CURING

The five basic methods used for curing rubber lining are autoclave, internal (pressure) steam, exhaust or atmospheric steam, chemical cure and hot water cure. The specific method used will depend on the nature and size of the vessel to be lined. Note that recommendations contained in this manual are suggested guidelines only. Actual cure times will depend on factors such as rubber thickness, vessel size and metal wall thickness, heat loss, ambient conditions and elevation.

All cures should have proper temperature recording charts and these should be properly identified with job number and date. If there are any questions regarding conformance of cure to published time and temperature recommendations, please contact your Polycorp representative.

1. Autoclave Cure

This refers to vulcanization where the rubber-lined vessel/part is placed inside a pressure vessel and subjected to controlled steam under pressure**. <u>An autoclave cure provides the best and most uniform cure and should be used whenever possible</u>**. Metal parts should be placed in the autoclave so that the best possible drainage of condensate from the rubber will be obtained. To obtain the most accurate and uniform cure, it is desirable to have the autoclave fully equipped with thermocouples and instrument controls on air pressure and steam. Sufficient boiler capacity should be available to raise the temperature from ambient to cure in a relatively short period of time. After finishing cure, it is recommended the rubber-lined vessel be cooled down by using water and/or air. Proper cool down of autoclaves will prevent post curing and preclude the possibility of cracking hard rubbers. The following cool-down procedures are suggested as recommended methods:

- Cool down soft natural and synthetic rubbers one hour with air and water.
- Cool down Triflex™ and hard rubber with air and water until autoclave temperature reaches 200°F (93°C). Continue a gradual cooling down of the autoclave with air and then with air and water. This cool down procedure can be modified, but a step-wise procedure will prevent cracking of the hard rubber.

During cool down it is important to maintain an air and water pressure equal to or greater than the steam pressure.

All autoclaves should be equipped with temperature and pressure recorders. The recording charts should be properly identified and dated.

Precautions must be taken against stratification of steam and air particularly in large vulcanizers. During start-up the bottom exit valve must be cracked open to allow a complete sweep of steam and cold air through the autoclave to avoid a cold bottom and subsequent undercured rubber.

In all cases, follow the Autoclave manufacturer's operation manual.

Follow the recommendations on the Technical Data Sheet for cure times and temperatures.

2. Internal Pressure Steam Cure

Internal steam pressure cures are used on vessels that are designed for pressure and are too large to be placed in an autoclave. The vessel should be positioned during cure so that complete condensate drainage is obtained. To accomplish this, tanks with a sump should be cured with a well pipe connected to a trap (see Fig. 10-1).

Tanks without a sump can be cured. A drain valve shall be open enough so that the continuous flow of steam can be observed (see Fig. 10-2). All nozzles should be bled with a 1/4" petcock. Drain valve should be left open long enough to be sure that all air is evacuated before building up pressure.

- Sufficient boiler capacity should be available to raise the temperature from ambient to curing in a relatively short period of time. Long uninsulated pipe runs from the steam source should be avoided. Low pressure steam plus un-insulated lines promote excessive condensate.
- Outside temperature has a significant influence on the time required to cure a vessel. In cold winter temperatures, if it is practical, the vessel should be insulated to effectively carry out the cure.
- Steel thickness is also a factor. Heavy thick steel needs additional time to compensate for the heat sink and warm-up period. This is where external temperature gauges are quite valuable in monitoring the time/temperature so one can judge and insure themselves that a complete cure is being obtained.

All flange faces should be lined with one of special constructions shown in Fig. 10-3, Fig. 10-4 and Fig. 10-5.

- Prior to introducing steam into the vessel, all outlets should be blanked off with a blind flange equipped with a petcock so as to insure the release of steam thereby guaranteeing the nozzle and flange are properly cured (see Fig. 10-6 for detailed assembly).
- Always insert Mylar or a like material between blind flange and rubber on the flange to insure removal of the blind flange after cure without damaging the rubber on the flange
- The blind flanges should not be bolted down too tight initially as they can be tightened as the cure progresses.

<u>To bolt the flange too tight initially forces the rubber to squeeze out as the temperature increases thereby leaving a very thin ply of rubber on the flange</u>

- The blind flanges may be tightened as the cure progresses. However, the rubber on the flange will have started to harden. So the blind flanges can be tightened down with less rubber squeezing out.
- The pressure should be brought up in the tank as quickly as possible.
- When the desired pressure has been reached, the petcocks can be slowly opened until there is a visible amount of steam flowing through the petcock. It will allow curing the nozzles and flanges properly.
- When the tank is being readied for cure, the air and steam line should be inserted separately so as to allow air to be inserted in the tank while the steam is still on.
- After curing completely, cool down internal steam cures by introducing air until temperature reaches 150°F (60°C). All cures should have proper temperature and pressure recording charts with identified job number and date.

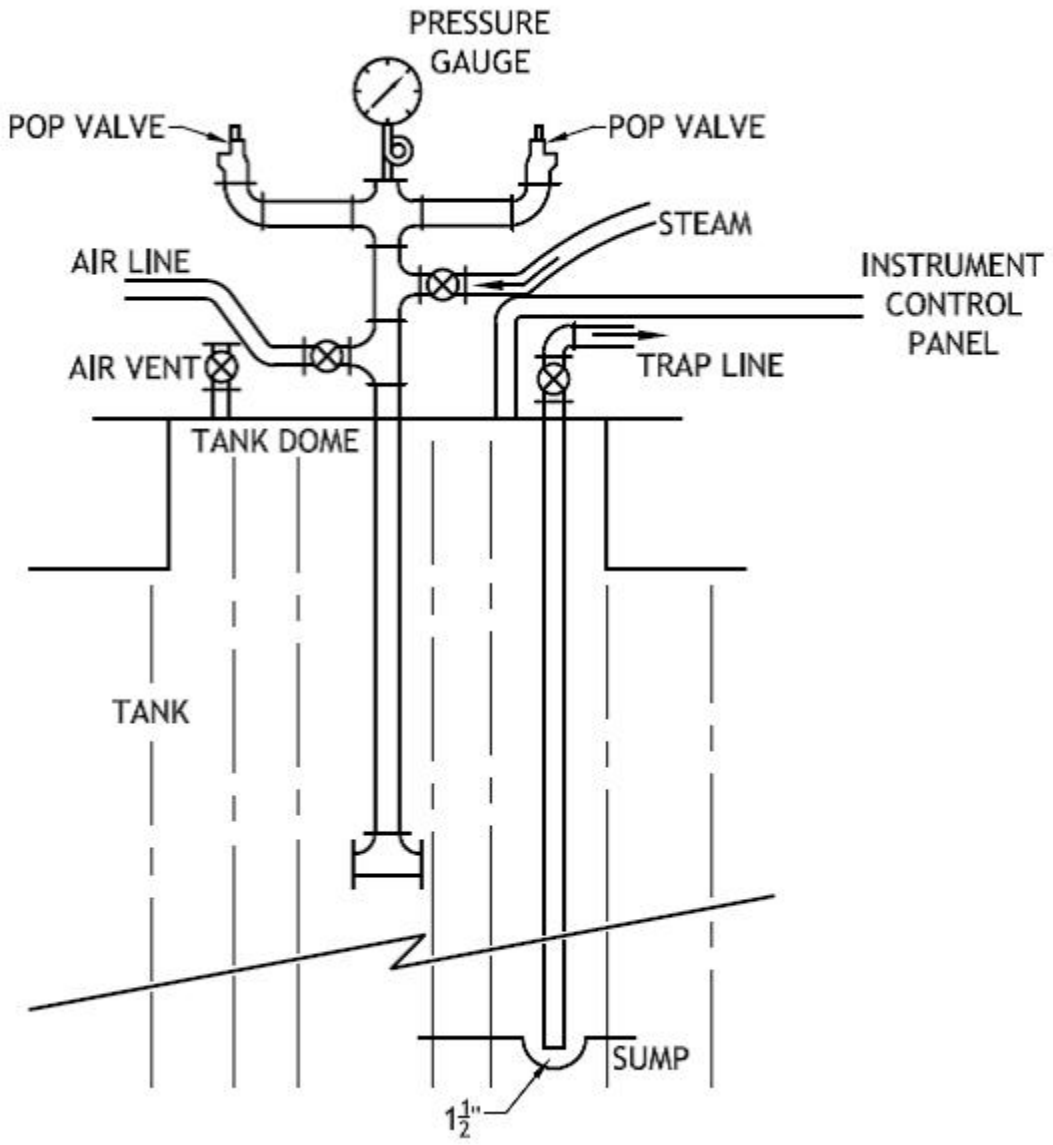

Fig. 10-1 Internal steam cure – tank with sump

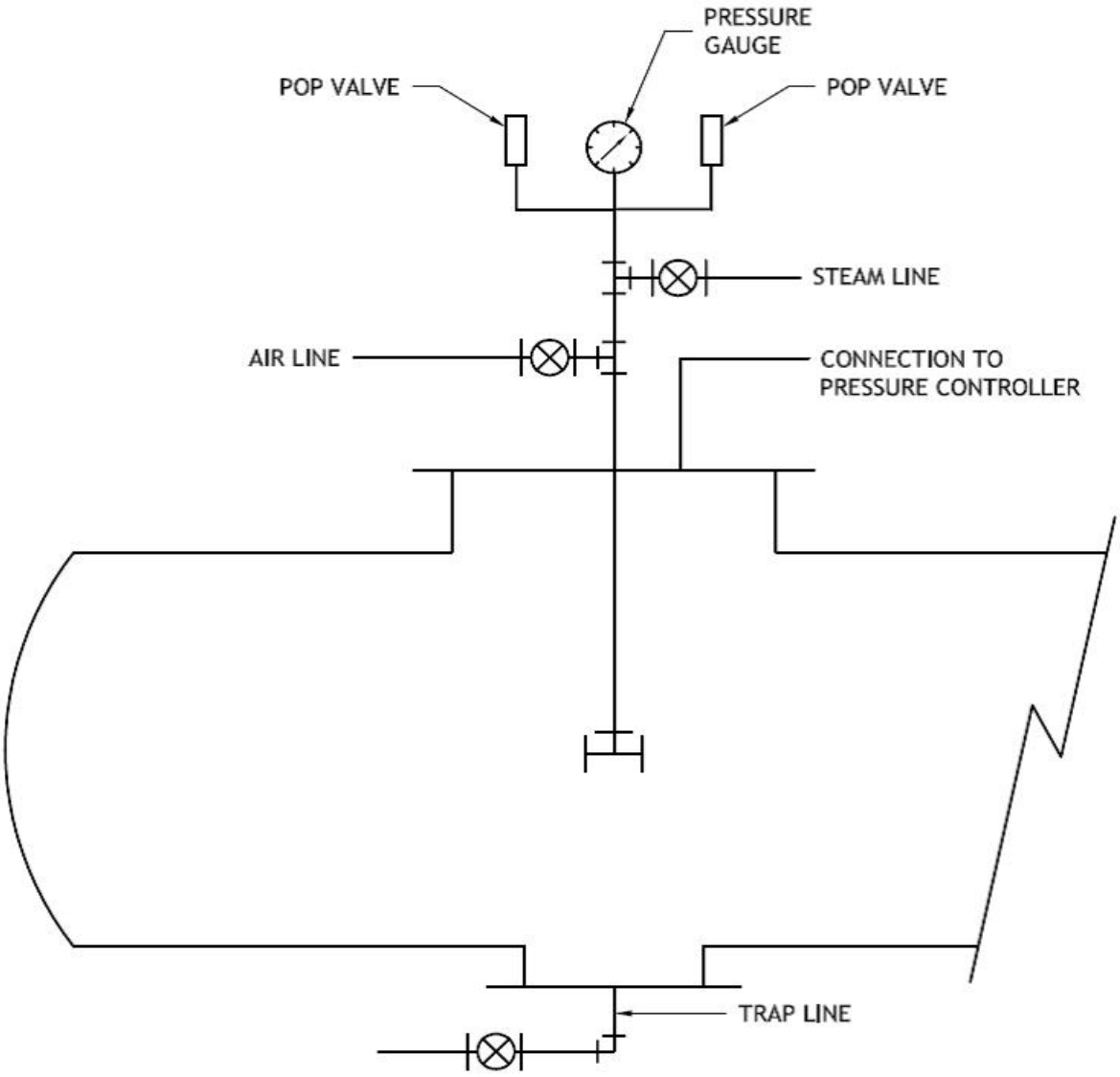

Fig. 10-2 Internal steam cure – tank without sump

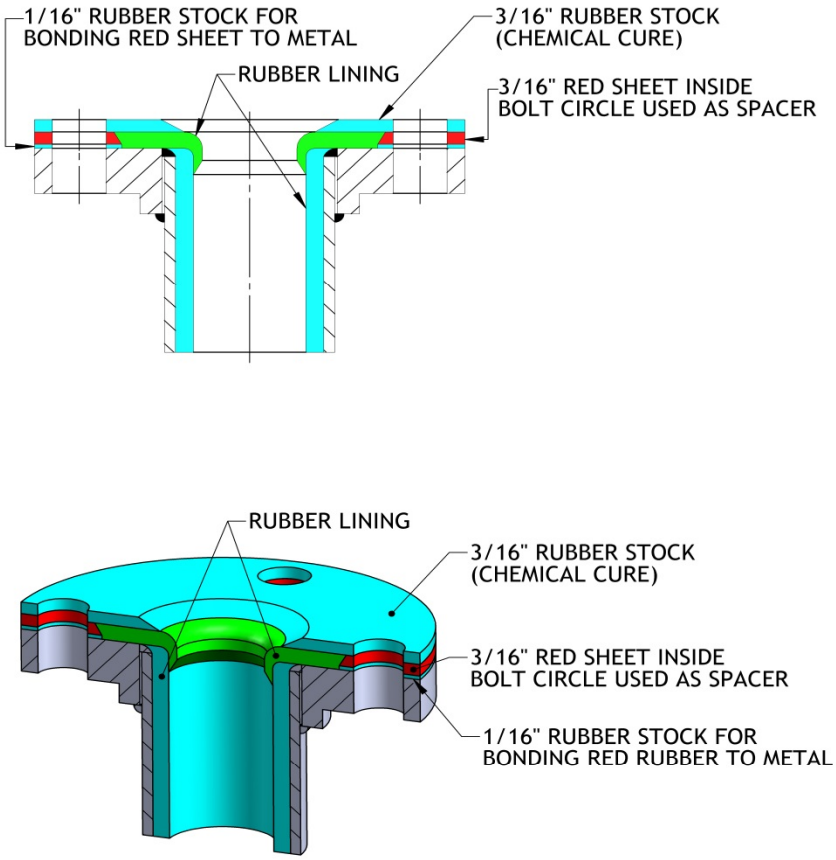

Fig. 10-3 Internal steam cure vessel - Flange detail for outlets
(This method is recommended on vacuum equipment)

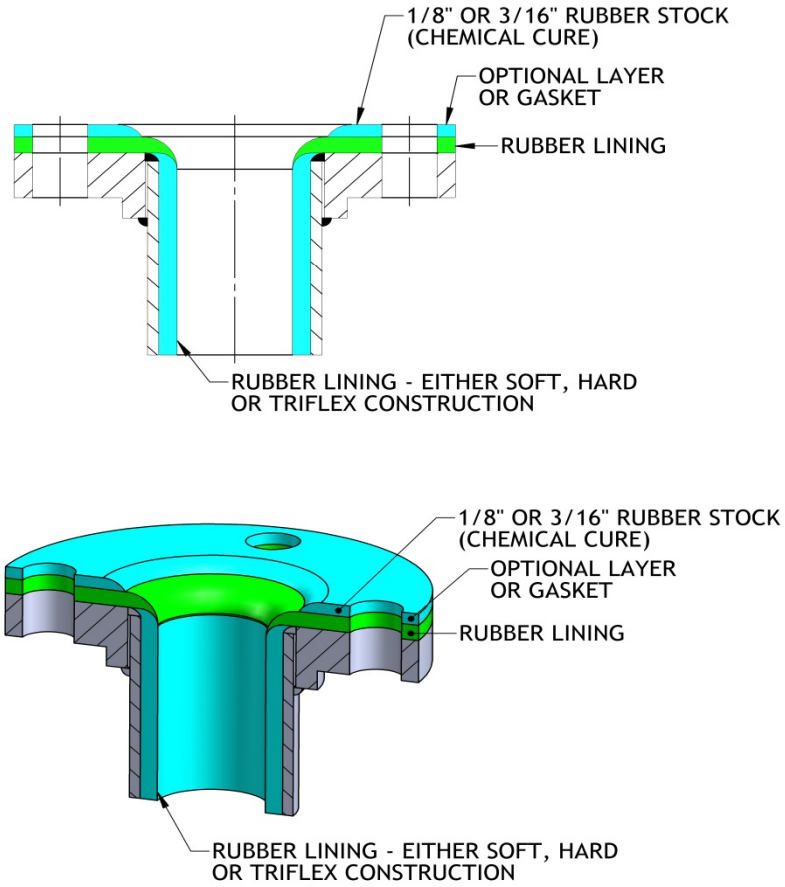

Fig. 10-4 Internal steam cure vessel - Flange detail for outlets

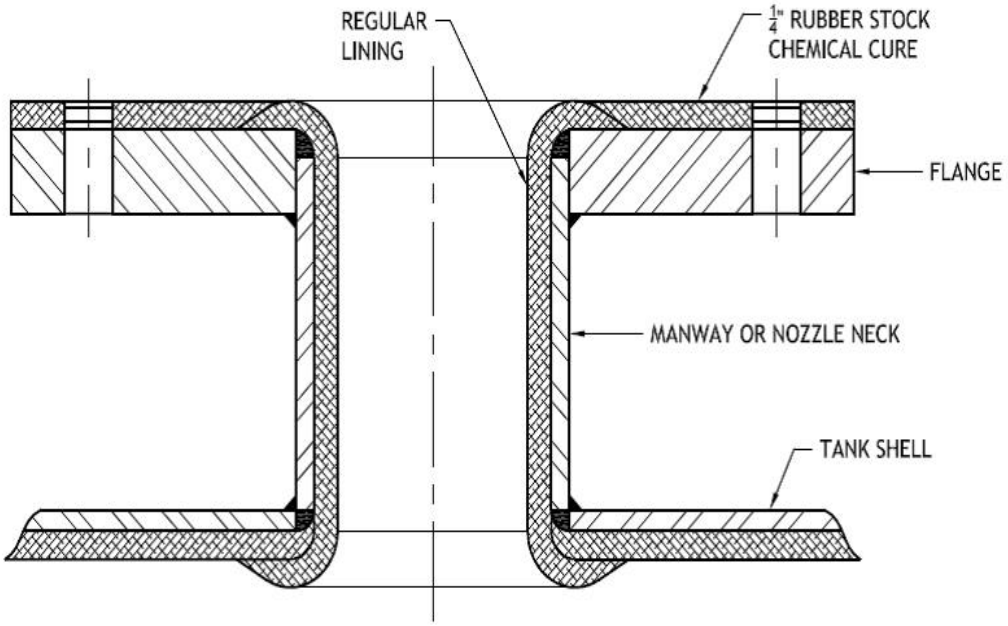

Fig. 10-5 Internal steam cure vessel flange detail for outlets

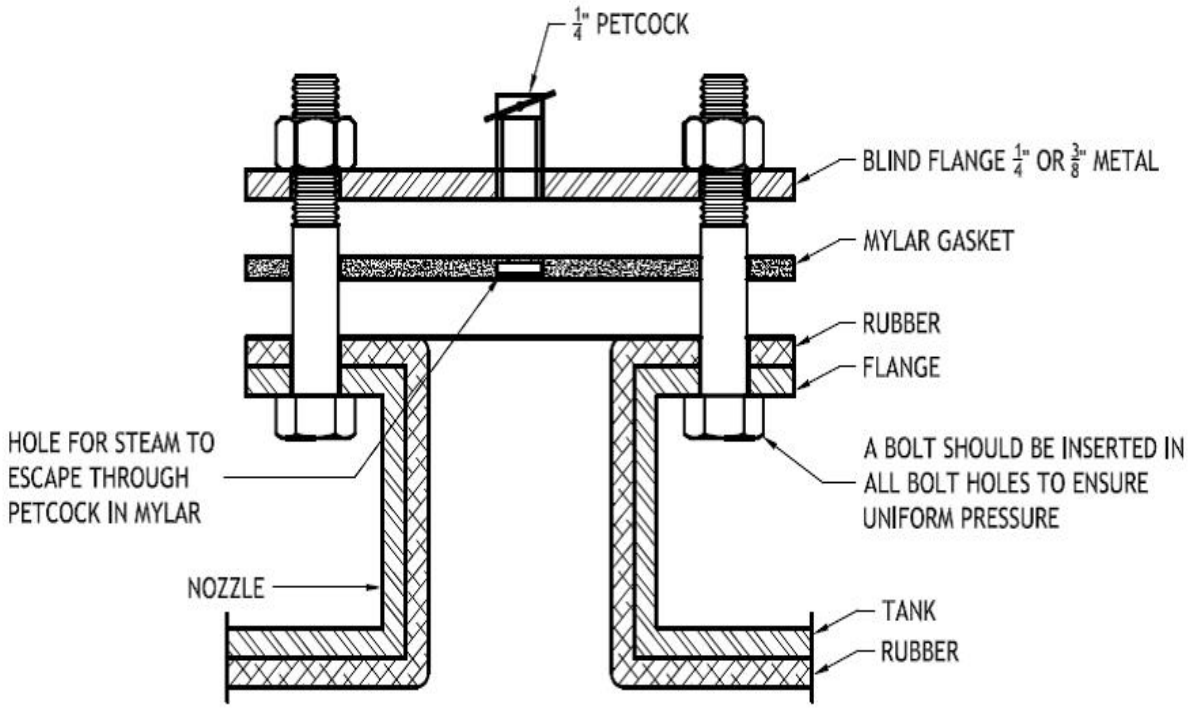

Fig. 10-6 Internal pressure steam cure – Flange assembly

3. Exhaust or Atmospheric Steam Cure

If it is practical, the vessel shall be adequately protected and insulated to prevent loss of the heat required to fully vulcanize the rubber. Exhaust or atmospheric steam is normally used for field vessels that have open tops and/or bottoms, vessels that do not withstand pressure or vessels that are too large to fit in an autoclave. In the case of open top tanks, the opening must be covered with fabric or combinations of fabric and plastic. The covering must be made tight so the steam will be contained. Steam should be introduced into tank by means of a steam line through an outlet from the bottom of the tank. It is absolutely essential that provisions be made to be able to remove all condensate from the vessel during cure. The bottom outlet on a closed top tank may be left open for drainage, but other outlets should be covered. See Fig. 10-7 for typical exhaust steam piping setup.

3.1 Tanks that have an enclosed top with bottom outlet should start timing the cure when the temperature of the bottom outlet is about 140°F (60°C) and the temperature of the rubber surface has reached the desired cure temperature (as measured in the coldest spot in the vessel).

3.2 Thermometers through outlets and internally located thermocouples at various points in the tank should be used to monitor the temperature. When temperature varies at different spots in the vessel, the coldest spot should govern how much the overall cure should be increased. No cool down period is required for this type of cure.

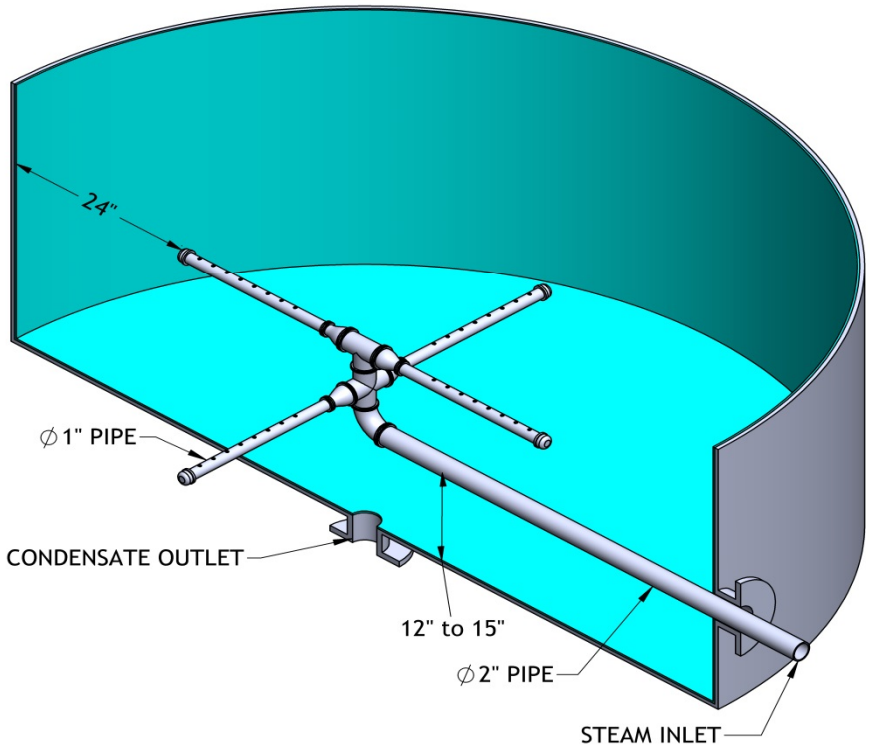

FIG. 10-7 TYPICAL EXHAUST STEAM PIPING SETUP

NOTE: *For large tanks or during cold weather, larger size piping to furnish more steam may be required (insulation may also be necessary) to maintain appropriate inside curing temperature that is in accordance with Polycorp's recommendation.*

3.3 Precautions

Specifications and information on the Technical Data Sheets is written based on

consistent lab conditions. Frequently the cure times are extended for the lining to receive the optimum cure. The following are all considerations in determining the correct cure cycle.

- Warm up vessel at a rate of 30 – 50°F/hour (16 – 28°C/hour). The time it takes to warm up the unit does not count toward the cure time.
- Curing is a function of time and temperature. Lower temperatures will lengthen the cure time. Tank insulation, temperature of the surrounding air, elevation and wind velocity over the tank can shorten or lengthen the cure.
- Thickness and surface area (structure) of the metal will act as a heat sink and increase the length of the cure.
- Cold spots can develop as a result of trapped air, condensate accumulation or ineffective steam circulation. Thermocouples must be strategically placed to monitor the coldest spots in the tank. Temperature readings must also be taken on the metal opposite the rubber lining to ensure the metal temperature is about minimum 150°F (66°C) to cure the rubber/cement interface.
- The amount of steam must be properly estimated for curing. To ensure proper cure of flange faces, steam must escape around openings. If the steam is stagnant, cold spots form. The steam supply must not only be adequate but must be directed in such a way to ensure it is flowing over all rubber lining surfaces, especially the bottom. Drains should be provided at the bottom of the vessel and elsewhere to ensure condensate will run off and not collect in any pockets. An open top tank or one sitting on a concrete pad can result in situations where the tank walls are cured but the floor is not.
- The entire cure and cool down must be monitored, especially if it is possible to pull a vacuum and collapse the vessel. Vacuum breakers may be necessary depending on the construction of the vessel.

3.4 Key Calculations for Steam Requirements for Atmospheric Cure

- Pounds of Steam per hour:
  Example - during 2-hour warm-up period and based on an enclosed vessel with 3/8” plate on bottom and 1/4" on sides and top

Pounds per hour of steam = 0.05V + 0.15A + 0.005W

Where: V = Volume in cubic feet
A = Area in square feet
W = Weight of rubber and steel in pounds

- Boiler Horsepower Required = Pounds of steam per hour ÷ 30
- Steam Flow Table: Table shows steam flow in pounds per minute through 1,000 feet of pipe

	Steam Pressure		
Pipe Size	**50#**	**75#**	**100#**
1”	4.27	6.32	8.15
2”	25.8	36.7	52.5
2 ½”	40.7	57.7	74.5
3”	71.5	101.0	130.0
3 ½”	89.0	146.5	185.0
4”	144.0	204.0	263.0

To the use the table, determine steam requirement in pounds per minute for 1,000 feet of pipe. For example, if 2,000 pound per hour are required (2000/60 = 33.3 lb/minute), a 2” pipe at 75 pounds of steam pressure is required.

To adjust for varying lengths of pipe, multiply flow rate from the table by the appropriate factor below:

Length of Pipe (Feet)	Factor
100	3.16
200	2.24
300	1.83
400	1.58
500	1.41
600	1.29
700	1.20
800	1.12
900	1.05

Example: If steam source is 100’ away, a 2” pipe is used and gauge pressure is 50# then steam delivery/minute = 3.16 x 25.8 = 81.53 pounds.

5. Chemical Curing

There are cases where using heat to cure the rubber is not possible. Steam may not be available or the equipment to produce the steam is inadequate. Chemical curing rubber is an acceptable solution for these situations. It is typically used in field repair situations.

Chemical activators are used to cure these specialized compounds. They are almost always used by coating the activator on the rubber lining sheet and then adding another coat on the lining after the first has dried. In some cases you may want to coat the rubber sheet prior to lay-up. Specific instructions are contained on the respective Technical Data Sheets. Activator should not be applied to the side of the rubber being applied to the substrate as this may interfere with bonding.

The chemical activator will only result in a rapid cure of the lining surface. Full cure of these types of linings may take an extended period of time.

6. Hot Water Curing

On field lined tanks, one way to obtain some pressure during cure is to use water for hydrostatic pressure. In preparation for water cure, the outlets and/or manways must be prepared using chemical cured or pre-cured rubber. The tank structure must be designed so that it is able to withstand the hydrostatic pressure of the water and curing temperatures up to 210 ºF (99°C). Also, the tanks need to have sufficient foundation to support the water filled vessel, either a sand base for non-installed, or the proper tank setting itself.

On open top tanks, the preparation procedures are the same, except the tank is lined all the way to the top and the water is filled to the top.

Prior to filling the tank with water, steam sparger piping should be installed near the bottom of the vessel. The steam shall be directed not to impinge on the rubber surface and it is recommended that the steam be introduced in an angled, downward direction. Steam should be introduced to the filling tank as soon as the lowest sprayer nozzles are immersed. Once the temperature has reached 180ºF (82°C), the cure can be considered as starting. It is best for the water temperature to be 180ºF - 205ºF (82°C - 96°C). No water source is acceptable that may contain oil.

Thermocouples should be used to monitor the temperature within the vessel from top to bottom. Also, metal temperature probes may be utilized on the outside for temperature information if the tank is not insulated.

After the cure is completed, if the water temperature is slow to come down, it is permissible to add cold water.