FREEZING PROBLEMS ASSOCIATED WITH STEAM SYSTEMS IN THE PETROCHEMICAL AND REFINING INDUSTRIES

In an attempt to avoid freezing problems and interrupted production, cracked valves to atmosphere and bypassed traps to the sewer have been common. The cost and scarcity of energy or fuel has made such methods not only impractical, but has also shrunk the profit on the product being produced. We need to look for other answers reducing downtime and costly maintenance caused by freezing. These answers, however, must keep in mind the ever important consideration of steam conservation.

Tracer lines and main and branch line drip installations make up better than 80% of the trap installations in chemical and refinery plants. These are the installations that generally cause freeze-up problems. Fortunately, however, a well-designed and engineered drip and tracer line system can be constructed to virtually eliminate the danger of freezing. Care must be taken in tracer line and return system design, trap selection, and production requirements. It is helpful to examine freeze resisting design criterion for trap stations.

1. <u>Eliminate the water from tracer lines that are out of service or operate intermittently during freezing conditions.</u>

If gravity discharge is possible, it has been said that so-called "free draining" steam traps have been used to drain water from the system when it is shut off avoiding freezing. Unfortunately, "free draining" steam traps, such as disc or bimetallic thermostatic traps, act as check valves. When an interruption of the steam supply occurs such as a stoppage in the tracer line or a closed valve, a portion of the steam is trapped in the tracer line. This trapped portion of steam naturally condenses. Since steam occupies many times the volume of its equivalent weight of condensate, vacuum forms pulling the disc to the seat, and the condensate is held in the tracer line as in Figure 1.

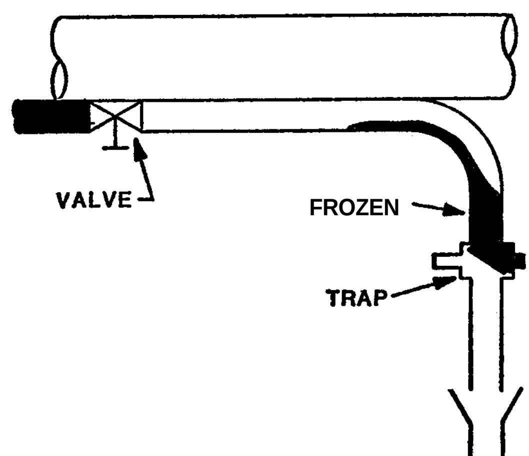


FIGURE 1.

The tracer line and trap freeze. This system is not self-draining and not freeze proof. Also, corrosion is aggravated by the presence of condensate and air held in the piping. A vacuum breaker in the tracer line allowing the water to drain by gravity may help these installations providing no low points in the tracer line exist. The real drawback for any self-draining installation is simply the fact that few companies can afford to waste energy by allowing condensate to drain by gravity to the sewer. Rising energy costs and environmental pressures are forcing the reclamation of condensate.

2. Isolate tracer and drip trap stations from freezing conditions.

To isolate trap stations from freezing conditions an enclosure must be built around the trap station including piping, valves, and traps. This is shown in Figure 2.

TRAP STATION ENCLOSURE

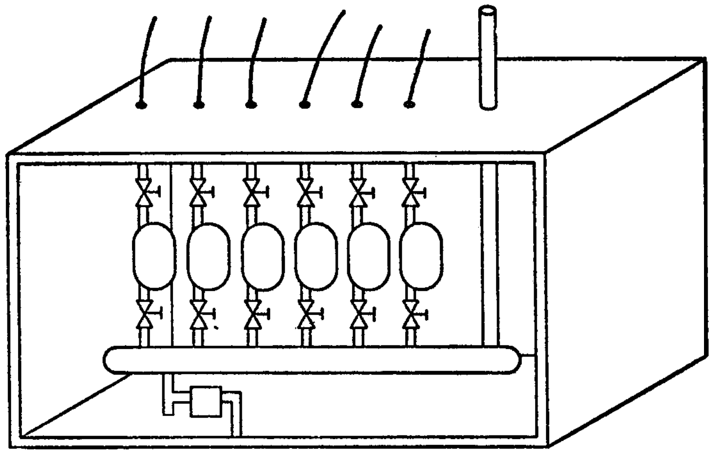


FIGURE 2.

This is, of course, expensive and consumes space. This installation requires a well-insulated enclosure with access panels or doors for maintenance.

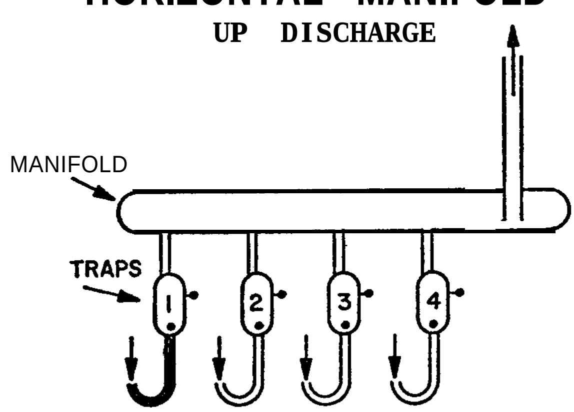
3. Utilizing existing heat found in condensate and flash steam to keep complete trap stations from freezing.

A practical design is one that uses the heat of the flash steam to prevent freezing even though tracer lines have been interrupted. In an attempt quantitatively to determine these conditions, extensive trap station freeze tests have been conducted. These tests were conducted to relate different tracer and drip trap station configurations to their freeze resistance.

All tests were conducted in a freeze chamber utilizing a condensate collection manifold discharging to an overhead return. The complete installation was thermocoupled and continuously temperature monitored. All tests utilized energy conserving inverted bucket traps of stainless steel construction. The first trap station utilized a horizontal manifold with the traps piped up to the bottom of the manifold as shown in Figure 3.

HORIZONTAL MANIFOLD

UP DISCHARGE



'THERMOCOUPLE LOCATIONS

FIGURE 3.

This test was conducted two ways, first uninsulated and then insulated. Trap #1 (in Figure 3) was the live or the main line drip trap, Traps #2, #3, and #4 were tracer line traps with the steam being turned off at the start of the test reflecting tracer line blockage or interrupted service. The results of the uninsulated tests are shown in Figure 4. The first trap to reach freezing, Trap #4, froze within an hour and a half. The same test was run with insulated traps and manifold under identical conditions. Figure 5 shows the results.

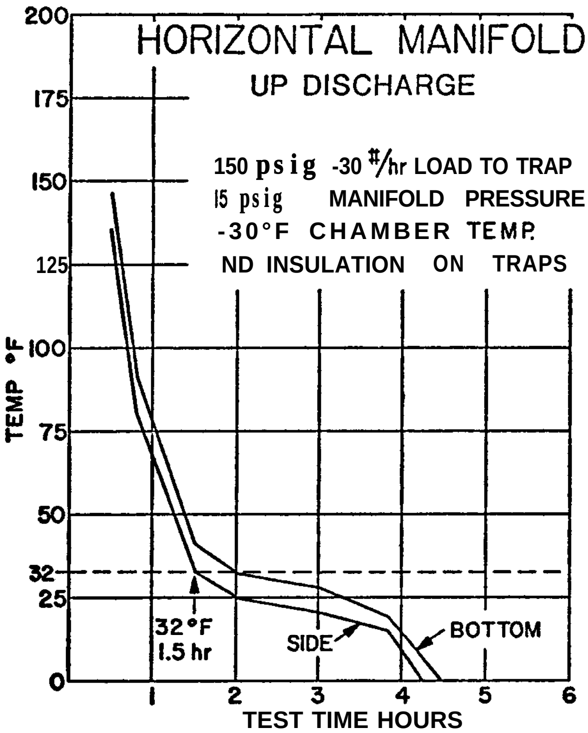


FIGURE 4.

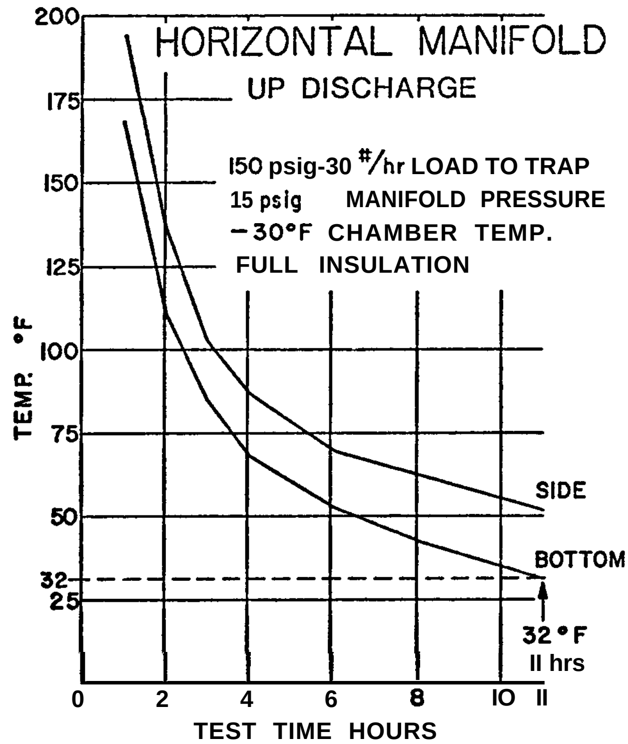


FIGURE 5.

The insulated traps took much longer to freeze, 11 hours, but they did freeze under these severe conditions.

The next trap station design tested, utilized the vertical manifold (the Christmas tree). This is shown in Figure 6.

VERTICAL MANIFOLD
BOTTOM IN-TOP OUT TRAPS

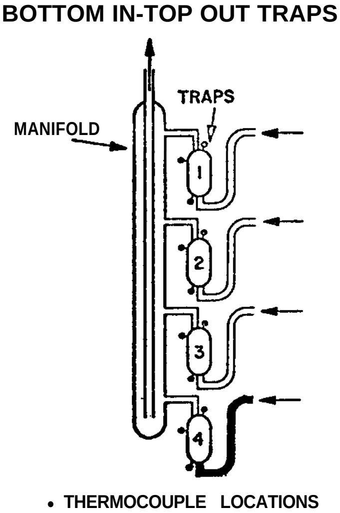


FIGURE 6

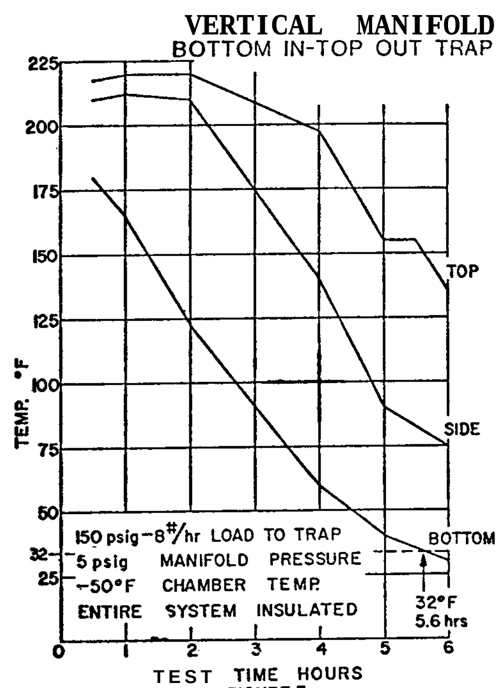


FIGURE 7.

A vapor space or flash steam space is insured in the manifold by extending the condensate riser down the length of the manifold as shown in Figure 6. The traps and manifold were fully insulated. Trap #4 was the live trap or main line drip trap and Traps #1, #2, and #3 were shut-off. Under these extreme conditions, chamber temperature -50°F., manifold pressure 5 psig, and live trap load 8#/hr. typical instrument tracer load, the first trap to reach freezing (Trap #1) froze in 5.6 hours.

The same test was then conducted except side-in and side-out inverted bucket stainless steel traps were utilized. This trap station was again subject to most extreme conditions, very low load 8#/hr. in the live trap (Trap #4), a low manifold pressure of 5 psig, and a chamber temperature of -50°F.

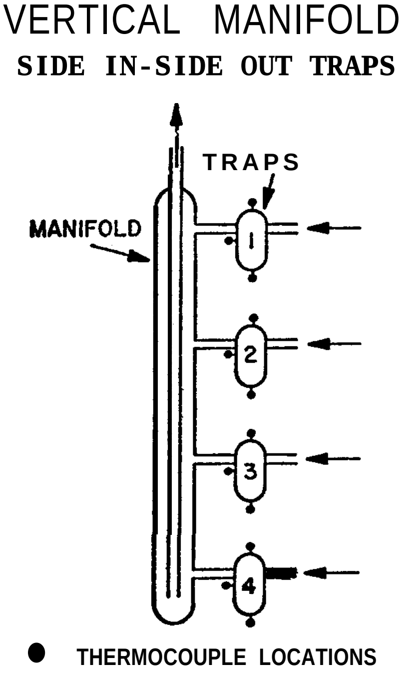


FIGURE 8.

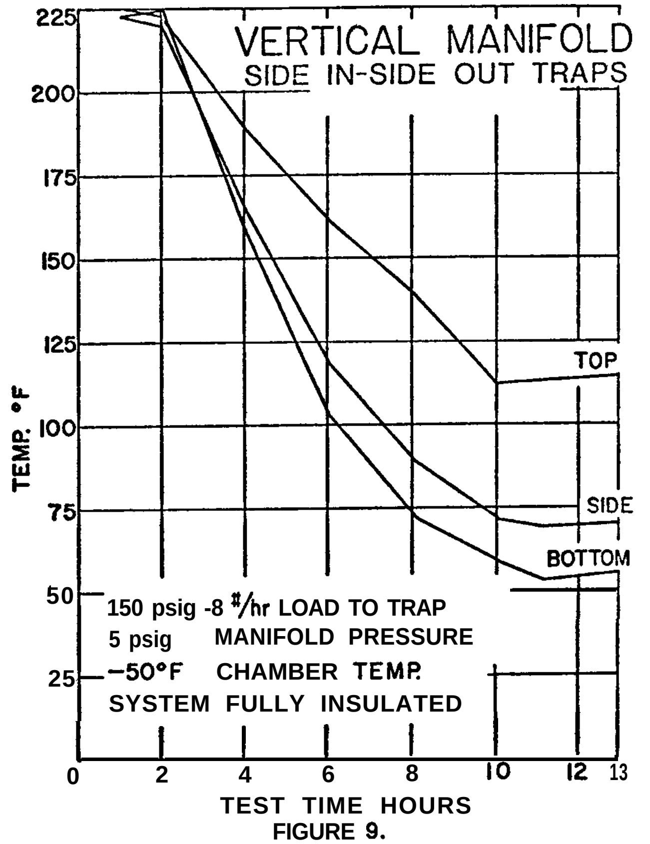


FIGURE 9.

As noted in Figure 9, this fully insulated side-in, side-out trap station would not freeze. Within 11 hours, the temperatures had stabilized and although the test continued for 30 hours the complete trap station stayed above freezing.

The next trap station design tested utilized a horizontal manifold with top-in, bottom-out traps. This design is utilized extensively in refineries and chemical plants. A condensate return line is commonly discharging up overhead to the main condensate line in the overhead rack system. Please note in Figure 10 that the condensate return line extends down to within a half inch of the bottom of the two inch collection manifold.

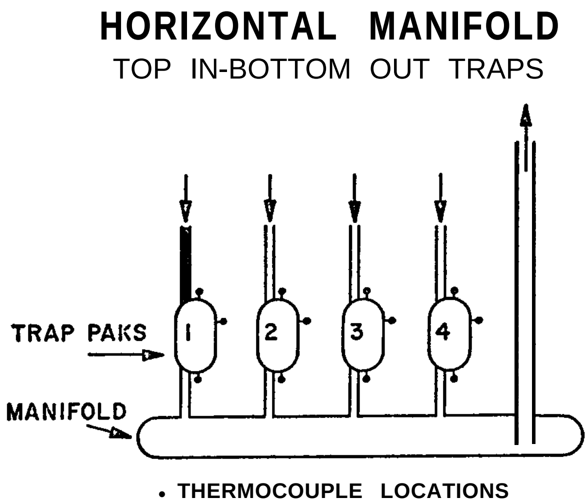


FIGURE 10.

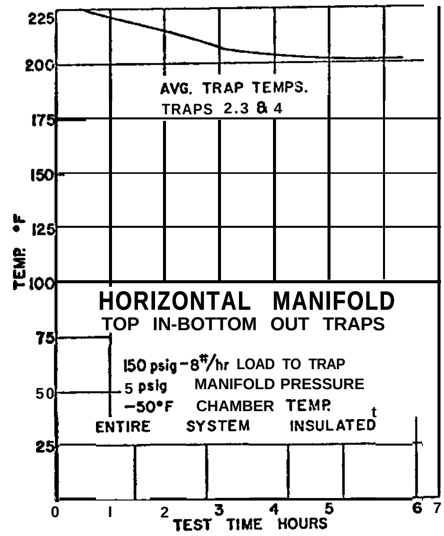


FIGURE II.

This permits the flash steam to collect in the manifold. All tests on this arrangement were conducted in a cold chamber of -50°F. Trap f1, simulating a drip trap or live tracer line trap had a low load of 8#/hr., a low back pressure or manifold pressure of 5 psig was maintained simulating the pressure needed to lift to the overhead condensate line in the rack system. Tests begin when Traps #2, #3, and #4 were shut off. As the temperature versus time chart shows (Figure 11), the system stabilized at about 200°F. The curve in Figure 11 represents the average trap temperature of traps #2, #3, and #4. The heat transfer from the manifold up to the inactive traps is effective even under these most severe test conditions.

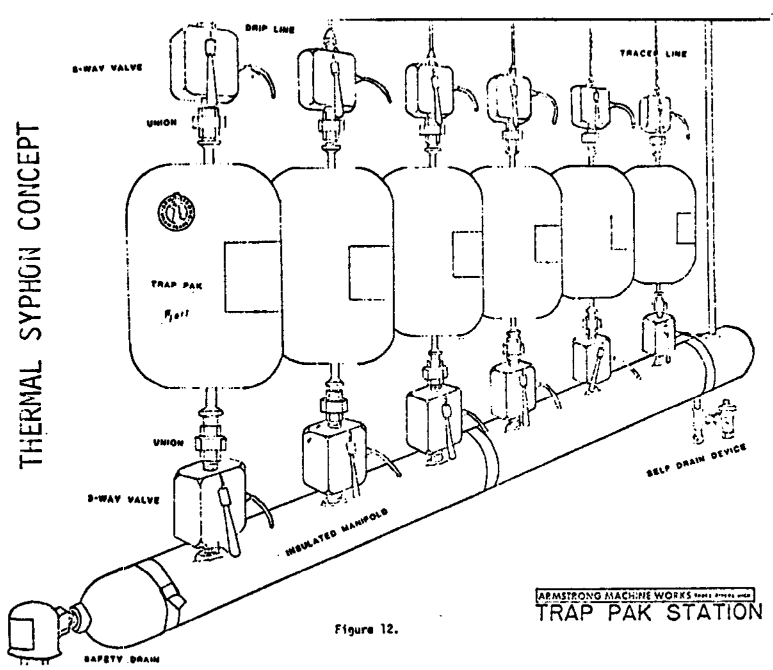


Figure 12.

This "thermal syphon design" trap station utilizes the heat pipe principle of transferring energy in the form of heat. The waste flash steam is transferred up to the insulated traps eliminating freezing. This thermal syphon design has been utilized in operating chemical plants and refineries successfully. The design as shown in Figure 12 utilizes this thermal syphon design. The thermostatic air vent at the end of the manifold prevents an accumulation of air in the horizontal collection manifold. As the air accumulates, the temperature is depressed and the thermostatic air vent opens discharging the cooler air. The thermo activated drain device connected at the bottom of the manifold is set at a much lower temperature draining the system if a total steam shutdown should occur in the plant. This thermal syphon trap station not only conserves energy by utilizing inverted bucket traps, it reduces downtime and costly maintenance due to freezing,

Another aspect important to consider regarding freezing steam systems is the ability of the pressure vessel of the steam trap to resist damage due to the forces of freezing. These forces caused by the expansion of freezing are enormous. Freezing will rupture pipes, steel or stainless steel traps, and crack cast iron even quicker. The thin wall stainless steel case of the inverted bucket trap shown in Figure 13 "gives" with the forces of freezing resisting the damage commonly associated with this problem. Sooner or later, any pressure vessel subjected to a full charge of water and repeated freezing will rupture, but the stainless steel thin wall pressure vessel resists rupturing longer than other pressure vessels.

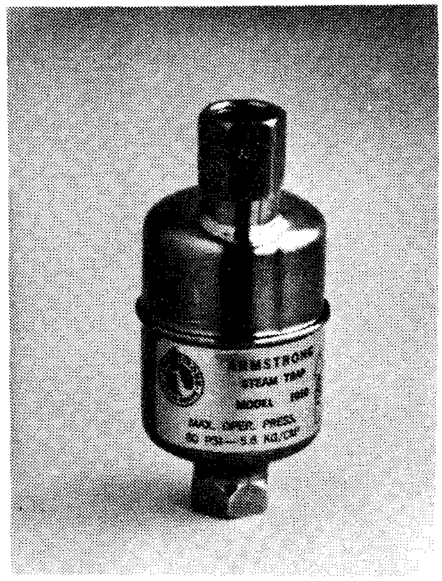


Figure 13.

After subjecting this type of trap to freezing conditions, many times the vessel tends to take a rounder shape (see Figure 14). These traps although frozen repeatedly, are still in operating condition and no damage is done to the internal parts. This is particularly significant considering the cost of steam. Although subjected to repeated freezes, this trap does not consume energy (see Figure 15). When the total energy loss across the trap is tested, its energy consumption is no more than a new one.

Figure 14.

TRAP LOSS CALCULATIONS

TRAP____ TEST CHAMBER____ TEMP____ T.R NO.____ DATE____

NOTES: TRAP HAS BEEN FROZEN SEVERAL TIMES

	TEST NO. →			101	102	103		
SUPPLY		STEAM PRESS.	PSIG					
		STEAM TEMP.	°F					
	hf	AT STEAM TEMP.	BTU/LB					
	hfg	AT STEAM TEMP.	BTU/LB					
HEAT EXCHANGER	TIN	OF WATER	°F					
	TOUT	OF WATER	°F					
	TAVE	½ (TIN + TOUT)	°F					
	ΔT	TOUT − TIN	°F					
	ΔW	AMT. OF WATER	LBS					
	Cp	AT TAVE	BTU/LB·°F					
	CONDENSATE LOAD GENERATED IN HEAT EXCHANGER							
	LHE	60·ΔW·Cp·ΔT/t hfg	LB/HR					
	Wc	WT. OF CAN	LBS					
	Ws	START WT.	LBS					
DISCHARGE COLLECTION	WE	END WT.	LBS					
	ΔW	WE − Ws	LBS					
	t	TIME	MIN					
	LOAD DISCHARGE BY TRAP							
	Lo	ΔW (60/t)	LB/HR					
	Wi	Ws − .883 Wc	LBS					
	Wf	WE − .883 Wc	LBS					
	Ti	START TEMP.	°F					
	hfi	AT Ti	BTU/LB					
	Tf	END TEMP.	°F					
	hff	AT Tf	BTU/LB					
	Δqt	(Wf·hff − Wi·hfi) 60/t	BTU/HR					
	TOTAL TRAP LOSS							
	LT	Lo − LHE	LB/HR	1.440	1.879	2.957		

Figure 15.

As we have seen, trap stations, when properly installed and constructed, are remarkably trouble-free even under the most extreme freezing conditions. It is very possible for trap stations to be constructed with little danger of freezing while the inlet or outlet lines are potential freeze problems. If dips or water pockets should occur in the line, water sealing the tube could freeze when steam is off (see Figure 16).

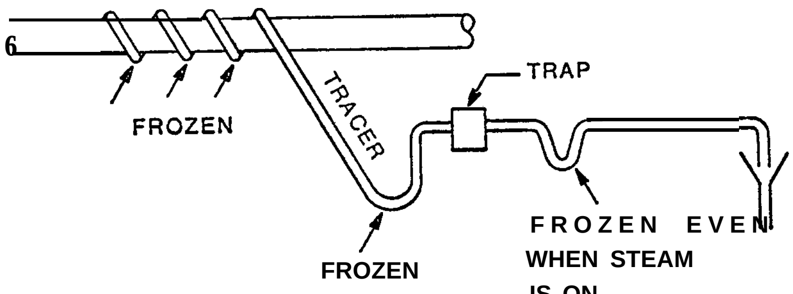


FIGURE 16.

A particularly severe problem occurs when an individual trap is installed discharging up to an overhead return (see Figure 17 and 13).

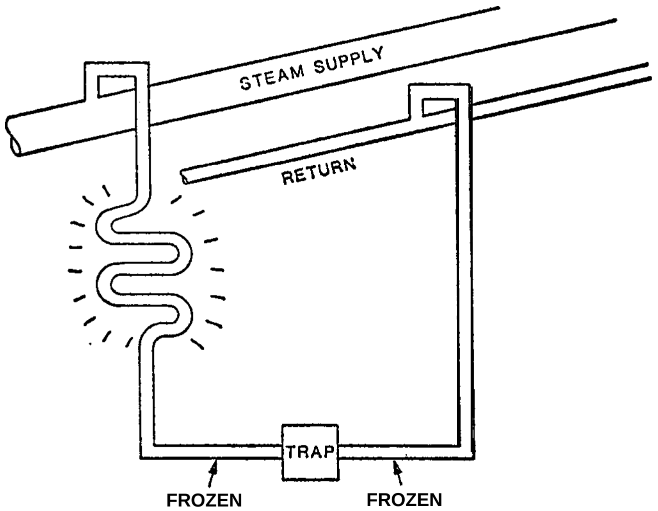


FIGURE 17.

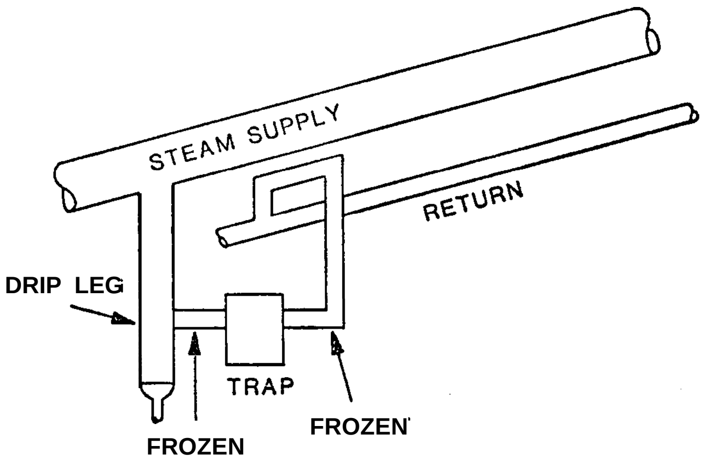


FIGURE 18

When the steam is interrupted, the whole loop, steam line, valves, traps, and return line, can and many times will freeze. When an interruption of steam during freezing conditions is a possibility, that installation should be avoided. Please remember that if freezing occurs in the tracer line or steam trap installation, it may be because of poor tracer line or trap station design. The need for sound engineering of tracer line and trap installations cannot be overemphasized.