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SUBJECT: Semipermanent Freeze Plug Tests for HRT-CP

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FROM: R. H. Winget

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Summary

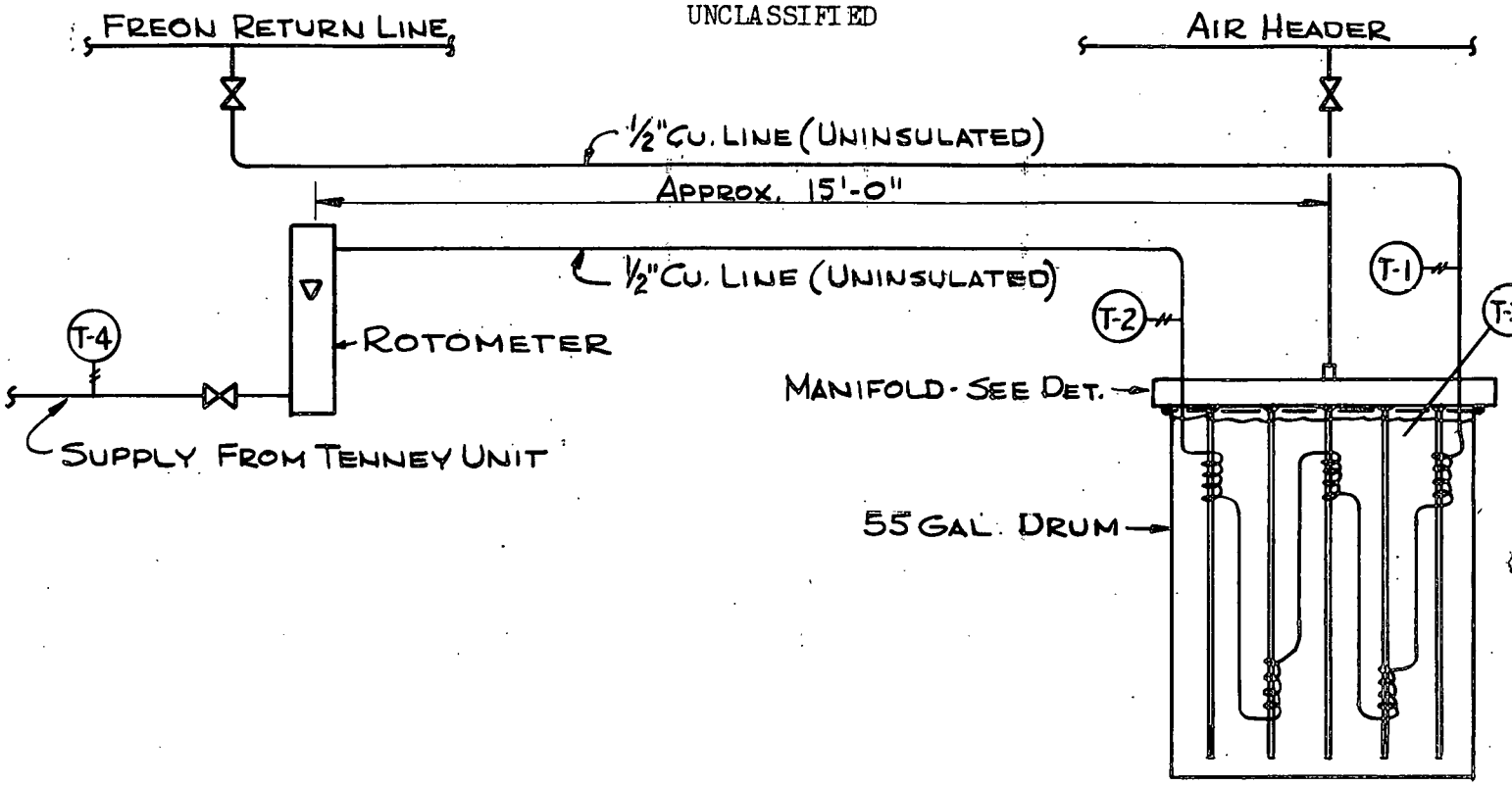
Five uninsulated semipermanent freeze coils, series connected, can be frozen when submerged in 70°F water with a Freon-11 flow rate of 1.85 gpm at an inlet temperature of -40°F. The refrigeration unit of the HRT-CP is capable of delivering >3 gpm to a similar semipermanent freeze coil system located in Cell C. Therefore the number of F-11 risers required in Cell C of the HRT-CP can be minimized by series connecting this many semipermanent freeze coils where required.

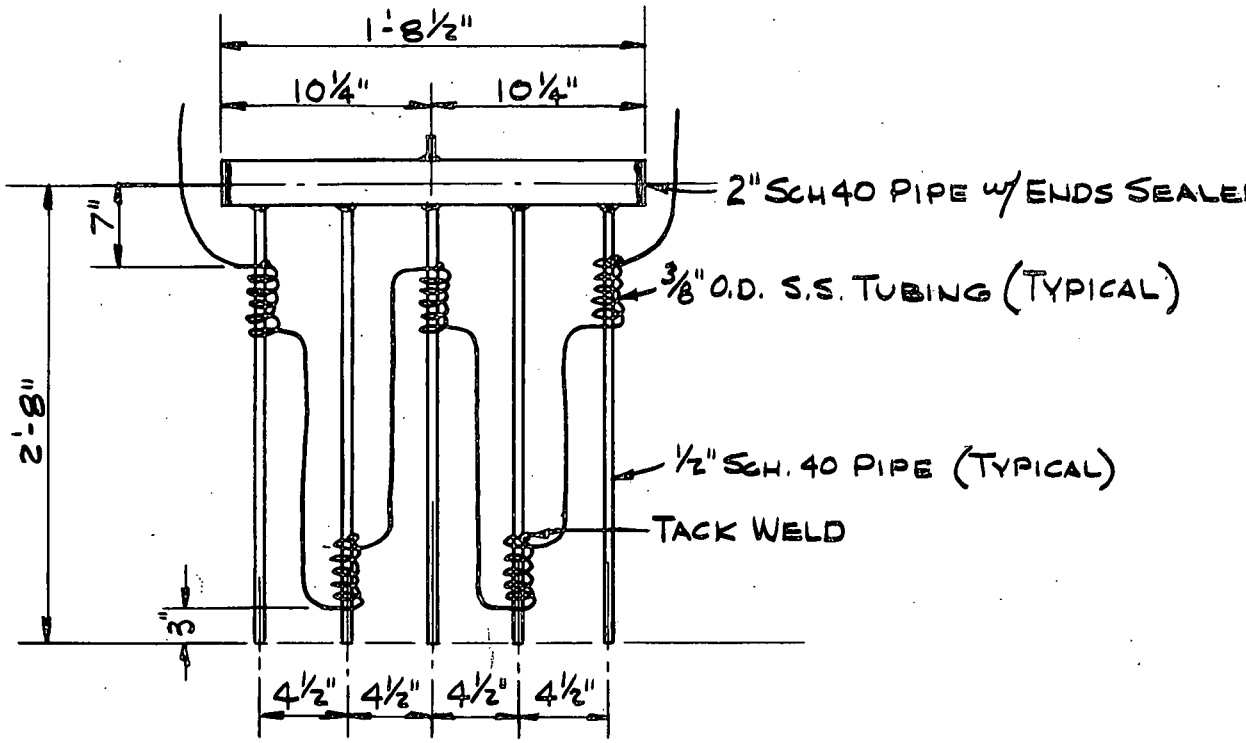
Equipment

A mockup consisting of five 32" lengths of 1/2" diameter Schedule 40 stainless steel pipe welded to and extending from a 2" diameter stainless steel header into a 55-gallon drum of water was fabricated to simulate submerged process lines. Approximately 12' of 3/8" continuous stainless steel tubing was used to wrap one freeze coil around each of the five submerged legs extending from the common header. The first coil of the first freeze plug was located 6" below the header and the final coil of the second freeze plug was located 3" above the end of the second leg. The three remaining freezers were located similarly to provide a maximum length of submerged uninsulated 3/8" stainless steel tubing. Each coil consisted of five turns with an over-all length of 6-1/2" and was spot welded to each 1/2" leg for support. An 80-psi air-supply line connected to the 2" header permitted a check of the number of solid ice plugs. Freon-11 was metered through a 2.5 gpm rotameter through about 15' of 1/2" uninsulated copper tubing from the F-11 pump to the submerged freezers and returned to the unit via a similar uninsulated line. Thermocouples were provided on the Freon line leaving the pump, the Freon line entering the first freeze coil, the Freon line leaving the fifth freeze coil, and in the water surrounding the coils. Figure 1 shows the details of the mockup.

Procedure

The drum containing the five series connected freeze coils was filled with process water. Steam was used as required to maintain the temperature of the water near 70°F. The 2" header was vented to allow the five legs to fill with water. Temperature readings were taken immediately prior to starting Freon flow. Flow was started to the system at a predetermined rate and temperatures were recorded every five minutes. After ten minutes of Freon flow, 80 psi of air was applied against each of the five freeze plugs to determine how many of the five





MANIFOLD DETAIL

Fig. 1. MOCKUP OF FIVE UNINSULATED SERIES CONNECTED FREEZE COILS

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freeze coils had formed ice plugs. Usually if one or more plugs were not holding, the system was vented to atmosphere and the flow stopped in order to allow the temperature of the Freon supply and exit lines to return to approximately room temperature. In a few instances, the header was vented while allowing the Freon flow to continue for several minutes before again testing for formation of ice plugs. Visual observation as well as the sense of touch proved quite useful in ascertaining if ice plugs had formed.

Results

Typical data for some of the runs are shown in Table I. The minimum flow rate of Freon which froze all five ice plugs capable of holding against 80 psi was 1.85 gpm with the Freon inlet temperature around -40°F. Approximately twelve minutes at this flow rate was required to form all five ice plugs. At a flow rate of 1.3 gpm, plugs were not formed in 30 minutes.

Run 1 demonstrated that all five plugs could be frozen in ten minutes with a Freon flow rate of 2.5 gpm. All five plugs held against 80 psi for 2 minutes and 20 seconds after the Freon flow was stopped.

Run 3 was allowed to continue after all five ice plugs had formed at a Freon flow rate of 1.85 gpm to determine the minimum Freon flow necessary to maintain all five ice plugs. The Freon flow rate was decreased from 1.85 gpm to 1.3 gpm for ten minutes, then decreased further to 0.8 gpm for ten minutes, and finally decreased to 0.6 gpm for ten minutes. All five ice plugs held against 80 psi of air during this 30 minutes; however, observation of the exit Freon temperature showed a marked rise after five minutes at 0.8 gpm. The final exit temperature at 0.6 gpm indicated that the plugs would thaw if Freon flow were not returned to at least 1.3 gpm.

TABLE I

Run No.	F-11, Flow Rate, gpm	F-11 Inlet Temperature, °F	ΔT, °F*	Water Temperature, °F	Time Required To Freeze, minutes
1	2.5	-42	17	74	10
2	1.3	-40	29	72	Unable to freeze
3	1.85	-40	21	66	12
3	1.3	-41	24	66	Plugs holding
3	0.8	-42	27	65	Plugs holding
3	0.6	-43	33	64	Plugs holding
4	1.85	-40	17	72	14

*Temperature rise of the F-11 across the five series connected coils.

Recommendations

It is recommended that five uninsulated semipermanent freeze coils be connected in series where required provided that a minimum Freon flow rate of 1.85 gpm is available at $-40^{o}F$ and not more than 12' of exposed tubing including the coils is used. The refrigeration unit of the HRT-CP is capable of delivering ≥ 3 gpm to a similar semipermanent freeze coil system located in Cell C.

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