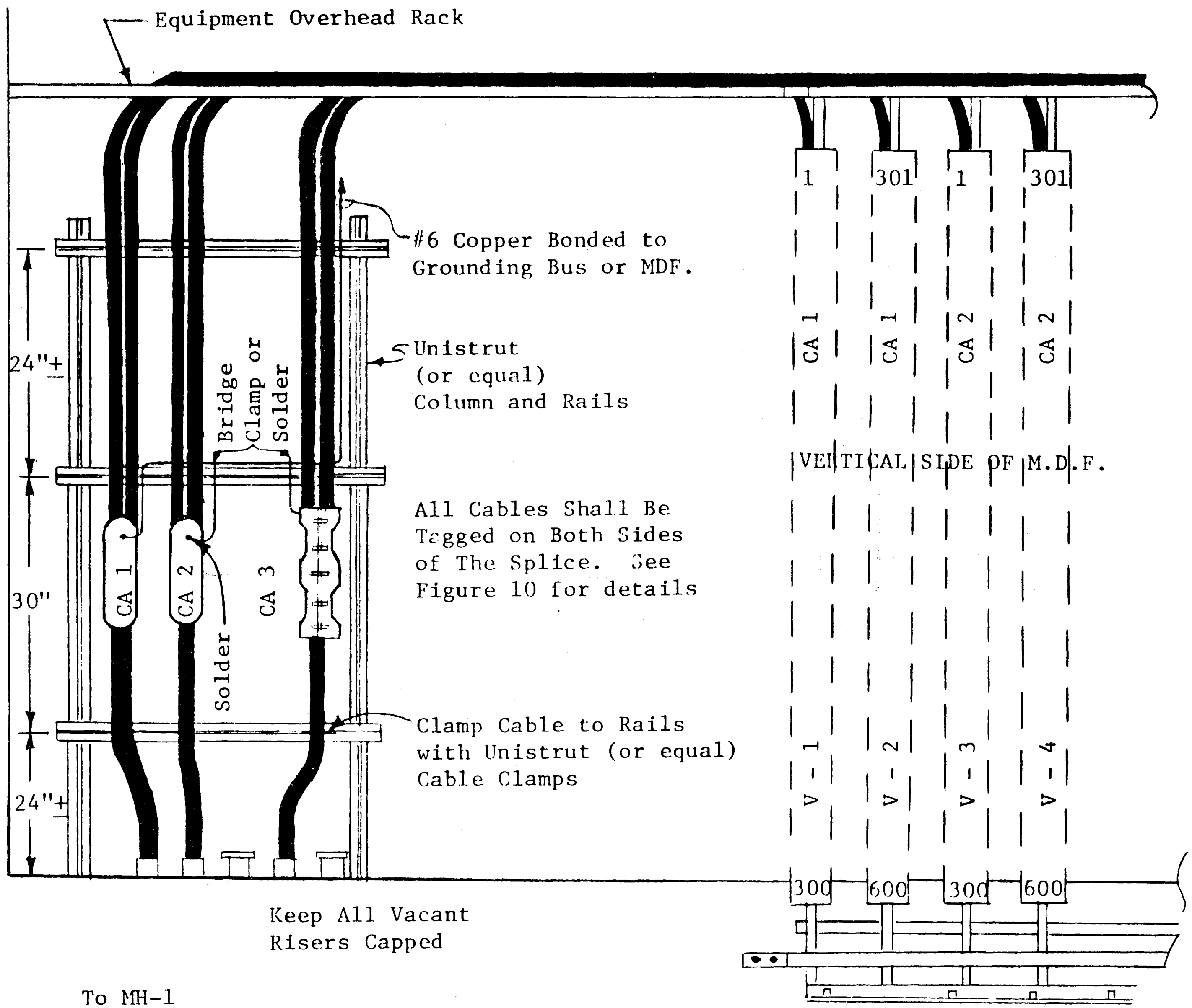


FIGURE 7
Typical Manhole Racking Diagram

FIGURE 8

Typical Central Office With Inside Wall Mounted Cable Racking



After Cable Installation Seal Risers with Water Plug or Plaster of Paris

To MH-1

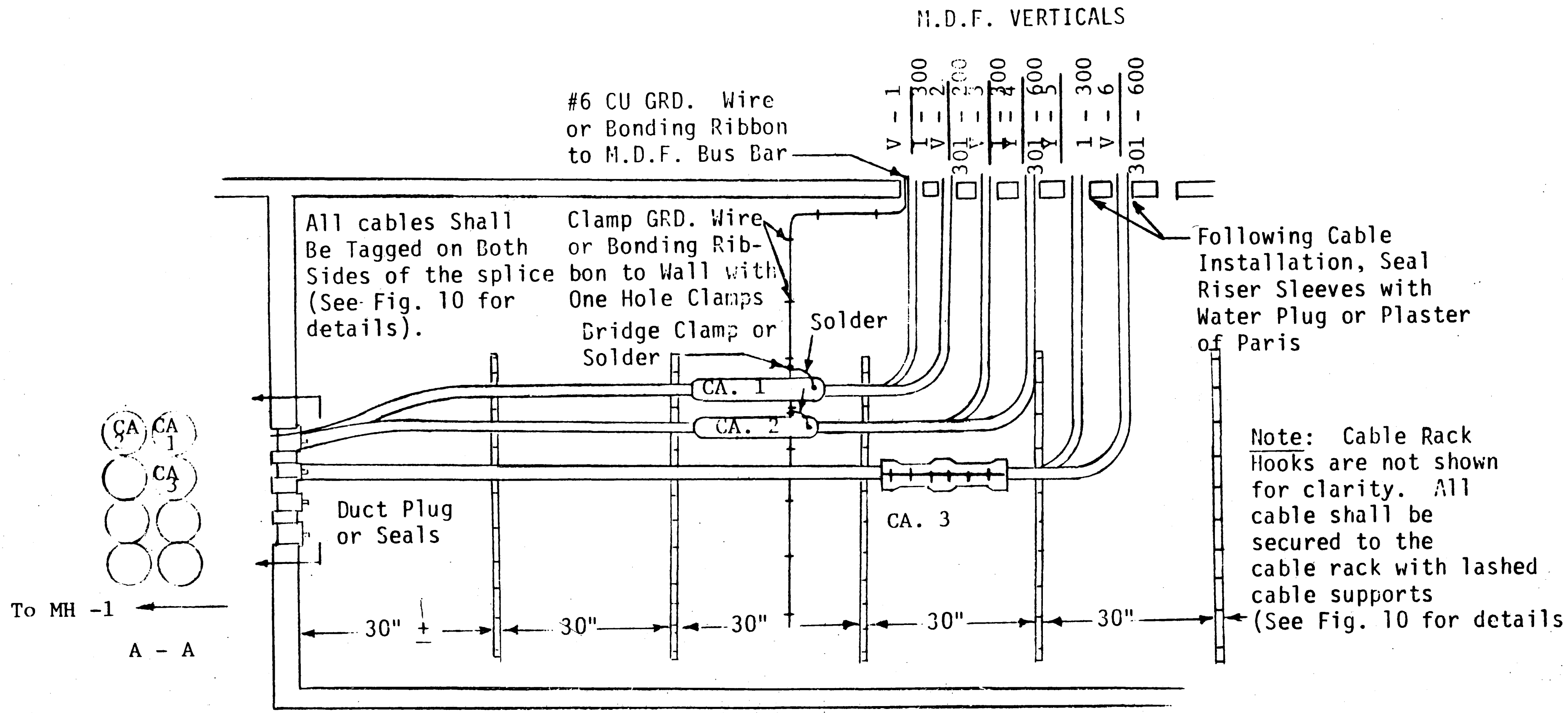
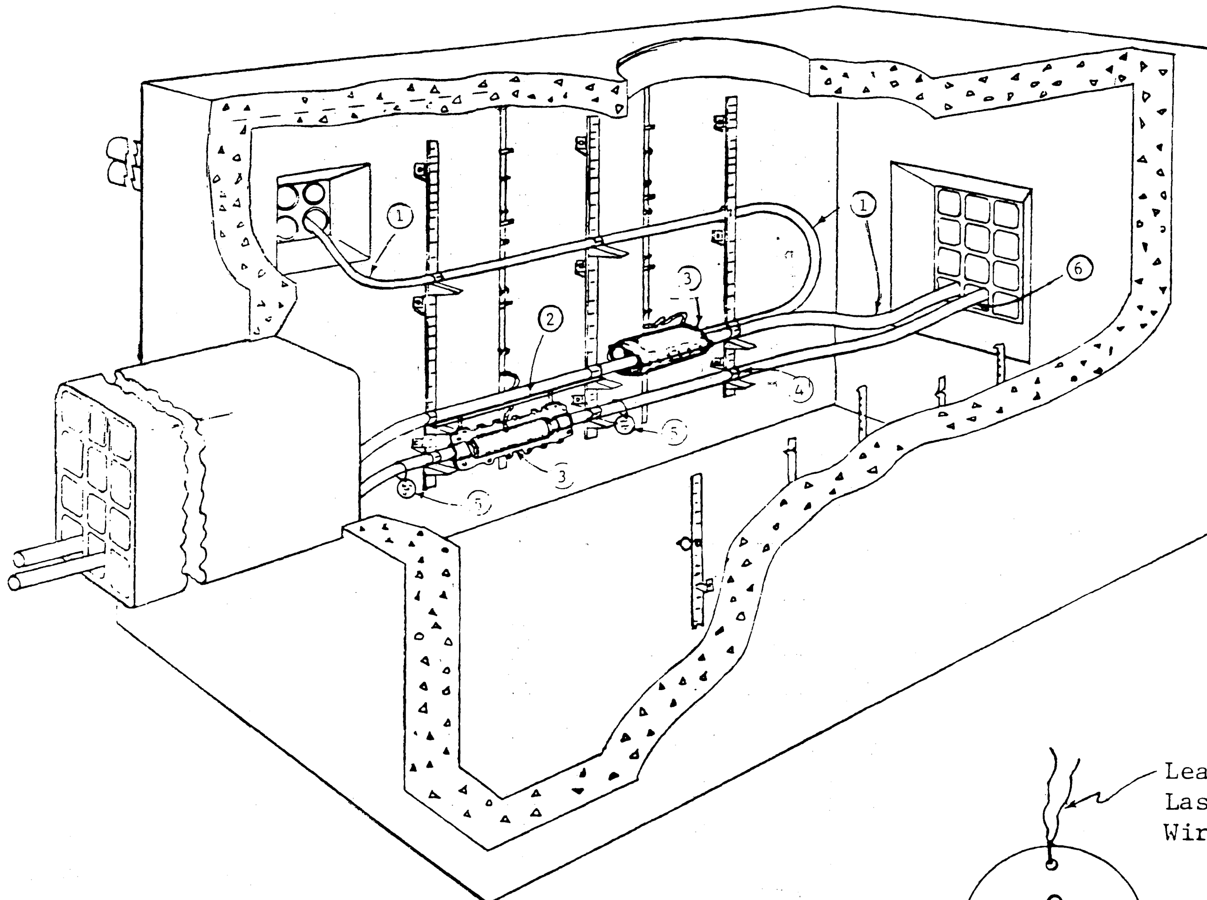


FIGURE 9

Typical Cable Vault With
Wall Mounted Cable Racking



Notes:

1. Extreme care should be used in the forming of cable(s) to prevent kinking. Cables should not be formed to a radius of less than ten times the diameter of the cable.

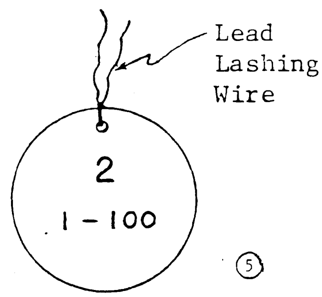
2. Cast iron splice cases must be supported by the cable racks to prevent cable damage. It is suggested that a 1/2" or 3/4" galvanized iron pipe be used for this support and installed as indicated on the drawing.

3. All splice enclosures should be bonded together. The method of bonding should be in accordance with instructions issued by the Engineer.

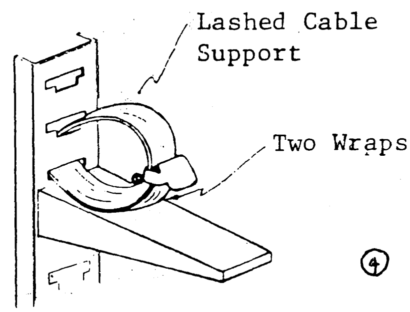
4. All cables should be secured to the cable racks with lashed cable supports.

5. Lead cable tags showing the cable identification and pair count should be placed on the cable(s) on both sides of splices.

6. Install duct seals or plugs as required.



LEAD CABLE TAG DETAIL



ATTACHMENT OF CABLE SUPPORT TO MANHOLE CABLE RACK

Figure 10 - Typical Cable Plant Manhole Installation Details

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