



**MINIMUM REQUIREMENTS FOR THE DESIGN AND INSTALLATION OF 038193  
ELECTRIC CONDUIT, INSULATED CABLE, AND FACILITIES**

**Asset Type:** Electric Distribution **Function:** Design and Construction

**Issued by:** Lisseth Villareal (LDV2) *Lisseth Villareal* **Date:** 03-25-22

**Rev. #15:** This document replaces PG&E Document 038193, Rev. #14 For a description of the changes, see Page 27.

**Purpose and Scope**

This document describes the minimum requirements for the design and installation of electric conduits and pulling insulated cables. This document also provides requirements of what facilities are allowed within the same enclosure.

**General Information**

1. A minimum of 24 inches of cover for secondary (0 – 750 V) electric service, or 36 inches minimum cover for primary (over 750 V) is required for electric trench only. Cover is the distance from the outer surface of an underground facility to the top of the final grade. The actual trench depth will be greater (approximately 30 inches or 42 inches minimum respectively) to accommodate the underground facility, bedding, enclosures, riser sweeps, and joint trench installations with other utilities.
2. For detail information for joint trench requirements see [S5453, Exhibit B](#).
3. There is no cut-off date of when a cable needs to be installed after it has been manufactured if the cable meets the following parameters
  - A. Cable is manufactured by a currently approved supplier and meets PG&E approved standard design cable requirements.
  - B. Cable was properly stored at PG&E, applicant or contractor facility, i.e. properly sealed with end caps at both ends so no water/debris could have entered the cable at any time.
  - C. The cable is in good condition, i.e. no damage on the jacket, or any other layers.
  - D. Print line is fully legible.
4. For riser to riser primary conduit runs, a PG&E approved primary enclosure is required to be installed near the base of one of the riser poles to facilitate cable installation and removal.
5. Refer to the utility procedure [TD-2002P-01](#) "Installing underground Cable in Conduits" for a description on the methods for pulling underground cables into and out of conduits. This utility procedure also includes the types of equipment needed for the pulling operation. Situations, methods, and equipment may vary based on the material and jobsite.
6. Electric conduits installed using horizontal directional drilling (HDD), can be installed without any separation between the conduits when installed in the same bore. However the current carrying capacity (ampacity) of the cables can be reduced when multiple load carrying cables are installed in close proximity. Refer to [Document 050166](#) or [Document 050167](#) or consult with the responsible planning engineer.
7. Design requirements for less frequently encountered field conditions such as bio swells, railroad, bridge and septic tank/leach field, are listed on Page 9 through Page 13.
8. Percent fill table for rigid PVC DB 120 conduit has moved to end of this document and it is shown for reference only. Percent fill table for currently approved rigid PVC schedule 40 conduit is shown on Table 9 on Page 19.

**Minimum Requirements for the Design and Installation of Electric Conduit, Insulated Cable, and Facilities**

**General Information (continued)**

9. There are many variables involved in designing underground electric conduit systems and installing cables that are peculiar to each installation and cannot be covered in this document. Some of these variables are listed below:
  - A. Physical requirements of the installation.
  - B. Limitations of available cable-pulling and reel-handling equipment.
    - (1) 1,000 pounds maximum for a single grip, 2,000 pounds maximum for two or more grips.
    - (2) 10,000 pounds maximum for reusable mechanical pulling eyes.
  - C. Number and radius of sweeps.
    - (1) Sidewall bearing pressure (1,000 pounds x radius).
  - D. Deflections, changes in direction, and obstructions encountered during conduit installation.
  - E. Coefficient of friction (COF) between cable and conduit surfaces.
  - F. Maximum allowable pulling tension for the cable size under consideration.
  - G. Conduit, cable, and facilities installation must comply with the job design and construction documents. When deviation from the original design is required due to field conditions, the originating engineering department must be notified and will determine if the deviation will require additional Substructures. Follow the variance request procedure. See [Document TD-2951P-01](#).

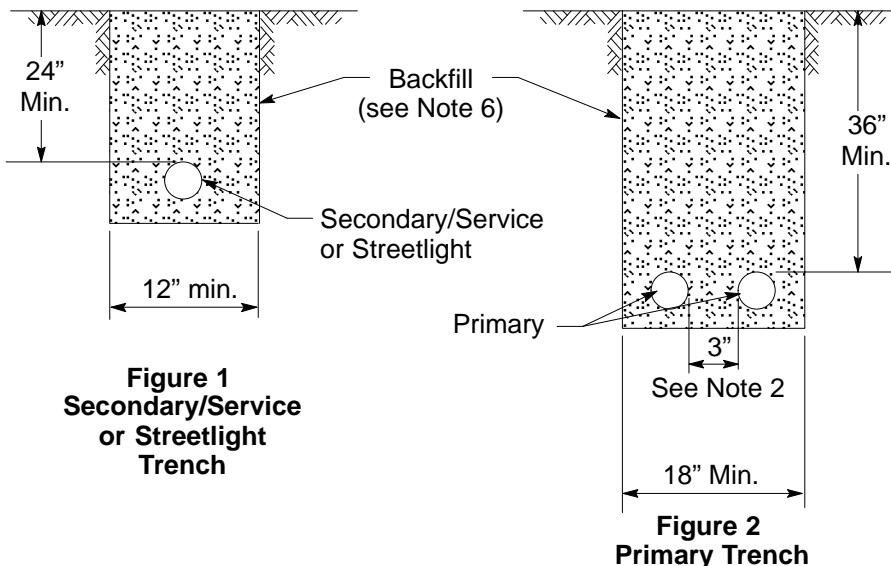
<b>References</b>	<b>Location</b>	<b>Document</b>
<a href="#">Cables for Underground Distribution</a> .....	<a href="#">UG-1: Cable</a> .....	<a href="#">039955</a>
<a href="#">600-Amp Separable Insulated Connectors</a> .....	<a href="#">UG-1: Terminations</a> .....	<a href="#">051071</a>
<a href="#">Ampacity of Underground Distribution Insulated Aluminum Cables</a> .....	<a href="#">UG-1: Cable/EPM</a> .....	<a href="#">050166</a>
<a href="#">Ampacity of Underground Distribution Insulated Copper Cables</a> .....	<a href="#">UG-1: Cable/EPM</a> .....	<a href="#">050167</a>
<a href="#">Underground Conduits</a> .....	<a href="#">UG-1: Conduits/Greenbook</a> .....	<a href="#">062288</a>
<a href="#">Methods and Requirements for installing Residential Underground Electric Services 0 – 600 V to Customer-Owned Facilities</a> .....	<a href="#">UG-1: Services/Greenbook/EDM</a> .....	<a href="#">063927</a>
<a href="#">Methods and Requirements for Installing Non-Residential Underground Electric Services 0 – 600 Volts to Customer-Owned Facilities</a> .....	<a href="#">UG-1: Services/Greenbook/EDM</a> .....	<a href="#">063928</a>
<a href="#">Request for Variance Distribution Standards</a> .....	<a href="#">TIL</a> .....	<a href="#">TD-2951P-01</a>
<a href="#">Installing Underground Cable in Conduit</a> .....	<a href="#">TIL</a> .....	<a href="#">TD-2002P-01</a>
<a href="#">Electric Distribution Conduits Installed on Bridges</a> .....	<a href="#">TIL</a> .....	<a href="#">TD-2310P-10</a>
<a href="#">Horizontal Directional Drilling Manual</a> .....	<a href="#">TIL</a> .....	<a href="#">TD-4135M</a>
<a href="#">Electric Design Manual</a> .....	<a href="#">TIL</a> .....	<a href="#">TD-9001M</a>
<a href="#">Casings for Highway and Railroad Crossings</a> .....	<a href="#">TIL</a> .....	<a href="#">A-70</a>
<a href="#">Casing Insulator and End Seals Selection Chart</a> .....	<a href="#">TIL</a> .....	<a href="#">A-73</a>
<a href="#">Modular Wall and Casing Seal</a> .....	<a href="#">TIL</a> .....	<a href="#">A-74</a>
<a href="#">Joint Trench Configurations &amp; Occupancy Guide Exhibit B</a> .....	<a href="#">TIL</a> .....	<a href="#">S5453, Exhibit B</a>
<a href="#">Electric Design Manual Chapter 2</a> .....	<a href="#">TIL</a> .....	<a href="#">TD-9001M</a>
<a href="#">Electric Design Manual Chapter 3</a> .....	<a href="#">TIL</a> .....	<a href="#">TD-9001M</a>
<a href="#">Electric Design Manual Chapter 5</a> .....	<a href="#">TIL</a> .....	<a href="#">TD-9001M</a>

## Minimum Requirements for the Design and Installation of Electric Conduit, Insulated Cable, and Facilities

### Trench Requirements

#### Notes

1. Field conditions may require a minimum depth greater than shown in Figure 1 and Figure 2 below.
  - Preferred maximum depth from final grade to the bottom of the trench is 60 inches.
  - When needed to avoid obstacles, maximum depth from final grade to the bottom of the trench is 120 inches.
  - Trenches deeper than 120 inches require a variance. Follow the instructions found in [Utility Procedure TD-2951P-01](#) to submit a variance request.



2. Joint trench requirements are specified in the [Utility Standard S5453](#). The table showing the minimum separation and clearance requirements for joint trench is listed in "[Joint Trench](#)," [Exhibit B](#). However, this table was last updated July 31, 2015 via a bulletin. The updated table is shown in Section 3.3.8 of Greenbook and for convenience it is also shown below:

**Table 1 Joint Trench Requirements \*\*\***

		MINIMUM SEPERATION AND CLEARANCE REQUIREMENTS (Inches)						
		G	DUCT T	BD T	C	S	P	SL
G	(Gas)	–	12	12	12	6	12	6
T	(TELEPHONE) DUCT	12	–	1	1	12	12	12
T	(TELEPHONE) DIRECT BURY	12	1	–	1	12	12	12
C	(CATV)	12	1	1	–	12	12	12
S	(ELECTRIC SECONDARY)	6	12	12	12	1.5	3	1.5
P	(ELECTRIC PRIMARY)	12	12	12	12	3	3	3
SL	(STREETLIGHT) SEE NOTE 5 ****	6	12	12	12	1.5	3	1.5
FE*	(FOREIGN ELECTRIC SOURCES. NON-PG&E) SEE NOTE 5 ****	12	12**	12**	12**	12	12	12

1 \* Must be considered a "Utility" as defined in [Utility Standard S5453](#), "[Joint Trench](#)".  
 2 \*\* For exceptions, refer to G.O. 128 rule, section B. Items (1) and (2).  
 3 \*\*\* These clearances/separations supersede old clearances/separation shown in [S5453 Exhibit B](#).  
 4 \*\*\*\* It is preferred to have non-PG&E owned streetlights at a level other than the gas or electric level. Non-PG&E owned streetlights may be at the electric level of the trench as long as minimum clearances are provided and comply with all special notes for a joint trench with a second electric utility.

**Minimum Requirements for the Design and Installation of Electric Conduit, Insulated Cable, and Facilities**

**Trench Requirements (Continued)**

**Notes**

- For independently installed electric trenches, most of the requirements are the same as for joint trenches. However, Table 2 below shows and clarify requirements when installing electric trench only.

**Table 2 Minimum Separation and Clearance for Electrical Conduit by Facility Type<sup>5</sup>**

Facility	Minimum Parallel Separation	Minimum Crossing Separation
Between multiple electric primary conduits	3 inches	6 inches
Between electric primary and secondary, service and streetlight conduits	3 Inches	6 inches
Between electric secondary, service and streetlight conduits	1.5 inches	6 inches
Between electric primary and gas distribution main and service conduits	12 inches	12 inches
Between electric secondary, service, streetlight and gas main and gas service conduits	12inches	6 inches
Leach field and electric primary, secondary, service and streetlight conduits	10 feet <sup>1</sup>	Not Allowed <sup>2</sup>
Steam lines from PG&E electric conduits	10 feet <sup>3</sup>	18 inches <sup>3</sup>
Tree trunk from PG&E electric primary, secondary, service, and streetlight conduits	5 feet <sup>4</sup>	5 feet <sup>4</sup>
Diesel or other volatile liquids; propane or other volatile, heavier-than-air gases and any type of electrical conduit	20 feet	20 feet
Edge of Underground gas tank and any type of electric conduits	10 feet	10 feet
Hydrogen cooling block, dispenser or storage and any type of electric conduit	5 feet	5 feet
Hydrogen compressor and any type of electric conduit	15 feet	15 feet
Any other pipe systems or other foreign substructures excluding wet facilities not listed above	12 inches	6 inches

<sup>1</sup> If this separation cannot be achieved, refer to the [Septic Tank/Leach Field/Leach](#) Line section starting on [Page 9](#).

<sup>2</sup> Mobile home park is the only exception, refer to the [Septic Tank/Leach Field/Leach](#) section starting on [Page 9](#).

<sup>3</sup> If this separation cannot be achieved, refer to the [Steam Line](#) section starting on [Page 12](#).

<sup>4</sup> Radial distance from the closest edge of the trunk to the edge of electric conduit.

<sup>5</sup> Wet facility requirements are the same as listed in [S5453](#).

- Separations in Table 1 and Table 2 may be reduced when conduits are entering enclosures, panels, pads, vaults, or structures. Allowance must be made for the installation of the conduit end bell fittings.
- Sharp turns, bends, or other irregularities in the conduit must be avoided.
- If the bottom of a trench which will contain plastic conduit is rocky, use backfill material conforming to the requirements of [Engineering Material Specification 4123](#). Before tamping in the area of plastic conduit, apply at least 6 inches of backfill over the top of the conduit to avoid breakage. Final backfill may then be placed in the trench and tamping employed to finish grade. The soil originally removed from the trench should be used as backfill wherever possible.
- Do not use salt-water sand backfill with steel conduit.
- Other utility practices may require a greater minimum conduit separation.
- Refer to state of California, Department of Industrial Relations; Trench Construction Safety Orders for trench construction requirements. These orders are issued by the Department of Occupational Safety and Health.

## Minimum Requirements for the Design and Installation of Electric Conduit, Insulated Cable, and Facilities

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### Conduit System Design and Installation

To minimize the possibility of cable damage during installation, the following conduit design parameters must be followed:

1. The total number of factory bends installed in conduit run for primary cable must not exceed 300 degrees, including the bend at the feed-in location. Only factory bends are allowed.
2. The total number of factory bends installed in conduit runs for secondary cable and services having a maximum length of 200 feet must not exceed 315 degrees, including the bend at the feed-in location. If the total length of conduit run exceeds 200 feet, then the total number of factory bends for secondary and service cable must not exceed 300 degrees.
3. The maximum length of any straight conduit run (no factory bends) must not exceed 1,200 feet.
4. The calculated pulling tension for the non-preferred (highest) direction must be used as the limiting pulling tension.
5. When the conduit run includes bends (300 degrees or less), the maximum length of the run must be limited to 800 feet.
6. For secondary, services, and 200-Amp primary applications, the conduit run must not exceed 600 feet if there is a vertical 90 degree bend at both ends of the conduit run.
7. The first 18 inches of conduits entering or leaving any primary or secondary underground 3' x 5' or larger enclosure must be straight with no bends, couplings, or swedge reducers.
8. To avoid potential burn-through of sweeps, use polyester pulling tape (material code **M560154**) as the "P-Line" to initiate cable pulling. For further information refer to [Utility Procedure TD-2002P-01](#) "Installing Underground Cable in Conduit".

For each primary cable run, the construction drawing must contain:

- A. The calculated pulling tension.
  - B. A preferred direction of pulling.
  - C. The maximum allowable pulling tension.
  - D. A place to record the actual pulling tension and direction of pull.
9. The tension on the pulling line, as seen on the dynamometer, is dependent on the number of rollers and sheaves used to rig the pulling line and the angle between the line entering and leaving the device. Multiply the calculated pulling tension on the cable by 5% for each 90° bend of the rope.
  10. The pulling equipment specified for a job should be capable of twice the calculated pulling tension. This is recommended due to the following variables:
    - A. Back tension.
    - B. Condition of the conduit.
    - C. Temperature of the conduit, cable, and the ambient air temperature.
    - D. Increase in friction due to rigging.
    - E. Static (start/stop) friction.

Combinations of the above could increase the actual pulling tension to twice (or more) of the calculated tension. Attention should be paid to minimizing these factors.

## Minimum Requirements for the Design and Installation of Electric Conduit, Insulated Cable, and Facilities

### Conduit System Design and Installation (continued)

#### Cable Pulling Requirements

To minimize issues during cable pulling, follow the steps below:

1. The use of approved pulling practices and equipment is required.
2. Before starting any cable installation or removal operation, all employees must be thoroughly familiar with the safe operation of the equipment and methods to be used.
3. Provide a reliable means of communications between feed-in and pull-out locations before and during the entire operation.
4. Provide an adequate number of employees to safely install or remove the cable.
5. The conduit must be cleared of dirt, rocks, or other debris before starting the cable installation.
6. The practice of attaching the pulling rope to a vehicle and then driving the vehicle to pull in or remove cable may damage the cable and is prohibited.
7. All cable must be lubricated (pre-lubed) before installing (see Table 6 on Page 7 and Table 7 on Page 8).
8. The use of a dynamometer or inline tensiometer to monitor the pulling tension during cable installation is **recommended** for cable pulls where the calculated pulling tension is less than 50% of the maximum allowable pulling tension for the cable being installed.
9. The use of a dynamometer or inline tensiometer to monitor the pulling tension during cable installation is **required** for cable pulls where the calculated pulling tension is equal to or greater than 50% of the maximum allowable pulling tension for the cable being pulled.
10. All locations where the actual pulling tensions exceed the calculated tensions by more than 25% must be reported to the originating engineering department and analyzed to determine the cause of the difference. The information will be used to improve the design parameters as well as PG&E's cable-pulling practices.
11. The minimum radius bend that an insulated cable can be subjected to cannot exceed the results of the OD of the cable times the multiplier shown in Table 3.

**Table 3 Minimum Allowable Cable-Bending Radius Multiplier**

Type of Cable	Multiplier
P&L or PL&N	10
15 and 22 kV XLP-PVC	12
5–35 kV CONC-PVC, LLDPE Encap, or EPR-CONC-PE	8
600 V XLP and EPR&N	5 (500 kcmil and larger)
	4 (less than 500 kcmil)

12. The recommended amount of cable lubricant depends only on the size and length of the conduit system. The appropriate quantity for use on any given pull can vary from this recommendation depending on the complexity of the pull. Consider the following factors:
  - A. Cable weight and jacket hardness (increase quantity for stiff, heavy cable).
  - B. Conduit type and condition (increase quantity for old, dirty, or rough conduits).
  - C. Conduit fill (increase quantity for conduit fills of 50% or greater).
  - D. Number of bends (increase quantity for pulls with several bends).
  - E. Pulling environment (increase quantity for high temperatures).
13. Front-end packs are conduit-sized polyethylene bags of lubricant. The packs are attached to the winch line, ahead of the cable, and are manually opened as they enter the conduit, pre-lubing the conduit. Codes for front-end packs are in listed Table 4 on Page 7 .

## Minimum Requirements for the Design and Installation of Electric Conduit, Insulated Cable, and Facilities

### Conduit System Design and Installation (continued)

#### Cable Pulling Requirements (continued)

**Table 4 Pulling Lubricant**

Description	Code
Front-End Pack 2" and 3" Conduit	500118
Front-End Pack 4", 5", and 6" Conduit	500117
Pourable Lubricant, 2.5-Gallon Container	500031
Pourable Lubricant, 5-Gallon Container	500099

14. Cable lubricant LZ type must be used when 500 kcmil, 750 kcmil, and 1100 kcmil Cu 15kV EPR flat strap with low smoke zero halogen (LSZH) jacketed cable is pulled through conduits. For more information regarding LSZH cable refer to [Document 039955](#).

Note: The use of standard pulling lubricant will have a negative impact on the physical integrity of the cable's LSZH jacket.

**Table 5 Pulling Lubricant to be Used With LSZH Cable**

Description	Code <sup>6</sup>
Lubricant, Squeezable Quart	500060

<sup>6</sup> 12 quarts is the minimum order quality.

15. Table 6 Below and Table 7 on Page 8 indicate the approximate amount of pulling lubricant for various cable pulls. Same tables apply for the lubricant LZ type.

**Table 6 Pulling Lubricant Needed for 2", 3", and 4" Conduit**

Pull Length (feet)	2" Conduit			3" Conduit			4" Conduit		
	Gallons Needed	Number of Front-End Packs	Pourable (gallons)	Gallons Needed	Number of Front-End Packs	Pourable (gallons)	Gallons Needed	Number of Front-End Packs	Pourable (gallons)
100	0.25	1	0	0.50	2	0	0.50	1	0
200	0.50	2	0	1.00	2	0.50	1.00	2	0
300	1.00	2	0.50	1.25	2	0.75	2.00	2	1.00
400	1.25	2	0.75	1.75	2	1.25	2.50	2	1.50
500	1.50	2	1.00	2.25	3	1.50	3.00	2	2.00
600	1.75	3	1.00	2.75	3	2.00	3.50	3	2.00
700	2.00	4	1.00	3.25	4	2.25	4.00	4	2.00
800	2.50	4	1.50	3.50	4	2.50	5.00	4	3.00
900	2.75	4	1.75	4.00	4	3.00	5.50	4	3.50
1,000	3.00	4	2.00	4.50	4	3.50	6.00	4	4.00

**Minimum Requirements for the Design and Installation of Electric Conduit, Insulated Cable, and Facilities**

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**Conduit System Design and Installation (continued)**

**Cable Pulling Requirements (continued)**

**Table 7 Pulling Lubricant Needed for 5" and 6" Conduit**

Pull Length (feet)	5" Conduit			6" Conduit		
	Gallons Needed	Number of Front-End Packs	Pourable (gallons)	Gallons Needed	Number of Front-End Packs	Pourable (gallons)
100	1.00	2	0	1.00	2	0
200	1.50	3	0	2.00	2	1.00
300	2.50	2	1.50	2.50	3	1.00
400	3.00	2	2.00	3.50	3	2.00
500	4.00	2	3.00	4.50	3	3.00
600	4.50	3	3.00	5.50	4	3.50
700	5.50	4	3.50	6.50	4	4.50
800	6.00	4	4.00	7.00	4	5.00
900	7.00	4	5.00	8.00	6	5.00
1,000	7.50	5	5.00	9.00	6	6.00



## Minimum Requirements for the Design and Installation of Electric Conduit, Insulated Cable, and Facilities

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### Design Requirements for Less Frequently Encountered Field Conditions

#### Conduit and Substructure Installation

Conduit and substructure installation must comply with the job design and construction documents. If field conditions require a deviation that is not within current standards, follow the variance request procedure. See [Document TD-2951P-01](#).

The requirements listed below are for the various field conditions where electric conduits are installed;

#### Bio Swale

It is preferred to install conduit around a bio swale. If it is not feasible to go around the bio swale, primary and/or secondary conduits under the bio swale must be installed following the requirements below:

1. Option #1
  - A. Install conduits with a minimum cover of 48" between the top of the conduit and the bottom of the bio swale.
  - B. Add 6" sand bed below conduit
  - C. Use PVC Schedule 40, and install a spare conduit
  - D. Install conduit 36" past bio swale on each side
  - E. Add 6" sand bed on top of conduit
  - F. Complete trench fill with native dirt
2. Option #2 (if option #1 is not feasible)
  - A. Install conduits with a minimum cover or 36" between the top of the conduit and the bottom of the bio swale.
  - B. Add 6" sand bed below conduit
  - C. Install PVC Schedule 40, and install spare conduit
  - D. Run conduit 36" past bio swale on each side
  - E. Add 6" sand bed on top of conduit
  - F. Add 3" Red Slurry Cap
  - G. Complete trench fill with native dirt
3. Option #3
  - A. Use horizontal directional drilling (HDD) to install conduits crossing under existing bio swales. For more information about HDD, Refer to [Utility Procedure TD-4135M](#).
  - B. The minimum depth burial for HDD is 48" from the bottom of existing bio swales.

#### Railroad

Railroad crossing may require electric conduits installation in a casing via HDD. For information about casing specifications, casing sealing, casing spacers refer to [A-70](#), "[Casings for Highway and Railroad Crossings](#)", [A-73](#), "[Casing Insulator and End Seals Selection Chart](#)", and [A-74](#), "[Modular Wall and Casing Seal](#)".

#### Bridge

For the design requirements of conduits installed on bridges see [Utility Procedure TD-2310P-10](#).

#### Septic Tank/Leach Field/Leach Line

Leach fields are used to dispose of sewage from septic-tank sanitary sewer systems. Typically, leach fields consist of a system of rock-filled trenches with drain line or perforated pipe and weir-type diversion boxes. They are grade-sensitive and create a wet environment.

Septic tanks and Leach fields are considered an unreasonable interference for UG distribution electric line easements. Substructure conduit connections are not designed to be used under pressure and are not air tight. As a result, sewage may enter the conduit and result in unsafe working conditions.

## Minimum Requirements for the Design and Installation of Electric Conduit, Insulated Cable, and Facilities

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### Design Requirements for Less Frequently Encountered Field Conditions (continued)

#### Septic Tank/Leach Field/Leach Line (continued)

Ensure that the entire leach field is located outside the right of way or easement of PG&E electric facilities.

Septic tanks are installed underground. The potential of seepage or leaks from cracks is a concern. Therefore, septic tanks are unacceptable in any right of way or easement of PG&E electric facilities. Variance requests for this requirement will not be considered and they will be denied.

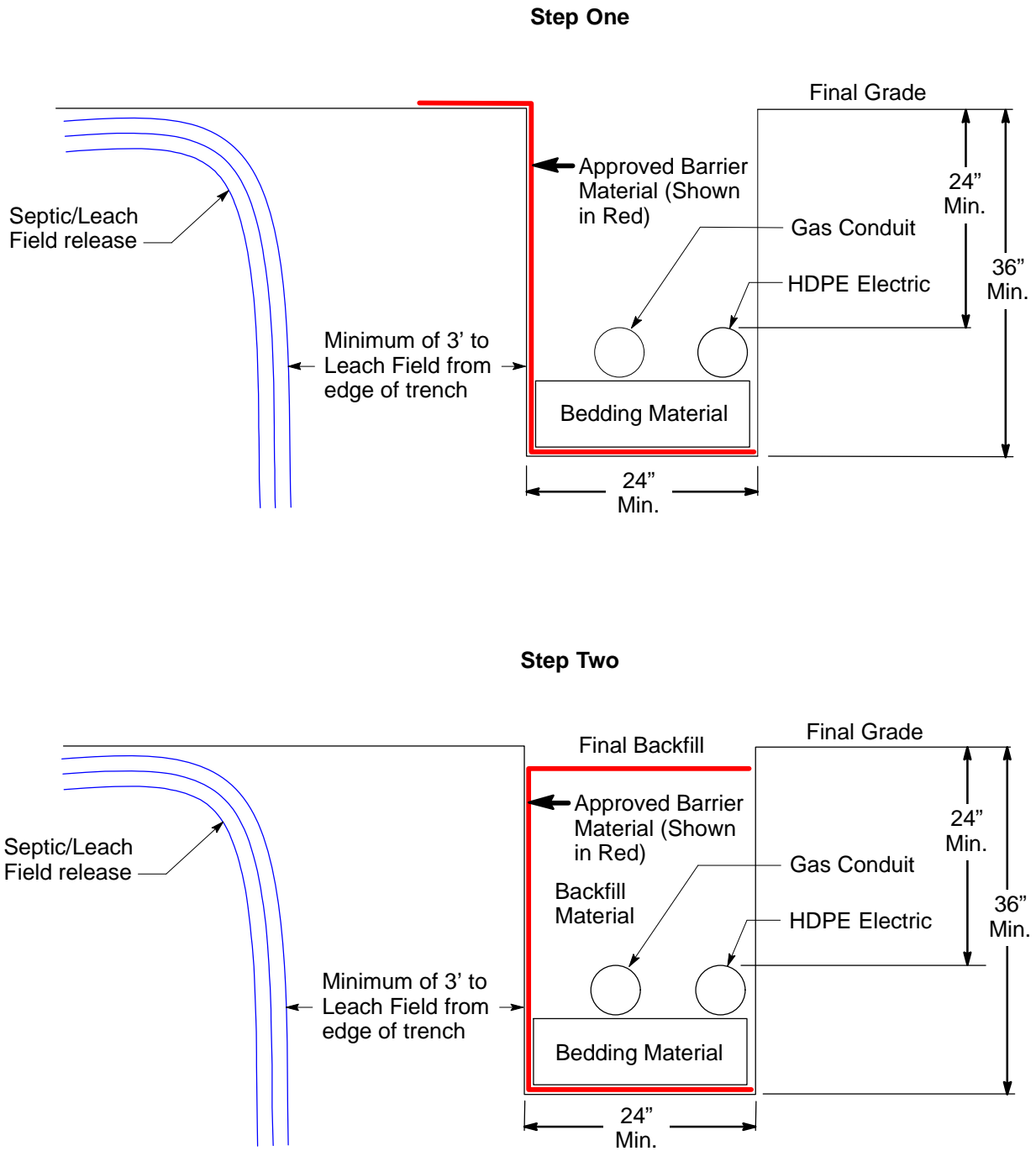
A horizontal distance of 10 feet away from the septic tanks and or leach systems must be maintained. Crossing over or underneath septic tank/leach lines is not allowed (see note 5e for the only exception). Installation of PG&E underground electric facilities across a new leach field is not allowed.

When all alternatives have been considered, and it is not feasible to achieve 10 feet of horizontal separation from the septic tank/leach lines, install PG&E underground facilities maintaining as much separation as possible. The minimum horizontal separation must not be less than 3 feet. Follow the steps listed in the notes below.

#### Notes:

1. Leach fields are regulated by Counties. Therefore, Counties may have different restrictions. The more stringent requirements must be followed. Without a written authorization from the Counties where the leach field is located, there will be no variances consideration for the installation of PG&E underground facilities within 10' from the septic tank/ leach system.
2. Provide valid evidence that it is not feasible to physically install PG&E electric underground facilities 10' away from septic tank and leach field. Cost alone is not a valid reason.
3. Provide detail information of the location of the septic tank and leach field indicating what part of the leach field is solid pipe and where does the perforated pipe start. Most of the release will likely happen soon after the transition from the solid to perforated pipe.
4. Provide the direction of the field grading in relation to the service trench.
5. Mitigate the hazards created by not installing underground facilities 10' away from the septic tank/leach field by meeting the following requirements:
  - A. Use a continuous run of HDPE conduit to avoid any effluent infiltration. Building a seal conduit system is the best way to mitigate migration of the contaminants.
  - B. Seal both ends of HDPE conduits entering and leaving the leach field.
  - C. Install electric enclosure 10' away from the septic or leach lines.
  - D. Install the approved laminated film (**M602637**) as the suitable barrier between the leach field and the service trench when the trench is outside of the leach field, but unable to meet the 10' separation requirement. Figure 3 on Page 11 illustrates the proper installation of the laminated film barrier material. The instructions listed below explain the steps illustrated in Figure 3.
    - (1) Step One: Install the laminated film barrier material (shown in red) into the empty trench so that it covers the trench floor; it will rise up the wall of the trench and be laid on the ground on the leach field side of the trench. Laying the barrier material over the top side of the trench will allow for the barrier material to be held in place while backfilling. The barrier material will later overlap the top of the trench as described on step two. Install the bedding material to pin barrier material down and install conduits as far from the septic tank/leach field/leach line as possible.
    - (2) Step Two: Begin backfilling and soil compaction to a level that allows for the barrier material to be laid over the backfill covering the top of the trench near final grade. Note that the barrier is placed before final grade is achieved. Finally, complete backfill and soil compaction to final grade.
  - E. Avoid crossing an existing leach field, mobile home park projects are the only exception to this rule. All other possible design alternatives must be considered before designing PG&E electric underground facilities across an existing leach field. The leach field is contaminated, therefore, no need to install a barrier as it will have no effect.

# Minimum Requirements for the Design and Installation of Electric Conduit, Insulated Cable, and Facilities



**Figure 3**  
Installation of Laminated Film Barrier (M602637) for Leach Field Application

## Minimum Requirements for the Design and Installation of Electric Conduit, Insulated Cable, and Facilities

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### Design Requirements for Less Frequently Encountered Field Conditions (continued)

#### Steam Lines

Steam lines present the potential problem of leaking even when they are insulated. Steam leaks migrate through the ground and into electric substructures resulting in damage of our electric conduits and cables. To mitigate the high temperature effects of the steam, the installation of a thermal insulation is required when our electric facilities cannot meet the following requirements,

–PG&E electric facilities must maintain a distance of 10 feet away from the steam line when paralleling, and a distance of 3 feet away when crossing over or underneath steam lines.

–Steel conduits are not allowed to be used within a radius of 10 feet from steam lines.

When all alternatives have been considered, and it is not feasible to achieve the required separation between PG&E electric facilities from the steam lines, the installation of a thermal insulation barrier is required. Install PG&E underground facilities maintaining as much separation as possible. Even with the installation of the thermal insulation barrier, the minimum horizontal separation must not be less than 3 feet, and the minimum vertical separation must not be less than 12 inches.

PG&E approves two installation methods for achieving a thermal insulation barrier between PG&E electric facilities and steam lines.

#### Method 1: Use of Fluidized Thermal Backfill (FTB) or Thermal Select Backfill

After PG&E has inspected and approved the duct bank or underground structure, the trench must be backfilled with native backfill, FTB, or thermal select backfill. Permit agencies may require specific backfill materials for areas within their jurisdiction. Approval of the backfill material is required before its use in the trench. The proposed material must have a thermal resistivity of not more than 60 C–cm/watt at critical moisture content (3% for FTB) and 90 C–cm/watt at 0% moisture content.

FTB is an engineered material that has very low thermal resistivity . FTB is a low-cement concrete with a fluidizing agent to fill unwanted voids. Fluidizing fly ash must be used along with the standard concrete aggregates of pea gravel and sand. The low strength mix must have a maximum nominal compressive strength of 70 – 300 psi. Higher compressive strength is unacceptable because of the difficulty of trenching above the duct bank or conduit.

Thermal select backfill must be placed to enhance heat dissipation. This backfill consists of limestone screenings, cement and water, mixed into a slurry to facilitate placement. The contractor must provide the mix proportions for thermal select backfill to PG&E inspection for review, and must obtain approval for thermal resistivity of the backfill from Geotherm, Inc.

Milpitas Materials Company is a PG&E-approved supplier of select backfill. It is located in Milpitas, CA.

The following is a representative mix design:

Limestone screenings: 1 cubic yard (approximately 3,000 lbs.).

Cement: 3/4 sacks (approximately 70 lbs.) per cubic yard of limestone

Water: 55 –60 gallons (approximately 544 lbs.) per cubic yard of limestone (depending on the moisture content of the limestone)

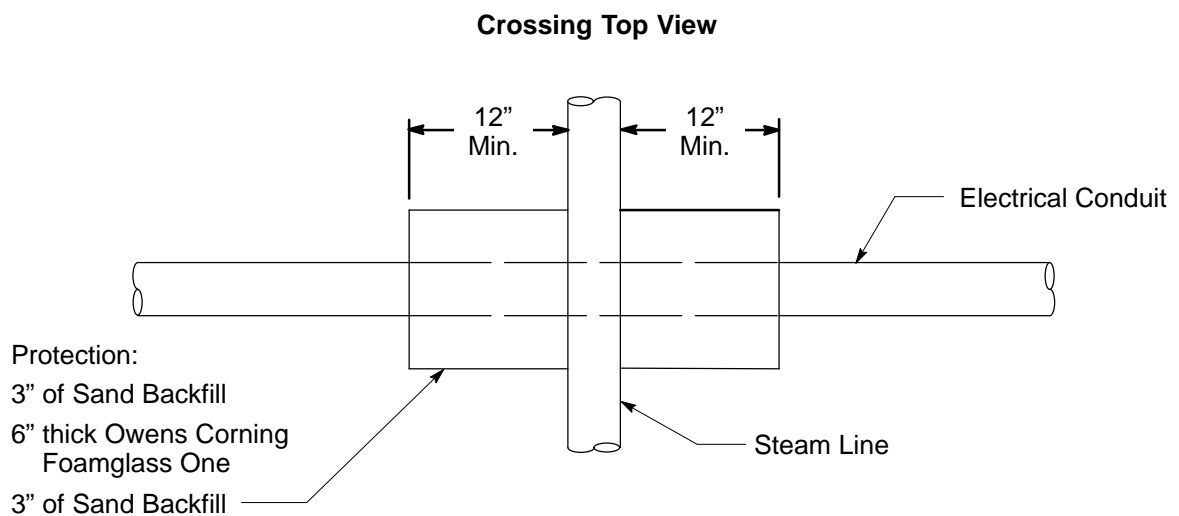
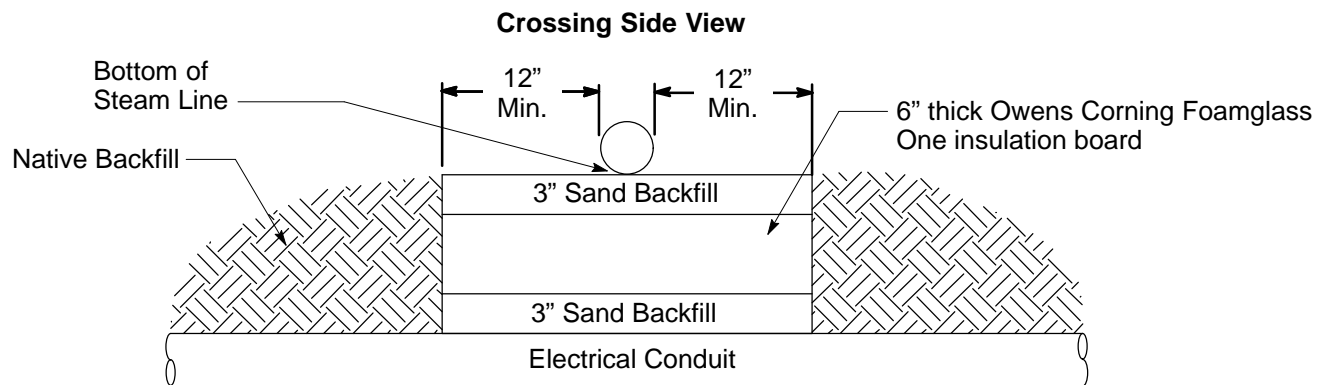
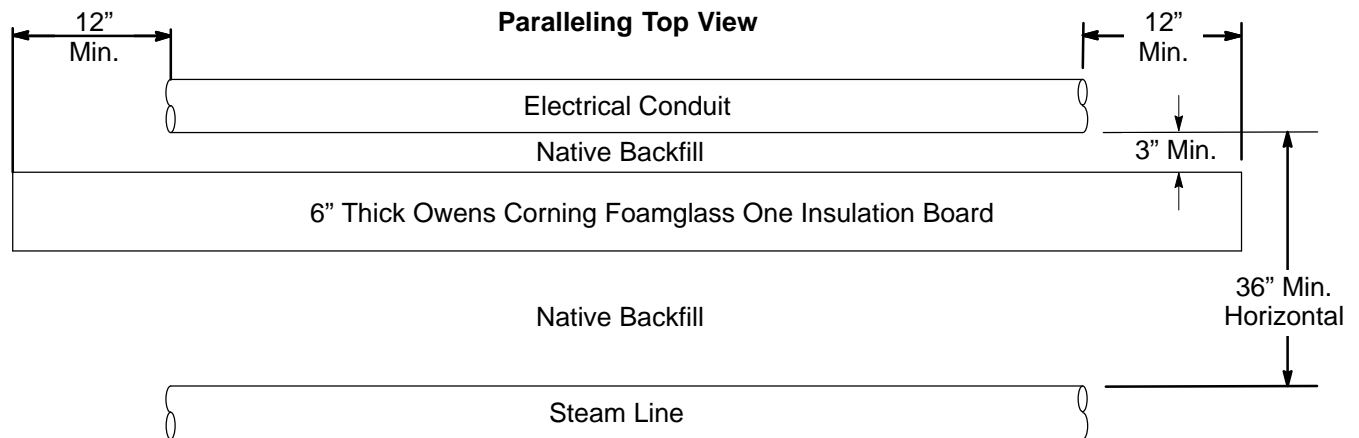
#### Method 2: Use of FOAMGLAS® ONE™ Insulation Barrier.

FOAMGLAS® ONE™ insulation is a lightweight, rigid material composed of millions of completely sealed glass cells. It is manufactured by Owens Corning in a block form and then fabricated into a wide range of shapes and sizes. This approved material is not coded. PG&E employees need to order this material as non–coded material using Ariba. The approved FOAMGLAS® ONE™ insulation may be of 3” minimum thickness of the FOAMGLAS® ONE™ , but 6” is preferable.

Configure each of the FOAMGLAS® ONE™ in a running bond brick pattern, so there is no gap between each block for the entire length electric conduits are installed less than the required separation from the steam line.

Install the approved Owens Corning FOAMGLAS® ONE™ insulation material as shown in Figure 4 on Page 13.

**Minimum Requirements for the Design and Installation of Electric Conduit, Insulated Cable, and Facilities**

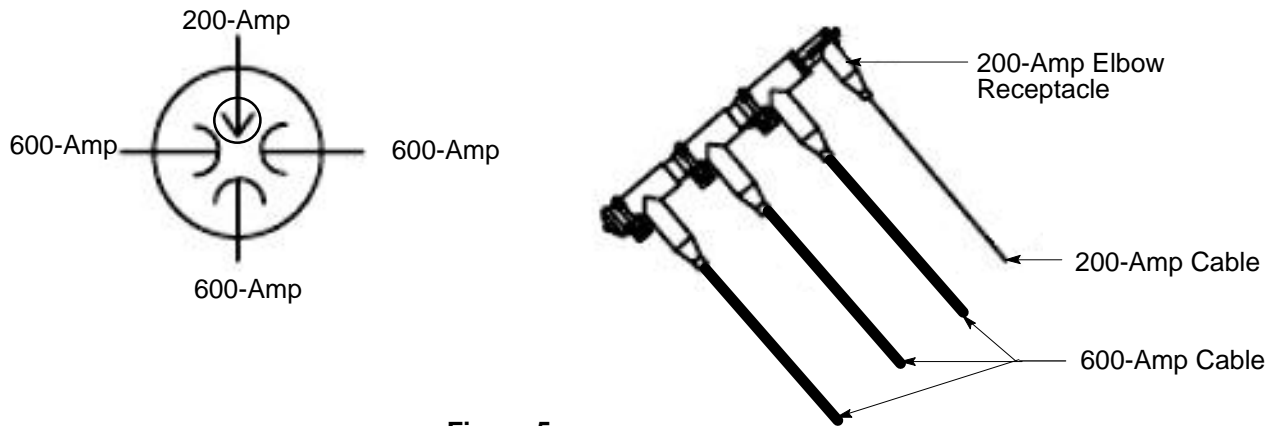


**Figure 4  
Steam Line**

## Minimum Requirements for the Design and Installation of Electric Conduit, Insulated Cable, and Facilities

### Material and Equipment Design Requirements and Restrictions

1. Two different 600-Amp or 200-Amp primary circuits of the same or different voltage are permitted in the same enclosure if each circuit is racked on opposite walls.
2. No more than one set of 600-Amp separable connectors is allowed in any one enclosure. One set means three 600-amp separable assembly. Figure 5 below shows one 600-Amp separable assembly.
3. No more than three 600-Amp elbows are allowed in any one 600-Amp separable assembly.
4. No more than one set of 200-Amp taps (piggy-backed) off of a set of 600-Amp separable assembly is allowed
  - A. A 200-Amp tap from a 600-Amp separable assembly must be made with a load-break reducing tap plug (RTP) and a 200-Amp load-break elbow receptacle, as shown in [Document 051071](#), "600-Amp Separable Insulated Connectors". See Figure 5.
  - B. Only one such connection is allowed between two 600-Amp main line switches.

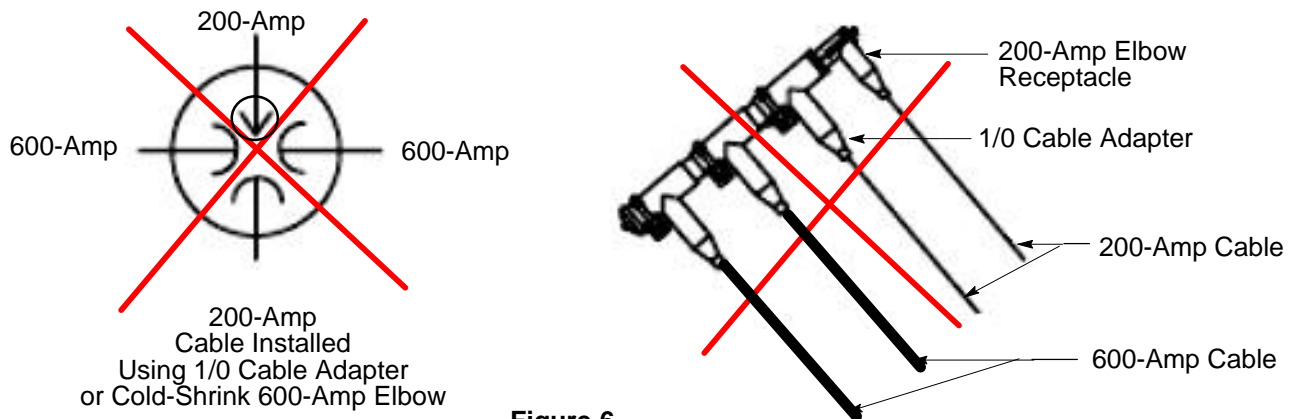


**Figure 5**  
**Allowed 600-Amp Separable Splice Assembly**

5. 600-Amp three-phase switching devices are required at all critical main-line intersections. Consult with the responsible electric distribution planning engineer for direction during the project's design phase.
6. Only one set of 600-Amp separable assembly is allowed between two 600-Amp main-line switches. However, for all main-line junctions, three phase switching devices are required.
7. No more than four-ways of cable on a 600-Amp subsurface switch is allowed.
  - A. A way is a conduit run from point A to point B. It can be one, two or up to three cables.
  - B. It is not allowed to tap off (piggy-back) 600-Amp elbows on top of each other 600-Amp elbows on the same switch bushing at any time. See Note 9 under Cable and Equipment in [Document 050859](#)
  - C. It is not allowed to tap off (piggy-back) 200-Amp taps off subsurface switches.
  - D. Subsurface switch bushings that are rated at 600-Amps may be converted to 200-Amps by using a bushing extension and a 600/200-Amp tap/plug.
  - E. 200-Amp taps that utilize 600-Amp bushing extensions are not considered piggy-back.
  - F. SCADA installation on 600-Amp subsurface switch is exempt from requirement 7. However, whenever possible install SCADA on 600-Amp subsurface switches with no 200-Amp tap (piggy-backed).
8. No more than four-ways of cable on a 200-Amp pad-mounted or subsurface junction is allowed.
9. It is not permissible to use 1/0 cable adapters with 600-Amp separable connectors to make a 200-Amp tap. See Figure 6 on Page 15. Material code for the 1/0 cable adapters is still active to be used for replacement of existing facilities only. See [Document 051071](#).
  - A. For SCADA jobs that require the installation of a 600-Amp switch on a 200-Amp application using 1/0 AI XLPE 15kV/22kV rated cable (previously installed standard cable) or currently approved 1/0 AI EPR 25kV rated cable; it is allowed to use cold-shrink 600-Amp elbow (**M301641**).

## Minimum Requirements for the Design and Installation of Electric Conduit, Insulated Cable, and Facilities

### Material and Equipment Design Requirements and Restrictions (continued)

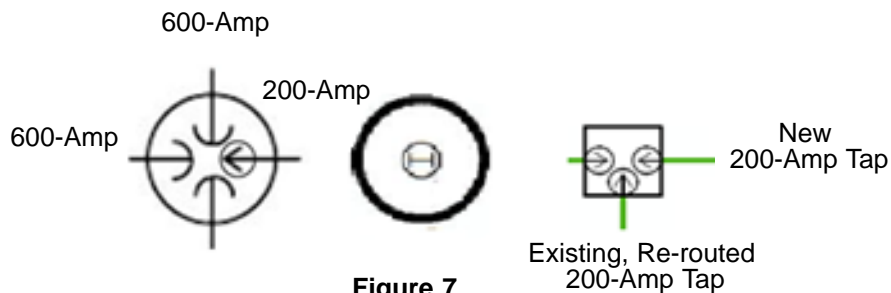


**Figure 6**  
**Not Permissible 600-Amp Separable Splice Assembly**

10. When necessary, use one of the following three options to establish additional 200-Amp tap from existing mainline cables that already has 600-Amp separable assembly with one existing 200-Amp tap.

**Option 1.**

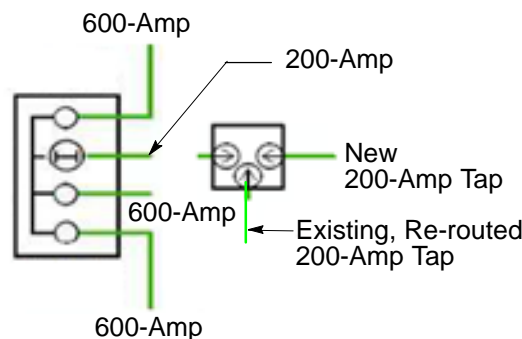
Leave existing 600-Amp separable assembly. Intercept and re-route existing 200-Amp tap to a new 200-Amp interrupter (install the 200-Amp interrupter as close as possible to the existing 600-Amp separable assembly). Extend the 200-Amp tap from the load side of 200-Amp interrupter and install a 200-Amp subsurface or pad-mounted junction. This installation is shown in Figure 7 below.



**Figure 7**  
**Upgrade Existing 200-Amp Tap**

**Option 2.**

Replace existing 600-Amp separable assembly with a pad-mounted switch, such as PMI-11, install a 200-Amp subsurface or pad-mounted junction with existing and new two 200-Amp taps. This installation is shown in Figure 8 below.



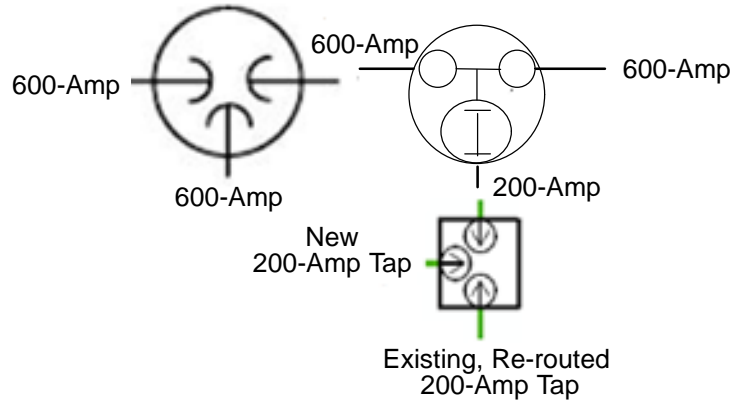
**Figure 8**  
**Replace Existing 600-Amp Separate Assembly with Pad-Mounted Interrupter**

## Minimum Requirements for the Design and Installation of Electric Conduit, Insulated Cable, and Facilities

### Material and Equipment Design Requirements and Restrictions (continued)

Option 3.

Install a Switch-Interrupter-Switch, 3-Way, 3-Way-Switched; extend the interrupter way and install a 200-Amp subsurface or pad-mounted junction with two 200-Amp taps. Re-route the existing 200-Amp piggy-backed of the existing 600-Amp separable assembly to one of the ways of the 200-Amp junction.



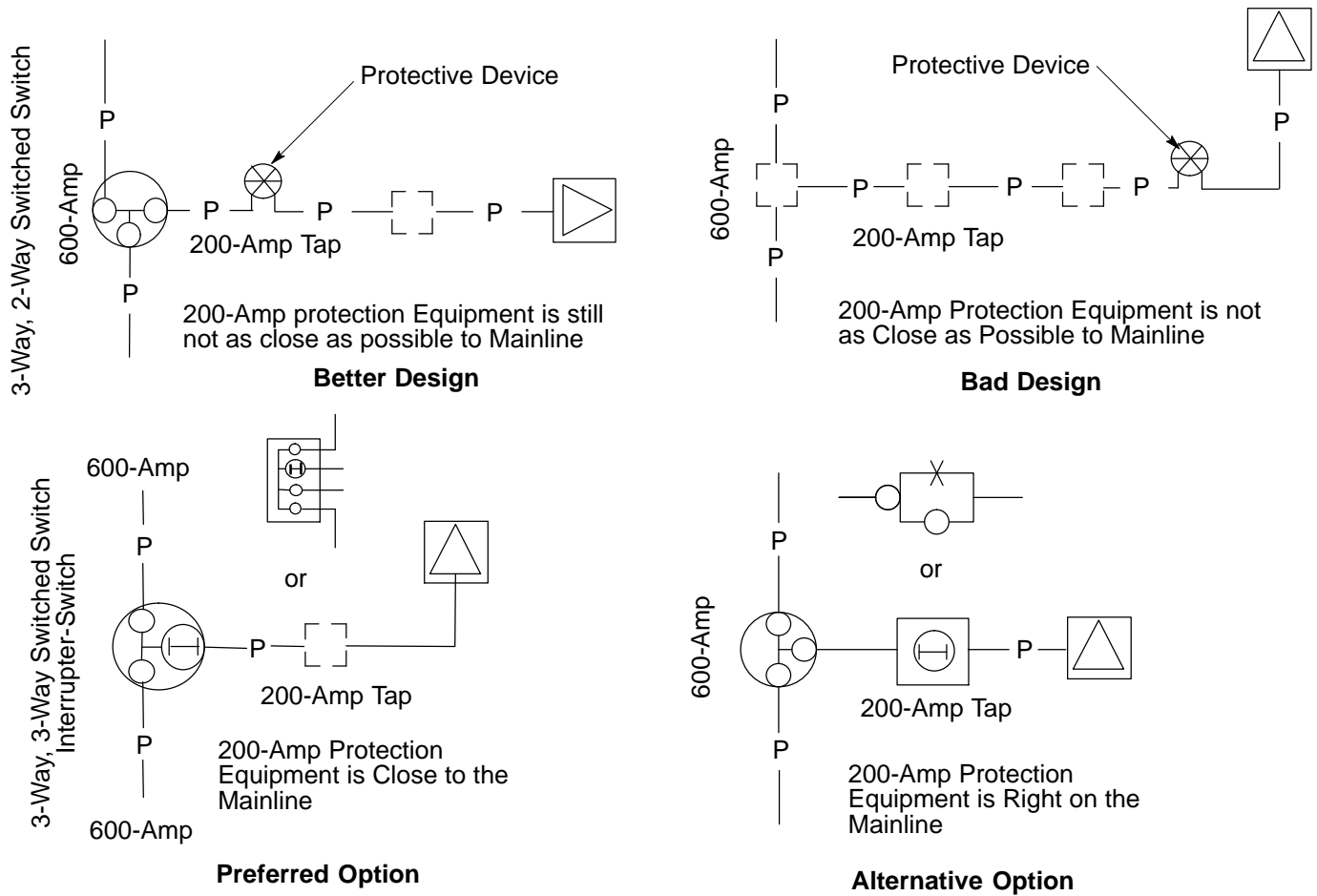
**Figure 9**  
**Re-route Existing 200-Amp Tap to One of the Position of the 200-Amp Junction**

11. Locate the protection devices as close as possible to the mainline tap when designing 200-Amp taps off the 600-Amp mainline. See examples in Figure 10 on Page 17.
12. **Do not install** the following facilities in the same enclosure (#5, #6 or #7 size).
  - A. 600-Amp separable assembly with or without 200-Amp piggy-backed tap and 200-Amp subsurface junction or any other operable equipment.
  - B. 600-Amp separable assembly with or without 200-Amp piggy-backed tap and 600-Amp straight splices.
  - C. 600-Amp separable assembly with or without 200-Amp piggy-backed tap and 200-Amp straight splices.
  - D. 600-Amp straight splices and 200-Amp straight splices installed on the same wall.
  - E. 600-Amp or 200-Amp operable equipment and 600-Amp or 200-Amp straight splices.
13. The requirements listed in Note 12 apply to new construction and reconstruction. However, if field conditions such as space constraints make it unfeasible to comply with these requirements, it is allowed for existing facilities to take exceptions to these requirements.



# Minimum Requirements for the Design and Installation of Electric Conduit, Insulated Cable, and Facilities

## Material and Equipment Design Requirements and Restrictions (continued)



**Figure 10**  
**Protection Design Device Location**

## Minimum Requirements for the Design and Installation of Electric Conduit, Insulated Cable, and Facilities

### Formulas and Parameters

#### Notes

1. The formulas and parameters used in this document are widely used in the utility industry. The parameters that must be checked are: **Conduit Fill, Cable Configuration, Minimum Bending Radius, Cable Jamming Potential, Cable Clearance, Maximum Pulling Tension, and Sidewall Bearing Pressure Limits.**

2. Cable Jamming

Jamming is a condition that may occur if the sum of the cable diameters is about equal to the inside diameter of the conduit. It will typically occur at bends when one cable is forced between the other two cables and wedges them against the inner wall of the conduit. Jam ratios between 2.8 to 3.1 should be avoided to prevent the possibility of the cables jamming at a sweep. Use the formula given below to calculate jam ratio.

3. Jam Ratio Formula

$$J = D/d$$

Where:

J = Jam ratio

D = Conduit inside diameter (inches)

d = Cable nominal diameter (inches), one cable



Check the probability of jamming using the formula:  $J = 1.05 D/d$

#### **$1.05*J = (p)$ probability of jamming**

- If the value J is less than 2.5, jamming is unlikely to occur. Cables are in triangular configuration.
- If the value J is between 2.6 and 2.7, jamming is very possible. Cables are more likely in triangular configuration.
- If the value J is between 2.8 and 3.1, jamming is very possible. Cables can be either in triangular or cradled configuration. The risk is higher if the sidewall bearing pressure in a bend exceeds 1000 pounds/foot.
- If the value J is greater than 3.1, jamming is unlikely to occur. Cables are in triangular configuration.

Check the probability of jamming using the formula:  $P = 1.05 D/d$

Probability of jamming =  $(P) = 1.05*J$

The 1.05 factor is to account for the oval shape of the bends in the section view.

4. Coefficient of Friction

A coefficient of friction value of 0.30 is recommended for lubricated PVC or PE conduits.

5. Minimum Bending Radius

The multipliers for determining the minimum cable bending radius for commonly used cables are listed in Table 3 on Page 6.

6. Percent Conduit Fill





Conduit fill is the percentage of area inside the conduit taken up by the cable(s).

- A. The recommended maximum percentage of conduit fill is shown in Table 8 on Page 14.
- B. The total combined percent conduit fill ratio of PG&E electric supply cable and fiber optic cable (FOC) must not exceed 75%.
- C. For new construction, the conduit is usually sized for the next-larger size of cable.

## Minimum Requirements for the Design and Installation of Electric Conduit, Insulated Cable, and Facilities

### Formulas and Parameters (continue)

**Table 8 Recommended Maximum Conduit Fill**

Number of Cables	Example	Percent of Total Internal Area of Conduit to Be Filled by Cable
1		60
2		40
3		55
4		55

**Table 9 Percent Fill for Common Cable/Conduit (Rigid PVC Schedule 40) Combinations**

	Type of Cable	2"	3"	4"	5"	6"
600 V	1/0 Triplex	17%	8%	–	–	–
	4/0 Triplex	28%	13%	–	–	–
	350 kcmil Triplex	–	20%	12%	–	–
	750 kcmil Triplex	–	36% <sup>1</sup>	21%	14%	10%
	1,000 kcmil Triplex	–	–	28%	18%	–
	1/0 Quadruplex	24%	11%	–	–	–
	4/0 Quadruplex	–	18%	10%	–	–
	350 kcmil Quadruplex	–	28%	16%	11%	–
	750 kcmil Quadruplex	–	–	30%	19%	14%
	1,000 kcmil Quadruplex	–	–	39%	25%	17%
15 kV	3-#2 AWG, Cu-EPR	–	25%	14%	–	–
	3-350 kcmil, Cu-EPR	–	–	28%	18%	13%
	3-500 kcmil, Cu-EPR	–	–	34%	22%	15%
	3-750 kcmil, Cu-EPR	–	–	42%	29%	20%
	3-1,100 kcmil, Cu-EPR	–	–	–	37%	26%
	3-500 kcmil, Cu-EPR <sup>2</sup>	–	–	38%	24%	17%
	3-750 kcmil, Cu-EPR <sup>2</sup>	–	–	48%	31%	21%
	3-1,100 kcmil, Cu-EPR <sup>2</sup>	–	–	–	40%	28%
25 kV	1-1/0, Al-EPR	37%	17%	–	–	–
	3-1/0, Al-EPR	–	–	29%	–	–
	3,600 kcmil, Al-EPR	–	–	–	37%	26%
	3-1,100 kcmil, Al-EPR	–	–	–	47%	36%
	3-1,100 kcmil, Cu-EPR	–	–	–	48%	38%
34.5 kV	3-1/0, Al-EPR	–	–	14%	–	–
	3,600 kcmil, Al-EPR	–	–	–	36%	25%
	3-1,100 kcmil, Al-EPR	–	–	–	–	43%

<sup>1</sup> Although percent fill is less than 55%, it is difficult to pull 750 kcmil triplex in 3" conduit. It is acceptable to pull 750 kcmil triplex in existing 3" conduit. New construction should use 4" conduit.

<sup>2</sup> This cable has low smoke zero halogen (LSZH) jacket for indoors substations application only.

**Minimum Requirements for the Design and Installation of Electric Conduit, Insulated Cable, and Facilities**

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**Formulas and Parameters (continue)**

7. Sidewall Bearing Pressure (SBP)

Sidewall pressure is exerted on a cable as it is pulled around a bend. **The following limits are recommended:**

- A. SBP = 500 pounds/foot for one solid dielectric cable (XLPE or EPR insulation).
- B. SBP = 1,000 pounds/foot for two or more solid dielectric cables (XLPE or EPR insulation).
- C. SBP = 300 pounds/foot for PILC (lead) cables.

8. Weight Correction Factor

This is an important factor to calculate because when you pull two or more cables in a conduit, the sum of the forces developed between the cables and the conduit is always greater than the sum of the individual cable weights. When you have three single cables of equal diameter and weight, you can expect a higher weight factor for the cradled position than the triangular position. Assume that the cables will sit in the cradled position (unless you are pulling triplexed cables from a single reel), because this will yield a higher and therefore more conservative pulling tension calculation.

For one or two cables

$$w_{\text{single}} = 1$$

For three cables in a cradled configuration

Where  $3 > J > 2.5$

$$w_{\text{cradled}} = 1 + (4/3) * (d/D - d)^2$$

For three cables in a triangular configuration

Where  $J < 2.5$

$$w_{\text{triangular}} = 1 \div \sqrt{1 - (d/D - d)^2}$$

For four cables (quadruplex) in a diamond configuration

Where  $J < 3.0$

$$w_{\text{diamond}} = 1 + 2 [d \div (D - d)^2]$$

9. Maximum Allowable Pulling Tension

The maximum allowable pulling tension is the lesser of the allowable tension on the pulling device and the maximum pulling tension that can be applied to the conductors.

Definition of symbols:

- w = Weight Correction Factor
- f = Coefficient of Friction
- W = Cable Weight, pounds per foot
- L = Length of conduit run, in feet

10. Equations to calculate pulling tension formulas

A. Tension, Horizontal Straight Section

$$T_{\text{out}} = wfWL + T_{\text{in}}$$

B. Tension, Natural or Factory Bend Section (except for "D" below)

$$T_{\text{out}} = T_{\text{in}} \cosh (wf\theta) + \sinh (wf\theta) \times \sqrt{T_{\text{in}}^2 + (WR)^2}$$

Where:

$$\sinh (wf\theta) = (e^{wf\theta} - e^{-wf\theta}) / 2$$
$$\cosh (wf\theta) = (e^{wf\theta} + e^{-wf\theta}) / 2$$

And

- $\theta$  = Angle of bend, in radians
- R = Sweep radius
- e = 2.718

## Minimum Requirements for the Design and Installation of Electric Conduit, Insulated Cable, and Facilities

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### Formulas and Parameters (continue)

C. Tension, inclined and Vertical Straight Section

(1) Pulling up a Straight Section

$$T_{out} = WL (\sin (\theta) + wf \cos (\theta) ) + T_{in}$$

Where:  $\theta$  = Angle of incline

(2) Pulling down a Straight Section (utilize equation for horizontal straight section)

$$T_{out} = wfWL + T_{in}$$

D. Tension, Convex Bend at Top of Incline, Upward Pull

$$T_{out} = T_{in} e^{wf\theta} + (WR / (1 + (wf)^2)) [2wfe^{wf\theta} \sin \theta + (1 - w^2 f^2) (1 - e^{wf\theta} \cos \theta)]$$

Where:  $\theta$  = Angle of bend (same as angle of slope)

$R$  = Sweep radius

$e$  = 2.718

11. When cable is pulled through a conduit bend or around a sheave, sidewall bearing pressure (SBP) develops between the cable wall and the bend or sheave. This pressure has a dramatic effect on the sizing of the conduit system, because it relates directly to the radii of bends, pulling tension and cable's weight.

For single cable:

$$SBP = T \div R$$

For 3 cables in cradled configuration:

$$SBP = [(3w_{cradled} - 2) T] \div 3R$$

For 3 cables in triangular configuration:

$$SBP = (w_{triangular} T) \div 2R$$

For 4 cables in diamond configuration:

$$SBP = (w_{diamond} - 1) (T \div R)$$

12. It is necessary to have adequate clearance between the uppermost cable and the top of the conduit to ensure a safe and easy pull. For straight pulls, a clearance of 1/4" is safe. For pulls that include bends, a clearance of 1/2" to 1" is needed. Use the outside diameters of the circumscribing circle listed on [Document 039955](#) to determine cable clearances.

## Minimum Requirements for the Design and Installation of Electric Conduit, Insulated Cable, and Facilities

### Determining Pulling Tension for Sections Containing Sweeps

#### Example

Given:

- Conduit layout as shown in Figure 11.
- Conduit size 6 inch, 6.11".
- Size of cables: three 1/C 1,100 kcmil Al. EPR-CONC-Encap PE, 25 kV.
- Weight of cable = 3 x 2.36 lbs. = 7.08 pounds/foot.
- Coefficient of Friction = 0.30

Find:

- If cable can be pulled without damage.
- Best direction of pull.
- What type of pulling attachment can be used.

1. The first step is to calculate conduit fill in percent:

$d = 2.05''$  from [Document 039955](#).

$D = 6.11''$  From Table 10-3 of the [Electric Design Manual](#).

$r = d/2 = 1.025''$

Cable Area =  $3\pi (d/2)^2$  or Cable Area =  $3\pi r^2$

Cable Area = 9.902 in<sup>2</sup>

Conduit Area =  $\pi (D/2)^2$

Conduit Area = 29.321 in<sup>2</sup>

Conduit Fill = (Cable Area/Conduit Area)\*100%

Conduit Fill = 33.771%

This is less than the 55% percent conduit fill allowed.

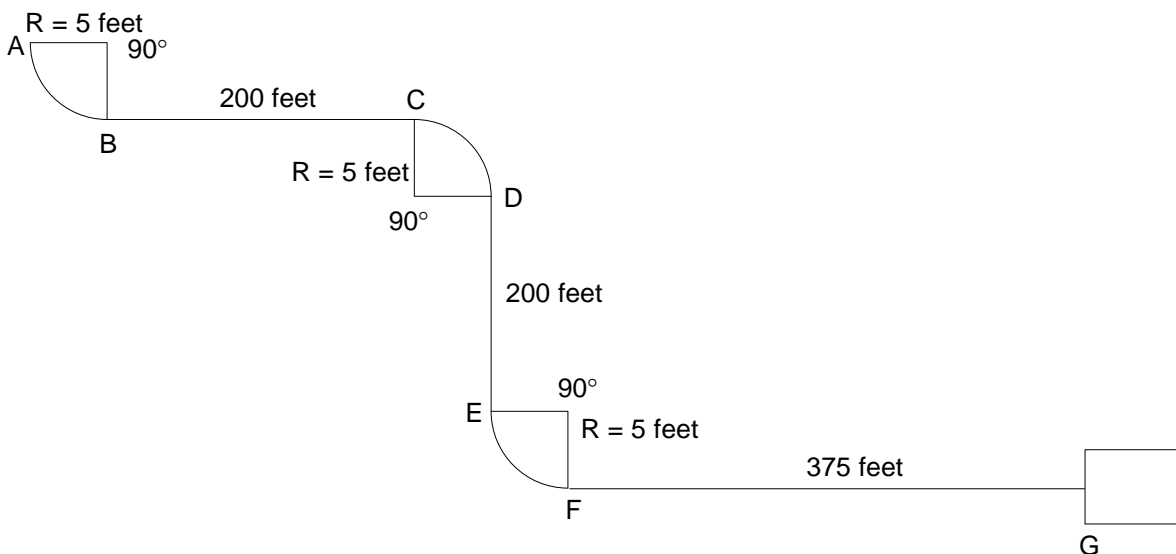


Figure 11  
Typical Duct Layout

## Minimum Requirements for the Design and Installation of Electric Conduit, Insulated Cable, and Facilities

### ***Determining Pulling Tension for Sections Containing Sweeps (continued)***

2. The next step is to calculate the jam ratio to determine the cable configuration and the probabilities of cable jamming.

$$J = D/d = 2.98$$

Since this ratio is larger than 2.5 but less than 3, it is assumed that the cables are going to be in the cradled configuration. Cable clearance does not need to be checked.

Check the probability of jamming by using the following formula:

$$P = 1.05 D/d$$

$$P = 1.05 * 2.98 = 3.13$$

In this case the probability of jamming is greater than 3.1; therefore, jamming is not expected to happen.

3. The next step is to calculate the weight correction factor for this cable:

$$w_{\text{cradled}} = 1 + (4/3) * (d/D - d)^2 = 1.339$$

4. We can now proceed to calculate the pulling tensions:

$$T_{\text{in}} = 0 \quad \text{Tension at A!}$$

Tension at B is calculated using the formula for horizontal bend section:

$$W = 7.08 \text{ lbs/ft} \quad R_{\text{AB}} = 5 \text{ ft} \quad f = 0.3 \quad \theta = \pi/2$$

$$T_{\text{AB}} = T_{\text{in}} \cosh(w_{\text{cradled}} f \theta) + \sinh(w_{\text{cradled}} f \theta) \sqrt{T_{\text{in}}^2 + (WR_{\text{AB}})^2}$$

$$T_{\text{AB}} = 0 + (0.674) \sqrt{0 + (35.4)^2}$$

$$T_{\text{AB}} = 23.85 \text{ lbs}$$

Tension at C is calculated using the horizontal straight section formula:

$$L_{\text{AB}} = 200 \text{ ft} \quad T_{\text{BC}} = w_{\text{cradled}} f W L_{\text{AB}} + T_{\text{AB}} \quad T_{\text{BC}} = 568.81 + 23.85 = 593 \text{ lbs}$$

Tension at D is calculated using the formula for horizontal bend section:

$$R_{\text{CD}} = 5 \text{ ft}$$

$$T_{\text{CD}} = T_{\text{BC}} \cosh(w_{\text{cradled}} f \theta) + \sinh(w_{\text{cradled}} f \theta) \sqrt{T_{\text{BC}}^2 + (WR_{\text{CD}})^2}$$

$$T_{\text{CD}} = 715.02 + 400.22 = 1,115 \text{ lbs}$$

Tension at E is calculated using the pulling down straight section formula.

$$L_{\text{DE}} = 200 \text{ ft} \quad T_{\text{DE}} = w f W L_{\text{DE}} + T_{\text{CD}} \quad T_{\text{DE}} = 568.81 + 1,115 = 1,684 \text{ lbs.}$$

$$T_{\text{EF}} = 3,165 \text{ lbs}$$

$$T_{\text{FG}} = 4,232 \text{ lbs}$$

Since this tension exceeds the maximum allowable tension of 2,000 lbs. on pulling grips (see Table 10 on Page 25), pulling eyes are needed for this pull (10,000 lbs. limit). Also, the maximum tension on the conductor can be calculated as follows:

$$A_c = \text{Area in cmil} \quad \text{cmil} = \text{mil}^2 \quad N_c = \text{Number of Conductors}$$

$$S_c = 0.008 \text{ lbs/cmil Maximum Stress on Al or Cu conductors!}$$

$$\text{The area of 1,100 kcmil is: } A_c = 1,100,000 \text{ cmil and } N_c = 3$$

$$T_{\text{conductor}} = N_c S_c A_c = 26,400 \text{ lbs}$$

## Minimum Requirements for the Design and Installation of Electric Conduit, Insulated Cable, and Facilities

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### ***Determining Pulling Tension for Sections Containing Sweeps (continued)***

The maximum allowable tension on these cables is the lesser value of the calculated tension on the conductor(s) and the maximum tension on the pulling device. In this case, the 10,000 lbs limit on the pulling eye is the maximum allowable tension. Refer to Table 10 on Page 25 through Table 12 on Page 26 for the maximum allowable tension on PG&E's cables.

Reverse Direction Calculations

Tension at F is calculated as follows:

$$L_{FG} = 375 \text{ ft.} \quad T_{in} = 0$$

$$T_{GF} = w_{cradled} f W L_{FG} + 0 = 1,067 \text{ lbs}$$

$$T_{FE} = 2,006 \text{ lbs}$$

$$T_{ED} = 3,422 \text{ lbs}$$

$$T_{DC} = 6,432 \text{ lbs}$$

$$T_{CB} = 7,001 \text{ lbs}$$

$$T_{BA} = 13,158 \text{ lbs}$$

Since the pulling tension from G to A is greater (13,158 lbs.) than the pulling tension from A to G (4,232 lbs.), and pulling tension from G to A exceeds the 10,000 lbs maximum allowable tension on the pulling eye, cable must be pulled in the direction from A to G.

5. Finally, the sidewall bearing pressure limits need to be checked at the bends.

The pulling tensions at B and D are not very significant, but the tension at F may be a concern in terms of sidewall bearing pressure.

$$SBP = [(3w_{cradled} - 2)T_{EF}]/3R_{EF} = [(3*1.339 - 2)*3,165]/15$$
$$SBP = 426 \text{ lbs/ft}$$

As we can see, the limit of 1,000 lbs/ft for two or more solid dielectric cables is not exceeded at the bend between points E and F.

However, if any of the limits are exceeded, consider one or more of the following options:

- Increase bend radii.
- Decrease conduit fill.
- Reduce the number of bends.
- Try reverse pull.
- Pull in stages.
- Decrease length of pull.



## Minimum Requirements for the Design and Installation of Electric Conduit, Insulated Cable, and Facilities

### Maximum Allowable Pulling Tensions for Various Cable Rating, Sizes, and Configurations

**Table 10 Maximum Allowable Pulling Tensions for 1/C Aluminum or Copper XLP or EPR Insulated Cables**

Cable Rating	Cable Size AWG or kcmil	Maximum Allowable Pulling Tension (lbs.)					
		1/C per Duct		2/C per Duct		3/C per Duct	
		Grip	Pulling Eye	Grip	Pulling Eye	Grip	Pulling Eye
600 V Through 35 kV	#4	334	334	668	668	668	668
	#2	531	531	1,062	1,062	1,062	1,062
	1/0	844	844	1,688	1,688	1,688	1,688
	2/0	1,000	1,065	2,000	2,130	2,000	2,130
	4/0	1,000	1,693	2,000	3,386	2,000	3,386
	250	1,000	2,000	2,000	4,000	2,000	4,000
	350	1,000	2,800	2,000	5,600	2,000	5,600
	500/600	1,000	4,000	2,000	8,000	2,000	8,000
	700	1,000	5,600	2,000	10,000 <sup>3</sup>	2,000	10,000 <sup>3</sup>
	750	1,000	6,000	2,000	10,000 <sup>3</sup>	2,000	10,000 <sup>3</sup>
	1,000/1,100	1,000	8,000	2,000	10,000 <sup>3</sup>	2,000	10,000 <sup>3</sup>
1,500	1,000	10,000 <sup>3</sup>	–	–	–	–	

<sup>3</sup> Limited by cable pulling and reel handling equipment.

**Table 11 Maximum Allowable Pulling Tensions for 1/C Copper P&L and PL&N Cables**

Cable Rating	Cable Size AWG or kcmil	Maximum Allowable Pulling Tension (lbs.)					
		1/C per Duct		2/C per Duct		3/C per Duct	
		Grip	Pulling Eye	Grip	Pulling Eye	Grip	Pulling Eye
1 kV	1/0	–	–	–	–	475	1,265
	250	–	–	–	–	677	3,000
	500	458	3,000	–	–	916	6,000
	750	571	4,500	–	–	1,141	9,000
	1,000	674	6,000	–	–	1,349	12,000
	1,500	897	9,000	–	–	–	–
5 kV	#4	–	–	415	501	415	501
	#2	–	–	460	796	460	796
	2/0	–	–	597	1,600	597	1,600
	250	–	–	725	3,000	725	3,000
	500	512	3,000	–	–	1,025	6,000
	750	631	4,500	–	–	1,262	9,000
15 kV	#4	–	–	653	653	653	653
	#2	–	–	693	796	693	796
	2/0	–	–	733	1,600	733	1,600
	250	–	–	916	3,000	916	3,000
	500	622	3,000	–	–	1,244	6,000
	750	750	4,500	–	–	1,498	9,000
	1,000	700	6,000	–	–	1,400	10,000 <sup>1</sup>
	1,500	857	9,000	–	–	–	–
	2,000	1,008	10,000 <sup>1</sup>	–	–	–	–
25 kV	#2	–	–	–	–	800	1,060
	250	–	–	–	–	928	3,000
	500	–	–	–	–	1,181	10,000 <sup>1</sup>

<sup>1</sup> Limited by cable pulling and reel handling equipment.

**Minimum Requirements for the Design and Installation of Electric Conduit, Insulated Cable, and Facilities**

**Maximum Allowable Pulling Tensions for Various Cable Rating, Sizes, and Configurations (continued)**

**Table 12 Maximum Allowable Pulling Tensions for 3/C Copper PL&N Cables, 1/C per Duct Revised**

Cable Rating	Cable Size AWG or kcmil	Maximum Allowable Pulling Tension (lbs.)	
		Grip	Pulling Eye
5 kV	#2	464	1,194
	2/0	510	2,400
	250	657	4,500
	500	875	9,000
15 kV	#2	708	1,195
	2/0	840	2,400
	250	866	4,500
	500	1,150	9,000
	750	1,434	10,000 <sup>1</sup>

<sup>1</sup> Limited by cable-pulling and reel-handling equipment.

## Minimum Requirements for the Design and Installation of Electric Conduit, Insulated Cable, and Facilities

*The Information on This Page is “For Reference Only”*

**Table 13 Percent Fill for Common Cable/Conduit (DB 120) Combinations**

	Type of Cable	2"	3"	4"	5"	6"
600 V	1/0 Triplex	15%	7%	–	–	–
	4/0 Triplex	24%	11%	–	–	–
	350 kcmil Triplex	–	18%	11%	–	–
	750 kcmil Triplex	–	32% <sup>1</sup>	19%	13%	9%
	1,000 kcmil Triplex	–	–	25%	17%	–
	1/0 Quadruplex	20%	9%	–	–	–
	4/0 Quadruplex	–	15%	9%	–	–
	350 kcmil Quadruplex	–	24%	15%	10%	–
	750 kcmil Quadruplex	–	–	27%	18%	13%
	1,000 kcmil Quadruplex	–	–	35%	24%	16%
15 kV	3-#2 AWG, Cu-EPR	–	21%	13%	–	–
	3-350 kcmil, Cu-EPR	–	–	26%	17%	12%
	3-500 kcmil, Cu-EPR	–	–	31%	20%	14%
	3-750 kcmil, Cu-EPR	–	–	42%	28%	19%
	3-1,100 kcmil, Cu-EPR	–	–	–	38%	26%
25 kV	1-1/0, Al-EPR	32%	–	–	–	–
	3-1/0, Al-EPR	–	–	27%	–	–
	3-600 kcmil, Al-EPR	–	–	–	38%	26%
	3-1,100 kcmil, Al-EPR	–	–	–	47%	34%
	3-1,100 kcmil, Cu-EPR	–	–	–	48%	34%

<sup>1</sup> Although percent fill is less than 55%, it is difficult to pull 750 kcmil triplex in 3" conduit. It is acceptable to pull 750 kcmil triplex in existing 3" conduit. New construction should use 4" conduit.

### Revision Notes

Revision 15 has the following changes:

1. Modify Note 1 and Note 4 on Page 1.
2. Added new Note 6 on Page 1.
3. Added Trench requirements to this document on Page 3 and Page 4. Some of these trench requirements were previously listed in document 062288.
4. Added size 1100 cable to Note 14 on Page 7.
5. Re-arranged conduit and substructure installation section to top of Page 9.
6. Updated Note 5D under septic tank/leach field/leach line on Page 10.
7. Added new Figure 3 on Page 11.
8. Added requirements for steam lines on Page 12 and 13.
9. Modify Note 5 and added new Note 12 under material and equipment design and restriction on Page 14 and 16.
10. Revised Figure 10 on Page 17 to change 2W–2W switched switch with a 3W–3W switched switch.
11. Corrected weight cradled corrected factor formula on Page 20.