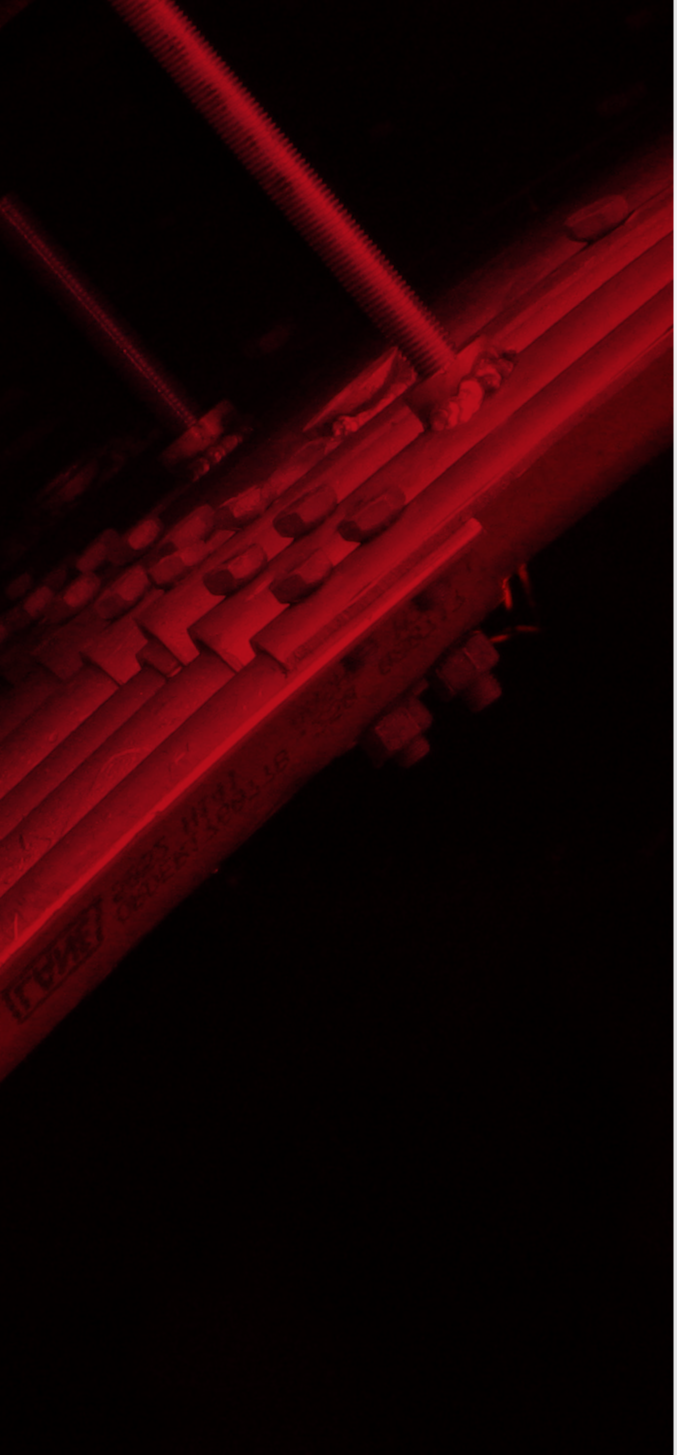
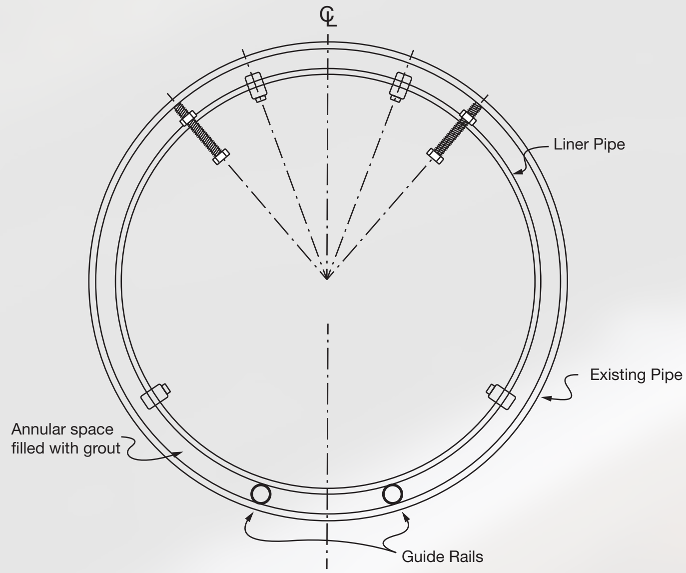
LANE

RELINE GUIDE

A GUIDE TO SPECIFYING RELINE PROJECTS





SPECIFICATION GUIDE OVERVIEW

Slip lining projects lend themselves to a multitude of reline materials and corresponding installation practices. Ultimately the engineer of record will need to ensure structural and hydraulic capacity while the contractor will decide how to best install and secure the liner based on experience, available resources and information. Each site will also have its own ingress and egress challenges at either end of the project, and grouting considerations become compounded as the length of the conduit increases and/or the slope steepens. That said, this guide can serve only as a brief introduction to some of the main considerations when specifying a reline material and installation plan using corrugated metal pipe (CMP) and structural plate pipe (SPP) materials.

A. LINER SELECTION

1. **Liner Materials[1]**

   Spiral Rib Steel Pipe[2] or Corrugated Steel Pipe (CSP) – Galvanized, Aluminized (ASTM A760) or Polymer Coated (ASTM A762)

   Spiral Rib Aluminum Pipe[2] or Corrugated Aluminum Alloy Pipe (CAAP per ASTM B745)

   Steel Structural Plate (SSP) – Galvanized (ASTM A761) or Polymer Coated (ASTM A1113).

   Aluminum Structural Plate (ASP per ASTM B746)

NOTE:

[1]CMP is available in round and pipe-arch shapes (up to 144-in dia. round). SPP is available in a variety of round, elliptical, pipe-arch, and bottomless arch shapes (up to 26-ft dia. round).

[2]Spiral Rib Pipe commonly used due to a Manning's n associated with a smooth interior (n = 0.012)

2. **Corrugation Profile, Gauge (Thickness) Requirements**
   Corrugation profile and gauge requirements generally follow published cover height tables using the burial depth of the host/liner installation. A more cost-effective specification can be developed using FEA (computer modeling) techniques, where it is typically demonstrated that loads are very minimally, if at all, transferred to the liner pipe.

3. **Corrosion Protection (Grout Side)**
   Grout specifications for pure aluminum pipe materials (CAAP, Aluminum Structural plate) should be non-acidic and contain no chlorides. Alternatively, the grout side of the pure aluminum liner could be painted to provide a barrier to absorption while the grout cures (special paints are unnecessary). All other liner materials or CSP coatings do not require special considerations to offset corrosion concerns.

4. **Corrosion Protection (Water Side)**
   Follow industry guidelines to ensure service life criteria is properly taken under consideration when specifying a liner material or CSP coating. This generally involves water chemistry and flow abrasion characteristics. See the Service Life Selection Guide published by the National Corrugated Steel Pipe Association (ncspa.org).

B. LINER PLACEMENT

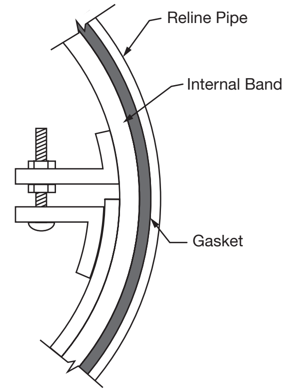
1. Liner segments are typically pulled into place with equipment suited to the operation. A distribution ring or nose cone is fabricated or rigged to the inside of the liner to ensure uniform distribution of the pulling force.
2. Site conditions may lend itself to a pushing operation. Like pulling liners into place, a distribution ring or push-stub is needed to distribute forces equally around the periphery. It will be more critical to investigate sliding resistance when a pushing operation accumulates pipe segments. Options to lesson sliding resistance include lightening the gauge, using aluminum reline materials, and selecting slide rails with lower coefficients of friction and/or greasing the rails.
3. Combining pulling and pushing methods is another option, especially when a pushing operation accumulates pipe segments until the sliding resistance cannot be overcome, or when the required pushing force exceeds the axial strength of the reline material.
4. Cranes or excavators rigged to the top section of a liner segment can hoist and swing a liner into place. Technically this is a combination of pulling and pushing but has the added benefit of removing substantial weight from the

SAFE PUSHING LOADS FOR CSP
(lb/in of circumference)

	2-⅔ x ½	3 x ⅕ x 1	¾ x ¾ x 7-½
16ga	200	100	60
14ga	300	150	90
12ga	500	250	150
10ga	800	400	240
8ga	1100	550	330

sliding surface and reducing sliding resistance. It should be noted that this method alone cannot fully insert the last segment and will need to be supplemented in some fashion to complete the reline.

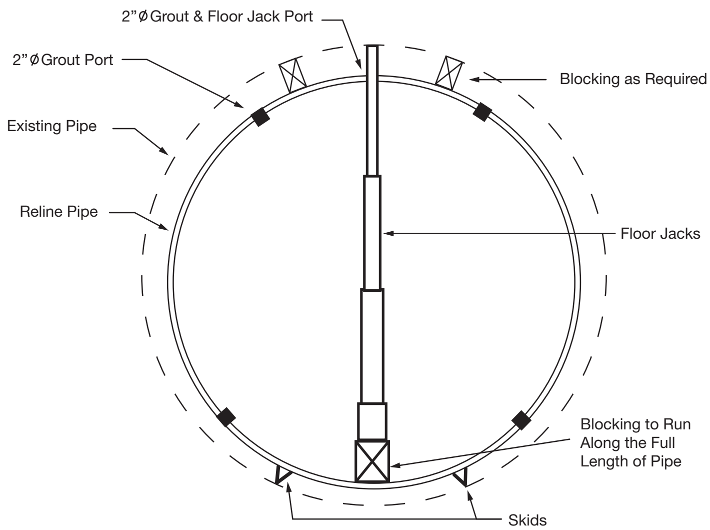
5. Slide rails or skids reduce friction and allow liners to be more readily placed. They can be fixed to the reline pipe (skids) or placed in the host structure (rails) and can take many forms such as one-half inch steel pipe, steel angle, plastic elements, pressure treated lumber, et al. It may be necessary to investigate the coefficient of friction for the various materials before developing an installation plan.
6. Structural plate affords the unique option of being assembled in place. Aluminum structural plate is particularly suited to this method when manual handling of plates is necessary.
7. Internal bands were designed especially for reline applications. However, external bands are better suited for pushing operations that accumulate segments. Alternatively, a low-profile internal flange joint can be used for any insertion method.



8. Alignment bolts are used to position the liner in the host. Manufacturer shop drawings indicate peripheral and longitudinal positions along the length of the liner for threaded inserts, nuts, or other welded attachments.

C. LINER SECUREMENT AND GROUTING CONSIDERATIONS

1. Gasketed joints are needed to address the potential of grout infiltration. Alternatively, low-profile internal flange joints can be field caulked before bolting.
2. Flotation due to buoyancy, primarily associated with the initial grouting operation, must be resisted by properly bracing the liner uniformly along its length. A common bracing method can be constructed using adjustable floor jacks braced against timber along the reline invert and extended to the host structure through the two-inch grout ports along the crown of the liner.



3. Grout ports are included in the liner to minimize grout travel lengths, being spaced around the periphery and along the length accordingly. Grout port locations are also conducive to the number of lifts required and serve as observation ports to help ensure the grout operation is properly advancing.
4. Bulkheads will be necessary for the grouting operation and should be constructed in accordance with industry formwork guidelines (ACI 347) to resist grout pressures. A permanent bulkhead (e.g. brick) may serve as the end finish. Alternatively, an end finish can be constructed after temporary bulkheads are removed. It should be noted that end finishes may be subject to greater durability demands than grout used for the annular space and will typically be specified at more traditional cementitious compressive strengths.

5. Flowable Fill Grout - Notes and Characteristics

   Self-consolidating cementitious mixture of cement, sand, and water with a compressive strength of 1200 psi or less.

   A portion of the cement component can be replaced with fly ash.

   The compressive strength need only be 40-80 psi for pipeline use.

   Buoyancy forces are typically calculated using a density of 100-130 pcf.

   Initial set is usually 3 to 4 hours.

   Better suited for large diameter applications.

6. Cellular Grout - Notes and Characteristics

   Cellular grout is a low-density grout mix comprised of cement and water (or cement, fly ash, and water) with a foaming agent.

   Cellular grouts with lower densities are normally preferred since they limit hydrostatic loads and buoyancy effects on the liner before initial set.

   Lower densities enhance flowability for longer travel lengths and are better suited for small diameter applications or tight annular spaces.

   Practically any grout used will have a compressive strength greater than the original soil surrounding the host structure. The compressive strength need not be greater than 80 psi and a minimum value of 40 psi will be stronger than the existing soil and have enough strength to be tested.

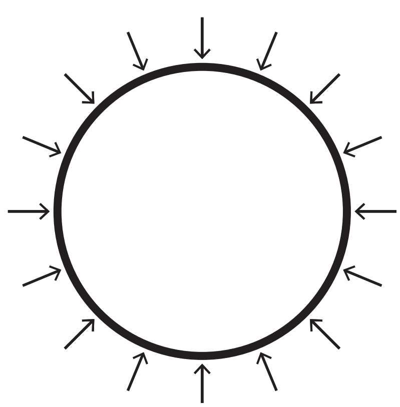
CELLULAR GROUT PROPERTIES		
Density (pcf)	Modulus (psi)	Strength (psi)
30	43,246	26
35	56,465	46
40	66,794	77
45	79,014	120
50	93,468	180
55	110,567	259
60	130,793	361
65	154,720	489
70	183,024	649
75	216,506	844
80	256,113	1,080
85	302,966	1,360

Conservative industry developed design values.

7. Grouting Pressures

   More pressure is needed at the pump for longer travel lengths and/or smaller annular spaces.

   Portland cement grouts require higher pressures at the pump.



Example Collapse Pressure

84-in, 5x1, 12 gauge CSP
Radius, r=42"
Modulus of Elasticity, E = 29,000,000 psi
Moment of Inertia, $I = 0.015650\ in^4/in$

Ring Buckling Critical Load, $p' = 3EI/r^3 = 18.38$ psi
[Roark's, 7th Edition, Table 15.1, Case 8]

$p'_{allow} = p'/2 = 9.19$ psi
[safety factor = 2]

   Grouting pressures are normally kept around 5 psi at the nozzle, but that pressure is not applied to the pipe for gravity-driven operations. However, provisions should be made so that the final lift does not become pressurized with the bulkheads in place (e.g. vent tubes).

   The hydrostatic head on the reline pipe is from the active grout plug to the bottom of the pipe or the next lower hardened zone. The pressure is the product of the head and density of the grout.

   The collapse pressure is applicable in vertical caisson pours but not gravity-driven reline-grouting operations, especially when grouting in lifts. However, knowing the collapse pressure (aka ring buckling critical load, $p' = 3EI/r^3$) is good information to have when developing a lift construction plan and may be useful for managing pressure during the final lift.

8. Lift Construction

   Grouting is typically done incrementally so as not to build up pressure on the reline pipe. A first lift just below the flotation point can form an anchor through adhesion and add an additional level of safety to the operation.

   The need to grout in lifts, or the number of lifts, becomes less critical as the reline diameter and/or the grout density decreases.

   Steepening slopes play a significant factor in developing a lift construction plan, increasing the need of advancing the lifts upstream in pre-determined segments.

   Controlled flow rates counteract buoyancy effects as the grout approaches initial set. The slower rates will also help ensure complete filling and balanced, side-to-side grout lifts.

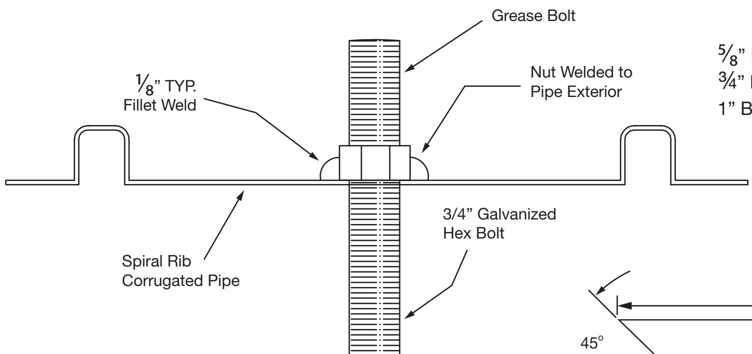
   A lift construction plan is developed based on how the reline pipe is braced for flotation. Reline pipe braced at the crown, or more preferably the invert, will develop bending moments along the line of contact. Grout lift heights are designed to ensure the pipe can safely resist these forces.

   Venting tubes placed through the bulkhead to the crown of the host structure will enable non-pressurized gravity flow of the final lift and will indicate when grouting is complete.

D. RELINE PIPE FITTINGS – GROUT PORTS, ALIGNMENT BOLTS, SKIDS

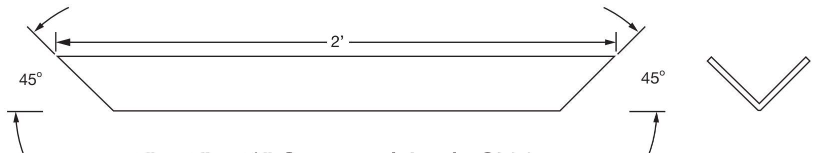
1. Reline pipe is fabricated to accommodate grout ports and alignment bolts using welded nuts or threaded inserts. These fittings may also be used for attaching pulling or pushing mechanisms.
2. Grout ports are typically two-inch diameter. Regardless of the number of lifts required it is common to provide grout ports at three elevations for the larger diameters: 4 and 8 o'clock, 2 and 10 o'clock, and 12 o'clock. The spacings are typically every 10 feet but it is preferable to stagger them in two groups every 5 feet, placing the bottom and top locations together. *(See details on page 7)*
3. Alignment bolts are typically three-quarter inch diameter, but the location can vary considerably. At a minimum, symmetrically placed alignment bolts 40° on each side of the top centerline is good practice. The engineer may decide to use another pair somewhere in the bottom half of the reline pipe. Alignment bolt spacings are every 5 or 10 feet. *(See details on page 7)*
4. Skids, when provided by the manufacturer, are typically steel structural angle welded at locations specified by the contractor. Two-foot lengths of angle are typical, with the corners mitered to form a ski. *(See details on page 6)*

WELDED ATTACHMENTS

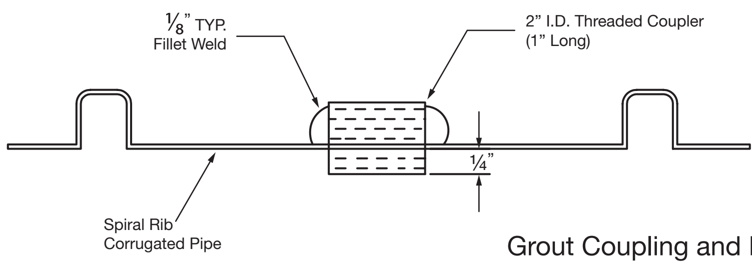


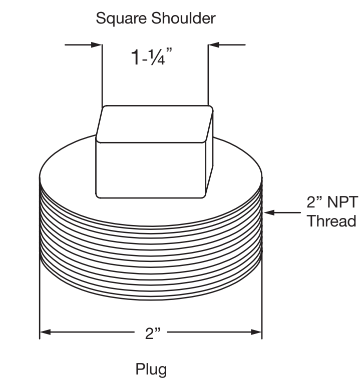
Alignment Rod Detail (Length TBD)
(Temporary - Remove after Construction)

⅝” Bolt for Pipe Diameters Less than 60”
¾” Bolt for Pipe Diameters Less than 102”
1” Bolt for Pipe Diameters 102” and Larger.



3” x 3” x ¼” Structural Angle Skid

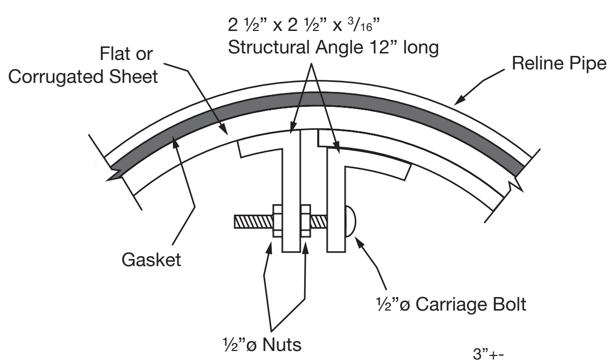


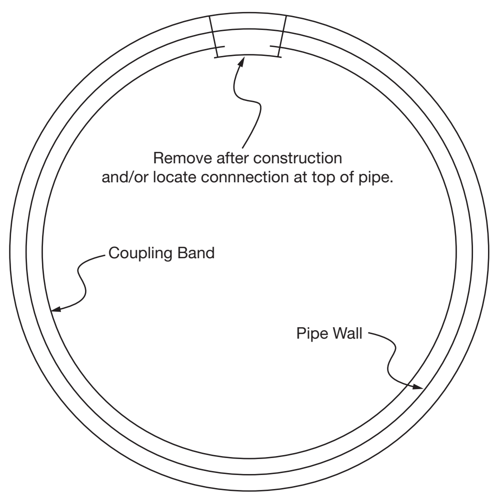


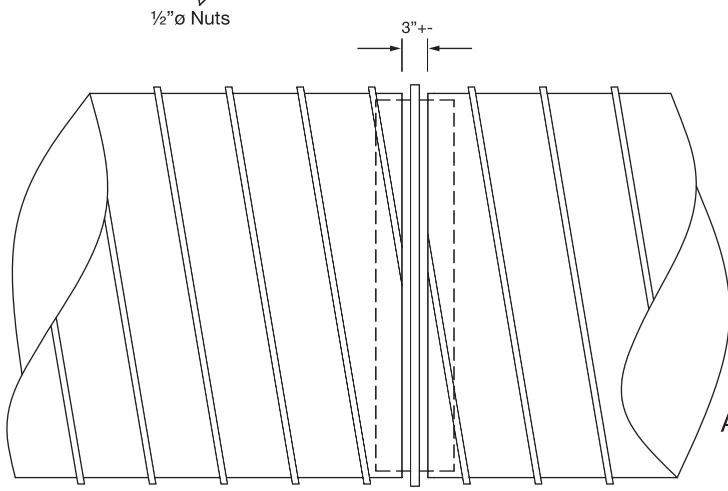
Grout Coupling and Plug Detail

INTERNAL COUPLERS

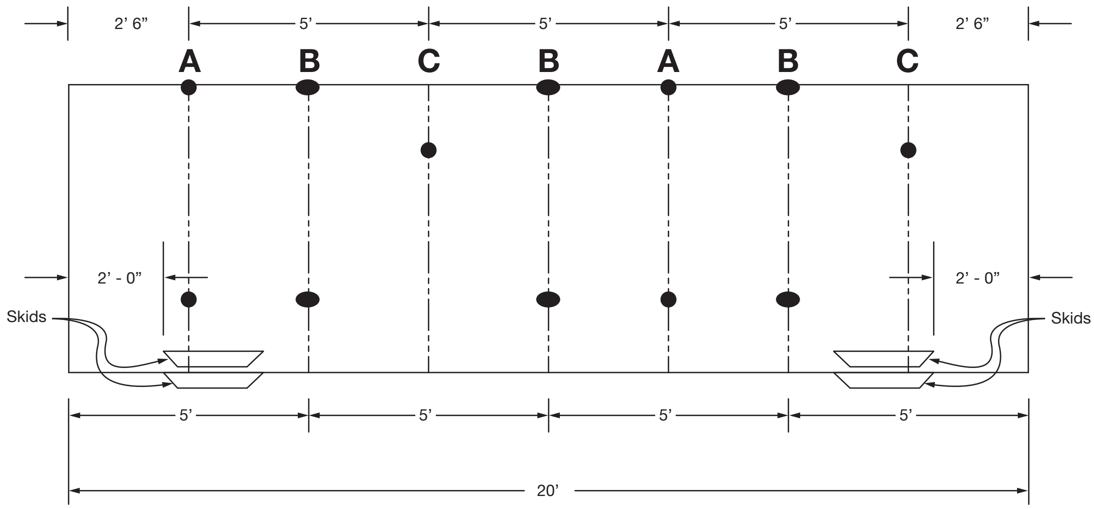
Internal Band

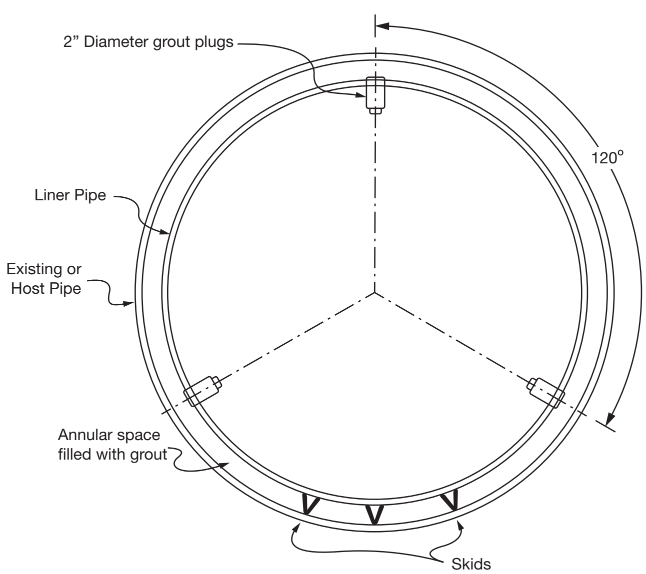




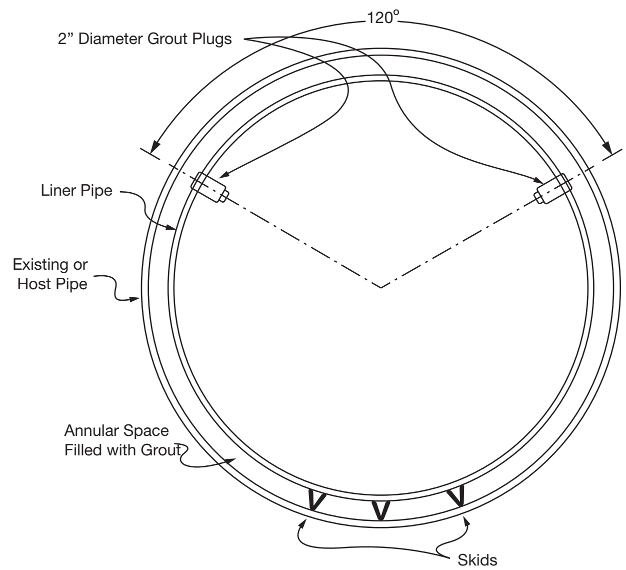


Alternate Push Stub Coupler

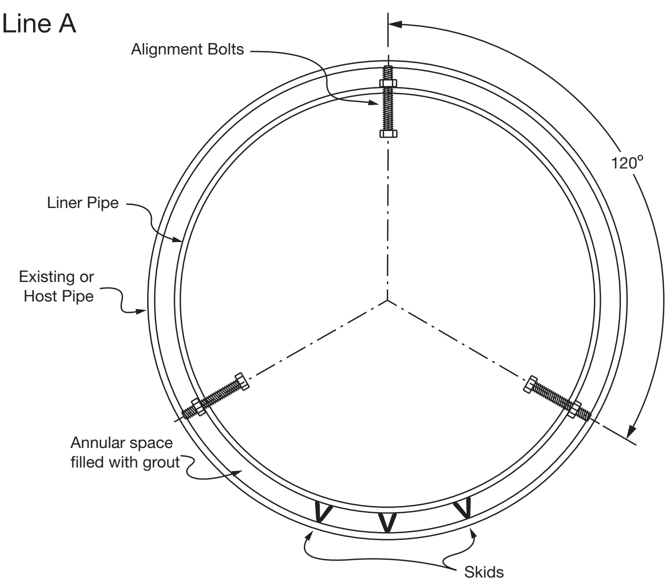




Line A



Line C



Line B

SPECIFICATION GUIDE NOTES

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