

CURING INSTRUCTIONS

It is recommended that the rubber lining be cured as soon as possible after the rubber is applied. All rubber lining curing specifications are determined under lab conditions. Adjustments must be made by an experienced rubber engineer to compensate for all possible variables that can affect the state of cure. Some of these variables are: altitude, weather conditions, vessel insulation, multiple layers of rubber, different lining types in the same vessel or autoclave, green strength (tendency of rubber to flow during cure), ozone and sunlight deterioration, etc. Cure Charts that indicate the temperature of the cure are necessary to ensure the lining is thoroughly cured. Several locations may be necessary to certify that there are not any hot or cold spots. Variation in temperatures from top to bottom or other locations within the cure indicate stratification and may result in damaging the integrity of the cure. Cure charts with diagrams indicating the location of the temperature probes or thermocouples is necessary to make a rubber lining warranty valid.

The methods of curing rubber, in order of preference, are as follows:

1. Autoclave Cure
2. Internal Pressure Cure
3. Exhaust, Or Atmospheric, Steam Cure
4. Hot Water Cure
5. Chemical Cure

1. AUTOCLAVE CURING

This type of vulcanization is the fastest, most economical, provides the best possible properties, and most uniform cure. All the air in the autoclave needs to be displaced by steam before the cure time is started. To ensure all air is displaced, a thermometer should be placed near the bottom of the autoclave and there should be a pressure gauge somewhere on the vessel. When the temperature approaches the theoretical temperature for the pressure shown, all the air has been displaced, i.e. 30 psi is equal to 274°F (134°C) and 50 psi is equal to 297°F (147°C).

All the rubber lined parts should be placed in the autoclave so that condensate will drain off and not collect in low points as this can cause a cold spot that will result in under cure. Ideally, the autoclave should be equipped to record the temperature and the pressure. At the very minimum, there should be a temperature recorder on the autoclave. Cure temperature variations can go unnoticed without any recording equipment.

The autoclave must be ASME certified to withstand the cure pressure and the boiler must be capable of producing enough steam to reach the required pressure in a short period of time and maintain the pressure throughout the cure.

When the cure is finished, the use of air pressure and water to cool down the autoclave and the parts within is recommended. To preclude the possibility of cracking hard rubber linings and over curing of natural rubber linings, care must be taken to properly cool down the autoclave. Cool down of soft and synthetic rubber linings may require one hour with air and water. Cool down of semi-hard, hard and three layer – soft-hard-soft – construction linings require a gradual cool down to prevent cracking of the hard rubber.

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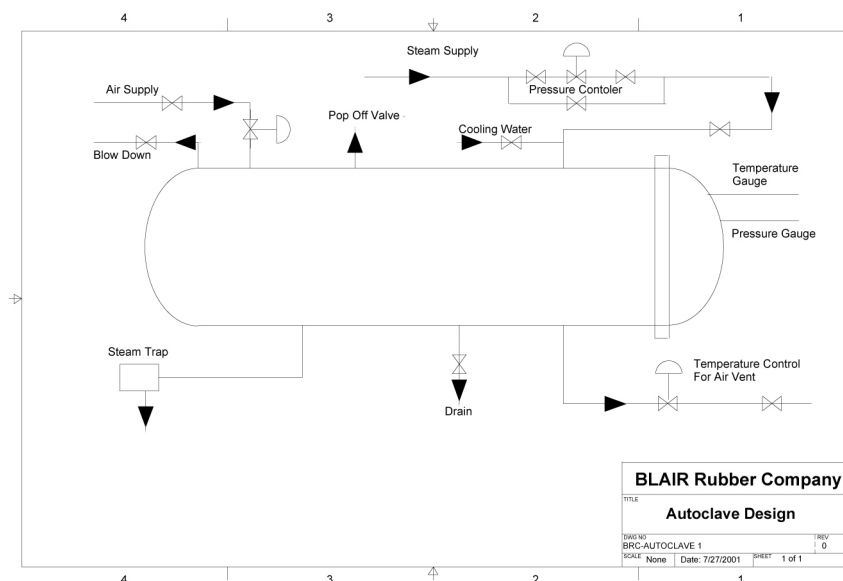
AUTOCLAVE CURING PRECAUTIONS

When curing semi-hard rubber linings - over 80 durometer "Shore A" - in an autoclave, special precautions must be taken to avoid either under- or over-curing the lining. Some of the variables to consider are:

1. Size of the autoclave. The time it takes the autoclave to come up to curing temperature will vary with the size. It may require 5 to 10 minutes for a small unit or 60 to 90 minutes for a large unit to reach the specified cure temperature. The same is true for the cool down. Some only have air for cooling others may have water-cooling. If you have a long warm-up and/or a long cool down time, it may be necessary to reduce the cure temperature or time to avoid overcure of the lining.
2. Amount of steel in parts or tanks being cured or how full or empty the autoclave is can affect the time required to heat and/or cool the parts.
3. Length of time to get up to cure temperature. If the time is short to heat it up, it may require a longer cure time, and if the unit requires a long time to heat - it may require a shorter cure time.
4. Length of time to cool down with rubber lined equipment left in autoclave will also have an influence on the cured lining hardness. If it takes a long time to cool down, the cure time may need to be reduced.
5. It should be noted that light color semi-hard linings, such as whites or tans, might darken at high cure temperatures.

The cure times stated on our individual lining specifications may require some adjustments when the above precautions are taken into consideration. Please contact Blair Rubber Company if there are any questions about the proper curing of the rubber lining.

AUTOCLAVE DESIGN AND BASIC OPERATION



The basic design and operating procedures are for informational purposes only and in no way should this be used in place of the autoclave manufacture's procedures. Most autoclave designs will require a pressure relief valve and a vacuum breaker.

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START UP

1. Check boiler to ensure it is operating properly
2. Check autoclave gasket to ensure it will seal properly
3. Close autoclave door and ensure it is locked properly
4. Shut air supply valve
5. Shut drain valve
6. Open condensate drain valve (steam trap)
7. Shut cooling water valve
8. Shut blow down valve
9. Set any automatic controls for the desired cure time and temperature
10. Open vent control valve
11. Open steam control valve
12. Monitor steam pressure and autoclave temperature
13. Make certain the recorder is operating properly

NOTE: The boiler and automatic controller operating instructions take priority over these instructions.

SHUT DOWN

1. When the cure is completed the air line should be opened
2. Close the steam valve
3. Shut the automatic vent valve (if installed)
4. Open the cooling water valve. Cooling water pressure must exceed the air pressure.
5. Caution must be exercised to ensure the pressure doesn't drop more than 10 psi below the cure pressure or pull a vacuum
6. For soft rubber, a one hour cool down is sufficient
7. For semi-hard, hard and tri-ply linings, and gradual cool down is required to prevent cracking. A three hour step process is best.
Start with air and water the first hour, reaching 200°F (93°C). then air only for the next hour and finish by adding water until cool.
8. Shut the cooling water valve
9. Shut the air valve
10. Slowly open the drain valve
11. Open the autoclave door only when there is no pressure and the water has completely drained

CAUTION: Opening the autoclave door when there is any pressure may cause death, injury or equipment damage

2. INTERNAL PRESSURE STEAM CURE

- A. Pressure Cure of Equipment too Large for your autoclave

CAUTION: Before proceeding with this method, you should get written permission from the owner stating the article can be safely cured at the proposed pressure.

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All flange faces should be lined with chemical cure or cured rubber. These areas should be lined early to allow for full cure so a good seal can be made without squeezing the rubber off the flange faces. It is recommended that the internal lining of the nozzles be turned out onto the flange face 1" to 1 1/2 " with an open skive. See Sketch 3 "Flange Construction". Then apply a donut of CU76BC cured Chlorobutyl with a matching skive using Endurabond™ primers and Normac™ 900R cement. A second donut of CU76BC is bonded over the flange face making certain the top layer covers the joint in the bottom layer. By using this construction, the blind flanges can be bolted down enough to hold the pressure without damaging the rubber on the flange faces. See sketch F-1. Other methods may be used on approval from Blair Rubber Company.

For tanks without a sump, place them in such a position that all the condensate can be drained during the cure. If necessary, use refrigeration grade copper tubing that can be bent by hand to reach the low points and allow the pressure of the steam to blow out the condensate.

For tanks with a sump, such as tank trucks and rail cars, use a sump pipe or dip tube that will reach the bottom of the sump, but not so long it will damage the rubber, and allow the pressure of the cure to push out the condensate.

Some live steam should escape from the condensate drains to make certain there is no condensate trapped in the tank. **CAUTION: If condensate is allowed to accumulate it may result in under cure and premature failure of the area covered with condensate.**

Always use adequate pressure gauges and thermometers to monitor the progress of the cure and be sure to record all the information. It is advisable to use surface thermometers at numerous locations on the tank to be sure there are no cold spots that could affect the service life of the tank. If the temperature at the bottom is colder than the top, gradually open the drain valve in the bottom until the temperature is more uniform. If the work is being done in cold weather, it may be necessary to insulate the tank to get uniform temperature. Additional steam cannot compensate for cold conditions.

Thick steel will effect the cure time because it is a greater heat sink and requires more time to get hot. Check with Blair Rubber Company for proper cure times.

The following table lists temperature equivalents for various pressures at sea level:

TEMPERATURES FOR VARIOUS PRESSURES	
10psi	240°F (115°C)
15psi	250°F (121°C)
20psi	258°F (125°C)
30psi	274°F (134°C)

It is best to contact Blair Rubber Company with vessel size, steel thickness, lining type, lining thickness and service conditions to get the proper cure time and temperature.

FIGURE P
INTERNAL PRESSURE CURE

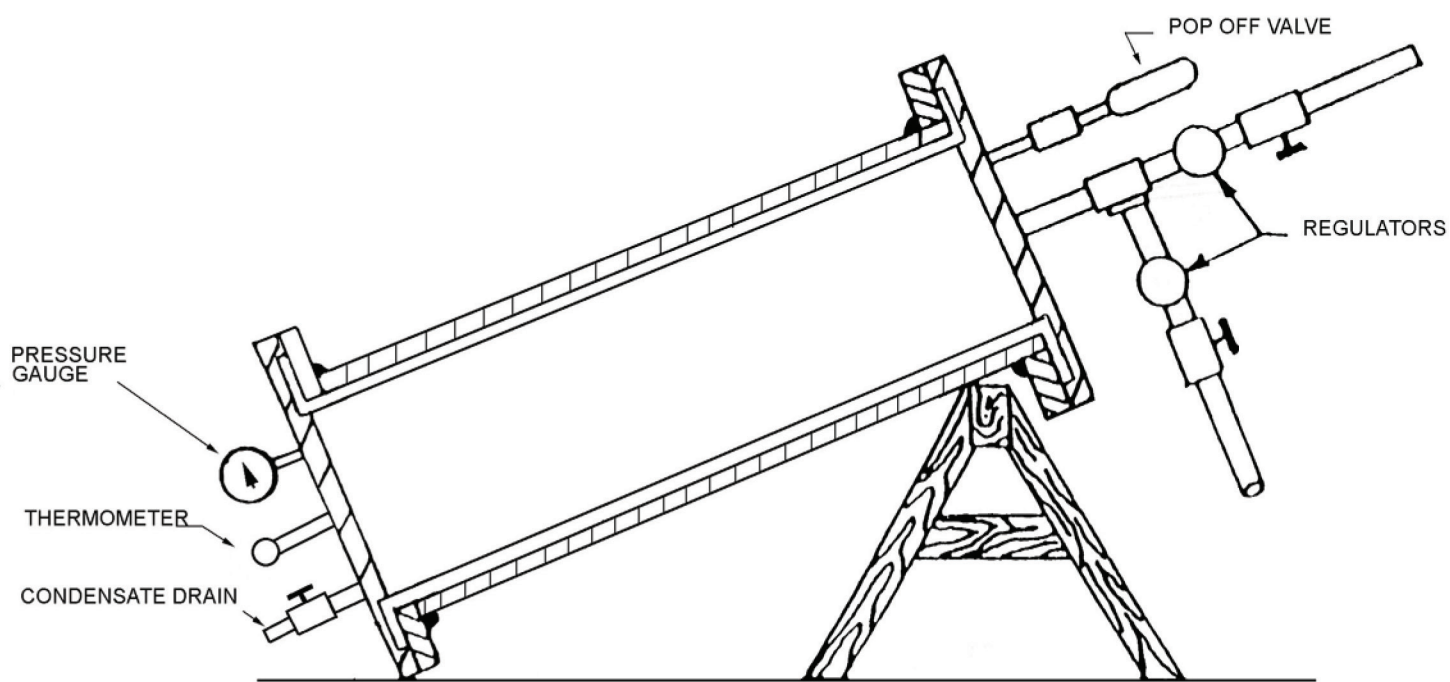
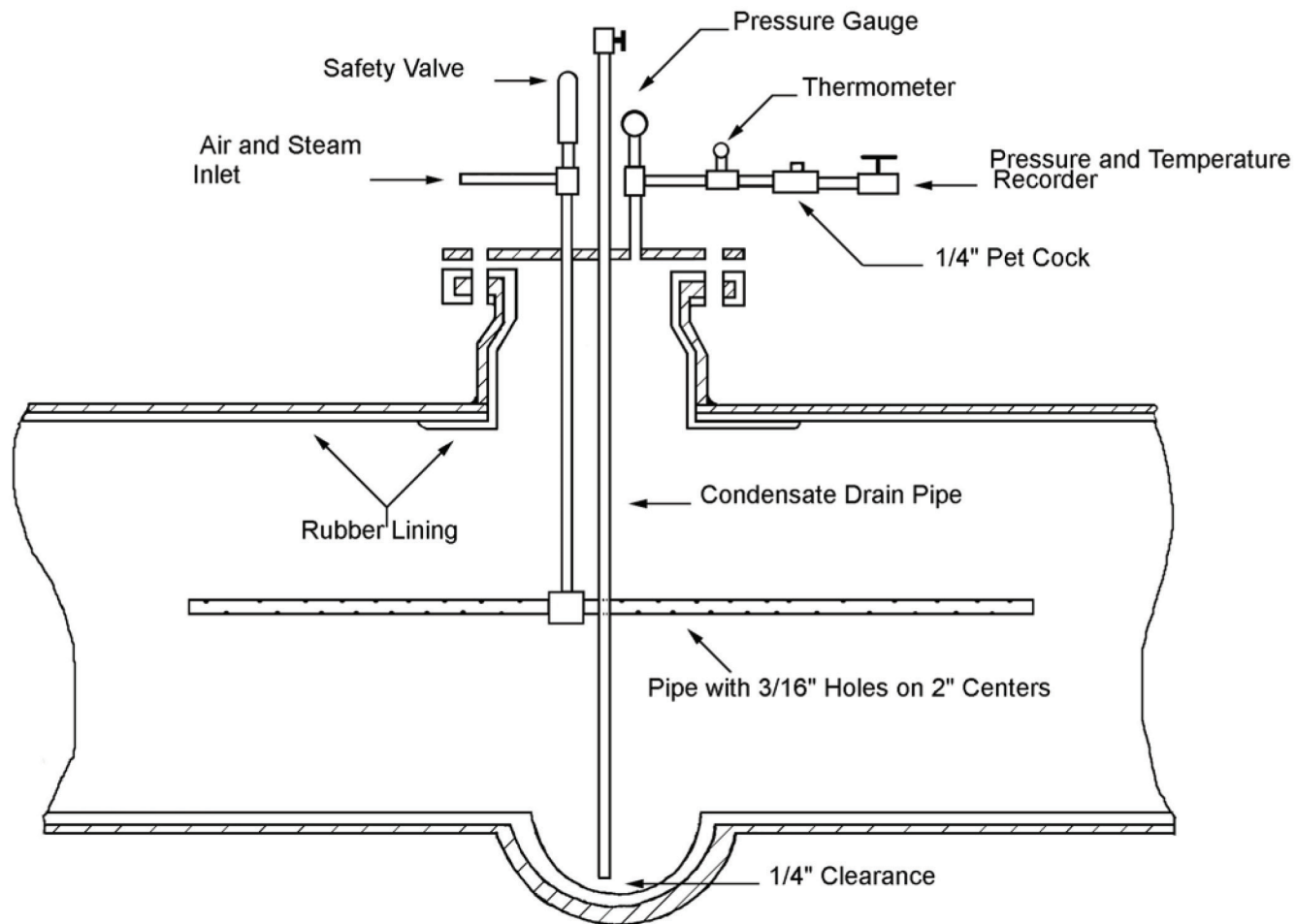
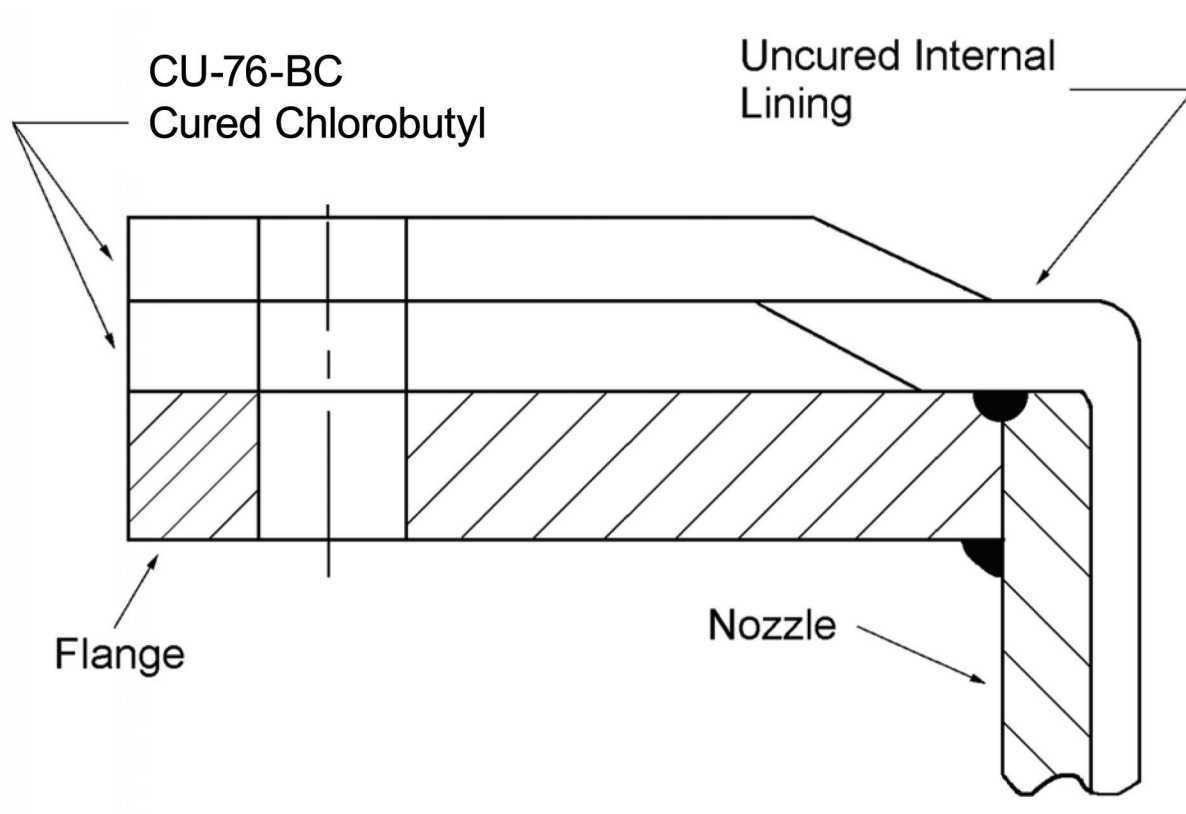


FIGURE P-1
TANK WITH SUMP INTERNAL PRESSURE CURE



SKETCH F-1

FLANGE CONSTRUCTION USING PRECURED RUBBER



3. EXHAUST OR ATMOSPHERIC STEAM CURING

This type of cure is performed when the article is too large to fit the autoclave, cannot be removed from its present location and/or cannot be pressurized for an internal pressure cure. Canvas or heavy plastic should be used to contain the steam as much as possible. The more live steam contained in the article being cured, the higher the temperature that can be obtained. In these cases, a bleed-off of some sort must be installed to drain condensate. Steam should be introduced into the tank through a piping system that will allow steam to flow across and around all the rubber covered surfaces (see drawing P-2). Steam must be introduced in a manner that direct impingement of the steam cannot occur and flow is directed downward in order to cure the bottom of the vessel.

The steam should be introduced slowly at first per the Lining Specification. During the first stages of the warm up (approximately after the first hour), the steam may be turned off and an inspection made. If there are any visible blisters, they can be repaired by removing the trapped air with a hypodermic needle and applying a small patch over the needle hole. The above inspection must be done while the tank is hot. This inspection is optional. Care must be taken or more damage to the lining could result due to equipment or personnel entering and leaving the tank. The rubber is very soft at this stage and is easily damaged.

EXHAUST STEAM CURING PRECAUTIONS

Cure specifications are based on consistent lab conditions. Frequently the cure times must be extended for the lining to receive the optimum cure. The following is a discussion on some of the situations you may find helpful in figuring and setting up your next cure.

1. **Warm Up.** Raise the temperature 10-15 degrees/hour until the cure temperature is reached. The time it takes to warm up the unit does not count toward the cure time as specified in the Lining Specification.
2. **Cure times** are figured as variables of time and temperature. Eighteen degrees Fahrenheit (ten degrees Celsius) lower temperature can lengthen the cure by as much as two times. Tank insulation, temperature of the surrounding air, and wind velocity over the tank can shorten or lengthen the cure.
3. **Structure.** The thickness and surface area of the metal acts as a heat sink and must be taken into account when calculating the steam required for proper cure. The metal structure must reach a constant temperature before the cure time is started.
4. **Cold Spots.** Cold spots form because of poor steam circulation, trapped air pockets in vessels with complicated shapes or condensate that is not continuously removed. Thermocouples must be strategically placed to monitor the coldest spots in the tank. Temperature readings must also be taken on the outside of the metal to ensure the metal temperature is high enough (150°F (66°C) minimum) to cause the rubber/cement interface to cure. Stiffeners or other weldments on the outside of a vessel can also cause cold spots that will prevent the interface from curing properly. Insulation around such areas can help solve the problem.
5. **Steam Volume.** The amount of steam must be properly calculated. For correct boiler size see the formula in this section of our Engineering and Application Manual. The steam must escape around the nozzles and other openings to assure proper cure of the flange faces. If the steam is stagnant, cold spots form. Petcocks can be installed on extended piping and used to insure that steam flows through those areas and across the flange faces. The steam supply must not only be adequate but must be directed in such a way to ensure it is flowing over all rubber lined surfaces, especially the bottom. All condensate must be removed. 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 steam must be directed towards the bottom of the tank and flow around all surfaces.



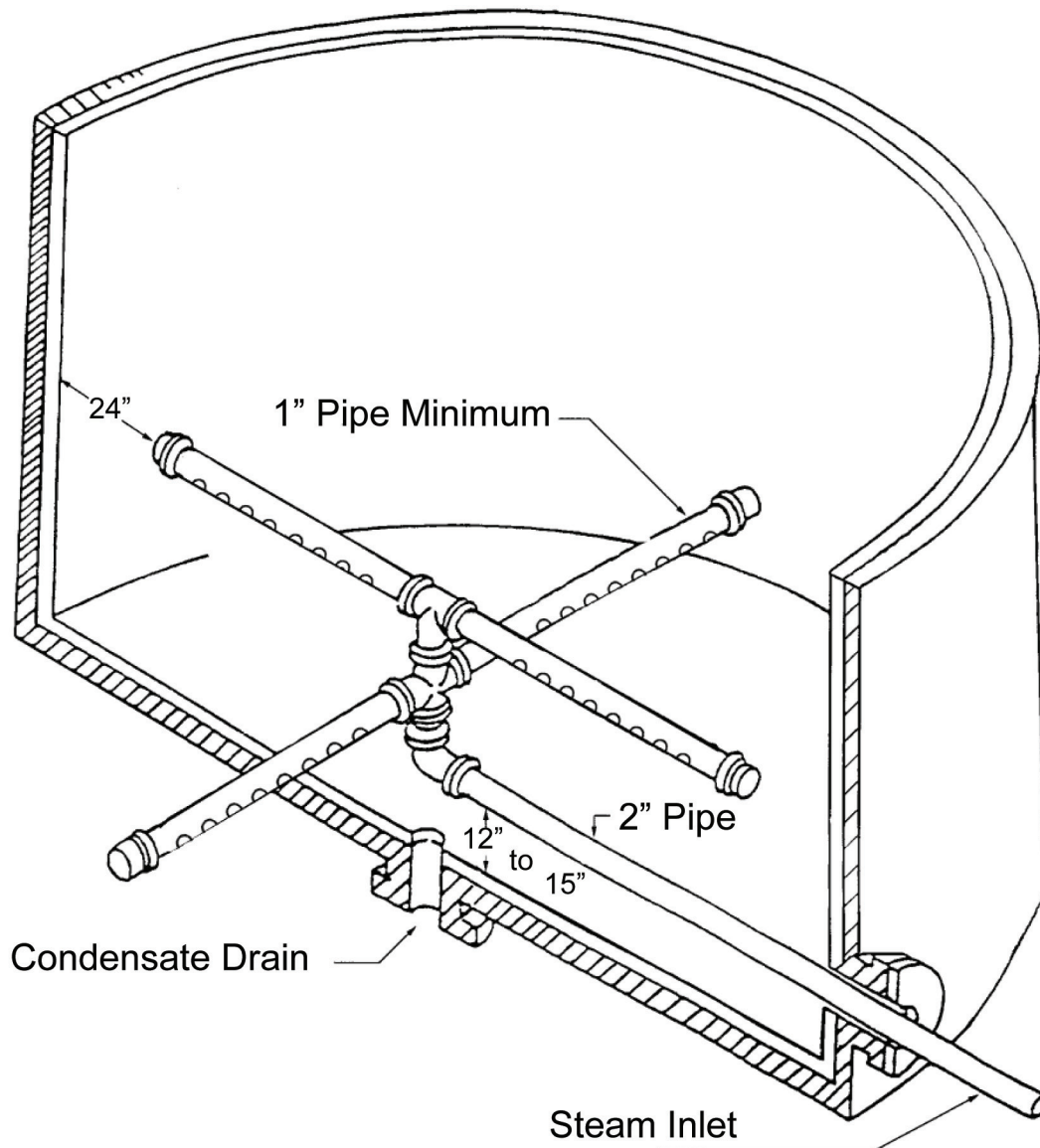
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6. **Vacuum Caution.** The entire cure and cool down must be monitored, especially if it is possible to pull a vacuum and collapse the vessel. Vacuum breakers may be necessary depending on the construction of the vessel.

We have tried to set the specific cure time on the individual lining specification that will provide a middle of the range cured durometer hardness. However, the supervisor on the job may be required to make adjustments to cure times to compensate for the many situations than can be found in the field. Good engineering practice and sound judgment cannot be over emphasized. Blair's Technical Department should be consulted concerning major changes to the cure specifications.

FIGURE P-2
TYPICAL EXHAUST STEAM PIPING ARRANGEMENT



NOTE: For larger tanks or during cold weather, larger sized piping and/or insulation may be required to maintain an inside curing temperature 180°F (82°C) to 200°F (93°C).

4. HOT WATER CURING SPECIFICATION

To be used only on specified linings (i.e. VE621BC). Consult with Blair's Technical Department before this procedure is implemented.

The only advantage for using a hot water cure on new installations is that it will add a little pressure from the weight of the water that may help secure the lining to a tank that is badly pitted. The disadvantages are that it takes much longer to cure, it requires more steam, it is not suitable for all linings and acquiring enough water, or disposing of the water, for a large tank can be a problem.

This method can offer some advantages for curing of a large tank that has been partially relined, i.e. the top portion or bottom portion.

If the top of a tank has been relined, fill the tank with water to just below the new lining and introduce the steam above the water to cure the new lining. This reduces the volume of steam required for cure and also dramatically reduces the amount of heat on the old lining. Without the water to protect it, the excess heat from the cure can destroy an old lining that is saturated with liquid.

If the bottom of a tank has been relined, fill the tank with water to just above the new lining and introduce the steam into the water and allow the hot water to cure the lining. Be sure to vent the top portion of the tank as much as possible to reduce the heat on the old lining. As above, this puts the heat where you want it without exposing the old lining to excess heat.

In preparation for water cure, the outlets and/or man ways either must be prepared using precured rubber as shown on Sketch F-1 on page 8 of this section or use chemical cure rubber on the flange faces and cure them with exhaust steam or have the outlet exhaust cured so the man way covers and blind flange plates can be tightened to hold the water. The tank must be vented to prevent any pressure build-up. The tank itself needs verification that is structurally designed to handle the hydrostatic weight of the water and the welds are suitable to withstand curing temperatures up to 210°F (99°C). Also, the tanks need to have sufficient foundation to support the water filled vessel.

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. After the hot water cure has been completed, a weather resistant chemical cure lining is then used to finish the top area.

Prior to filling the tank with water, steam sparger piping should be installed near the bottom of the vessel. The steam itself shall be directed so it will not impinge directly on the rubber surface, and it is recommended that the steam be introduced in an angled, downward position.

It may take considerable time for the water mass to heat. Once the temperature has reached 180°F (82°C) and the outside wall temperature is a minimum of 150°F (66°C), timing of the cure may commence. It is best for the water temperature to be 180°F (82°C) - 205°F (96°C). Time to cure: 180°F (82°C) - 60 hours minimum; at 190°F (88°C) - 48 hours minimum; and at 205°F (96°C) - 36 hours minimum to cure. The higher curing temperature of 190°F (88°C) to 200°F (93°C) is recommended. Well water or tap water may be used as the liquid media. A water source containing hydrocarbons of any type is not acceptable.

Thermocouples shall 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. If the vessel is exposed to cool weather or wind it will decrease the cure rate of the rubber. If this happens, insulation will need to be installed on the tank walls.

After the cure is completed, it is recommended that the water be allowed to cool down to approximately 110°F (43°C) before draining the vessel. This reduces any trapped air expansion. If the water temperature is slow to come down, it's permissible to add cold water.

5. CHEMICAL CURING

There are cases where using heat to cure the rubber lining is not possible. Steam may not be available, or the equipment to produce the steam is inadequate. Chemical cure rubber has been in the industry for many years. The cure system is based on sulfur and accelerators activated by amines at low temperatures. Carbon Disulfide was used frequently in the past but because of its extreme flammability and toxicity, it is not recommended today. **We specifically do not recommend the use of carbon disulfide with our linings.**

Chemcure™ activator is coated on the rubber lining sheet and allowed to dry. Then another coat is applied and allowed to dry. It is essential that the Chemcure™ is allowed to completely dry before any heat is applied. Failure to do so may result in blisters from the trapped solvent in the lining.

Chemical cure linings are typically used for field repairs. This type of curing can only be done with a chemical activator that is added to a lining that is designed to be cured in this manner. Curing of these types of linings may take days to weeks to fully cure depending on the temperature it is exposed to. Steam, heat lamps or other heat sources may be used to accelerate the curing process.

Even the best of chemical curatives applied with several coats may not penetrate through the lining and cure the lining adhesive. Care must be taken to ensure that no dynamic forces (chemical or physical) will be applied to the lining until it has cured throughout the lining.

Chemcure™ is solvent based and, as in the adhesives and cements, may be hazardous to the health of the applicators. Suitable masks and breathing apparatus during application of the products are required. All vapors should be removed from the tanks via adequate ventilation. Always observe proper safety precautions when using chemical cure rubber. Consult Blair's technical department as well as lining and Chemcure™ specifications for details. Refer to the Chemcure™ and lining MSDS for information regarding safety.

STEAM REQUIREMENTS FOR ATMOSPHERIC CURES

Pounds of steam/hour during 2 hour warm-up period:

Based on an enclosed vessel with 3/8" plate on bottom and 1/4" on sides and top:

$$.05V + .15A + .005W = \text{pounds of steam/hour}$$

V - Volume in cubic feet

A - Area in square feet

W - Weight of rubber and steel in pounds

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Pounds of steam per hour 30 = Boiler Horsepower
 Example of steam requirement @ 2000 pounds/hour:

Steam source 1000' away with 2" line - 75# pressure needed Steam source 500' away with 2" line - 50# pressure needed Steam source 200' away with 2" line - 30# pressure needed

FLOW OF STEAM PER 1000' OF PIPE IN POUNDS/MINUTE

50# GAUGE PRESSURE

1"	2"	2.5"	3"	3.5"	4"
4.27	25.8	40.7	71.5	89.0	144.0

75# GAUGE PRESSURE

1"	2"	2.5"	3"	3.5"	4"
6.32	36.7	57.7	101.0	146.5	204.0

100# GAUGE PRESSURE

1"	2"	2.5"	3"	3.5"	4"
8.15	52.5	74.5	130.0	185.0	263.0

LENGTH OF PIPE	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
1000'	1.02

Example: If steam source is 100' away and if a 2" pipe is used and gauge pressure is 50#, then $3.16 \times 25.8 = 81.53\#$ of steam delivery/minute.

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BOILER SIZE CALCULATIONS

$$\text{BTU/HR} = \frac{\text{Heat Loss} \times (T_f - T_i)}{1 - e^{-\left(\frac{\text{Heat Loss}}{\text{Specific Heat}}\right)}}$$

Heat loss is expressed as BTU's lost per square foot per degree Fahrenheit above ambient.

T_f is the final temperature you expect to achieve.

T_i is the initial or ambient temperature.

e is the natural logarithm.

Specific heat is expressed as the BTU's required to raise the temperatures of one pound of material one degree Fahrenheit in one hour.

This formula uses the heat loss and specific heat of the entire tank. You will need the area of the tank in square feet for the calculations. To calculate heat loss of a tank sitting on a concrete pad, multiply the area of the roof and sides by 2.4 if uninsulated and by 0.5 if insulated. Add this to the area of the bottom multiplied by 0.1 and you have the heat loss of the tank. If the tank is elevated use the same multiplier for the bottom that you used for the roof and sides.

To calculate specific heat, you will need the total weight of the tank and 4 inches of concrete under the tank. 1/8 inch steel weighs 5.1 pounds per square foot. Concrete weighs 140 pounds per cubic foot. For open top tanks, assume 1/4 inch thick steel. Multiply the total weight by 0.14 and you have the specific heat of the system. If the tank is elevated use only the weight of the steel.

As an example, to calculate the boiler required to cure a 40 foot diameter by 40 foot high open top tank on a concrete pad. The average thickness of the walls is 5/16 inch thick, the floor is 3/8 inch thick and 1/4 inch steel is assumed for the open top. Ambient temperature is 60°F (16°C) and final temperature is 180°F (82°C).

Area of the roof = 1257 square feet

Area of the walls = 5027 square feet

Area of the floor = 1257 square feet

The volume of concrete = 0.33 ft x 1257 sq ft = 415 cu ft

CALCULATE HEAT LOSS - UNINSULATED

1257 FT² + 5027 FT² = 6284 FT²

6284 x 2.4 = 15,082 BTU/HR/°F

1257 FT² x .1 = 126 BTU/HR/°F

Total heat loss = 15,208 BTU/HR/°F

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CALCULATE SPECIFIC HEAT

Roof	=	1257 ft ² x 10 lbs	=	12,570 lbs.
Walls	=	5027 ft ² x 12.5 lbs	=	62,838 lbs.
Floor	=	1257 ft ² x 15 lbs	=	18,855 lbs.
Concrete	=	415 ft ³ x 140 lbs	=	58,100 lbs.
Total Weight			=	152,363 lbs.
Specific heat	=	152,363 x 0.14	=	21,331

You now have all the information to calculate boiler size.

$$BTU / HR = \frac{15,208 \times (180 - 60)}{[1 - e^{-\left(\frac{15,208}{21,331}\right)}]}$$

$$= \frac{15,208 \times 120}{[1 - e^{-.71}]}$$

$$= \frac{1,824,960}{1 - .49}$$

$$= \frac{1,824,960}{.51}$$

$$BTU/HR = 3,578,353$$

$$1 \text{ boiler horsepower} = 33,500 \text{ BTU/HR}$$

$$3,578,353 \div 33,500 = 107 \text{ horsepower}$$

A 100 horsepower boiler will work but a 125 horsepower boiler is recommended.

The same tank with insulation calculates to 84 horsepower. It is recommended that a 100 horsepower boiler be used.

Generally, you should increase the boiler size for open top tanks because it is impossible to prevent steam leaking around your cover.

For very large tanks, please call for more information.

PRESSURE-TEMPERATURE EQUIVALENTS OF SATURATED STEAM

GAUGE PRESSURE AT SEA LEVEL			GAUGE PRESSURE AT SEA LEVEL		
POUNDS PER SQUARE INCH	TEMPERATURE		POUNDS PER SQUARE INCH	TEMPERATURE	
	°F	°C		°F	°C
0	212.0	100.0	85	327.6	164.2
5	227.1	108.4	90	331.2	166.2
10	239.4	115.2	95	334.6	168.1
15	249.8	121.0	100	337.8	169.9
20	258.8	126.0	105	341.1	171.1
22	261.2	127.8	110	344.1	173.4
24	265.3	129.6	115	347.2	175.1
26	268.3	131.3	120	350.1	176.7
28	271.2	132.9	125	352.9	178.3
30	274.1	134.5	130	355.6	179.8
32	276.8	136.0	135	358.3	181.3
34	279.3	137.4	140	360.9	182.7
36	281.8	138.8	145	363.4	184.1
38	284.4	140.2	150	365.9	185.5
40	286.7	141.5	155	368.2	186.8
42	289.0	142.8	160	370.6	188.1
44	291.2	144.0	165	373.9	189.4
46	293.5	145.3	170	375.3	190.7
48	295.5	146.4	175	377.4	191.9
50	297.7	147.4	180	379.6	193.1
52	299.7	148.7	185	381.7	194.3
54	301.6	149.8	190	383.7	195.4
56	303.6	150.9	195	385.9	196.6
58	305.4	151.9	200	387.9	197.7
60	307.4	153.0	205	389.8	198.8
62	309.2	154.0	210	391.6	199.8
64	310.8	154.9	215	392.9	200.5
66	312.6	155.9	220	395.4	201.7
68	314.2	156.8	225	397.2	202.9
70	316.0	157.8			
72	317.7	158.7			