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HRT LEAK DETECTION SYSTEM

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Summary

All HRT process piping and equipment is contained in a large tank and flanged connections with stainless steel ring gaskets are used where needed to permit the removal of valves and items of equipment. Underwater remote maintenance is to be employed and special provisions are required for indicating and locating leaks at all mechanical joints in the process system. Each joint is monitored and a signal is given when a leak occurs.

The valve operator stems are sealed with stainless steel bellows and a means of detecting a leak in the bellows has been included.

Introductions

A hole 1/8" diameter is drilled to the "V" groove of each flange pair. Figure 1 shows the typical connection to the flange. Each "V" groove is connected by a stainless steel tube to a header located in the bottom level of the control area. The headers, tubing and flange grooves contain D_2O at a pressure ~ 500 psi above the design operating pressure, to assure leakage into the system of a compatible material should a leak across the gasket occur. Two high pressure and two low pressure headers are located in this area and are arranged to provide a valving station for all leak detector lines. A liquid-filled system has been selected to obtain the sensitivity required for detecting very small leaks.

A single pressurizer supplies all four headers. The pressurizer connects to the gas converter, equipment item 26a; a drum of D_2O mounted on the second level of the control area; an air vent; and each of the four headers. It is equipped with a liquid level sight gauge.

Headers are sectionalized to simplify the search for individual leaks, and each of the four systems is equipped with a bourdon tube type pressure gauge and a low level alarm connected in series to an annunciator (Number 8540-1). The low pressure headers each have a bypass line to the D_2O supply drum with a 1000 lb rupture disc in the line to protect the low pressure pipe flanges from excessive loads.

The valve operator bonnets, enclosing the bellows, are connected to valves mounted just under the roof plug in the "valve bay". A leak in the bellows of the valves would leak through the valve packing and actuate the cell air monitor. After draining the system to the dump tanks and removing the roof plugs, gas pressure can be applied to the system and all bellows checked from one location. This test would consist of opening the valves in succession and checking each for bubbles of the pressurizing gas.

Operation

The leak detection system is divided into four separate systems connected to a common pressurizing header. Flowsheet drawing E-25588 details the combinations of flanges and valves.

1. Filling Procedure

(a) After the complete system has been installed, pressure tested, and found to be tight, a vacuum pump should be connected to the pressurizer header vent line and the system evacuated to 50 microns of Hg. The valves to the D_2O fill tank and to the oxygen supply(or compressor) should be closed, and all other valves should be opened.

(b) When the specified vacuum has been reached, close valve C in the vent line and open valve A to the D_2O fill tank, allowing the system to fill up and the liquid level in the pressurizer to rise in the sight gauge to approximately 1" from the top of the glass.

(c) Close valves D, E, F, and G to the four systems and open valve B to the O_2 or compressor line and build up the pressure to 2500 psig. Close valve B.

(d) Open valves D, E, H, I and J to the high pressure systems, building the pressure to 2500 psig as indicated by the dial gauges mounted on the headers. When the systems have reached the designed pressure, close valves D and E to the pressurizer.

(e) Repeat step (c) and build up pressure to 500 psig. Open valves G, F, and H to the low pressure systems building the pressure to 500 psig as indicated by the dial gauges mounted on the headers. When the design pressure of 500 psig has been reached, close valves G and F to the pressurizer.

(f) Connect and check the audio alarm and lights.

Leak Hunting Procedure

A leak in any of the lines connected to the headers will cause the header pressure to drop actuating the alarm. On alarm signal, the four pressure gauges mounted on the headers at the valve station will have to be checked to locate the system in which the leak has occurred. Proceed as follows:

(a) Open valve to the pressurizer just sufficient to maintain pressure (with the leak equalized).

(b) Close the valve between the sectionalized headers. (1) If the pressure continues to hold steady, the leak is in section of header adjacent to the pressurizer. (2) If the pressure rises, the leak is in the header away from the pressurizer.

(c) Close all individual valves in the section of header containing the leak, bring system to pressure and close the valve to the pressurizer.

(d) Open valves in succession until a pressure drop signals a leak. Close this valve and continue the check for balance of header section to see if other leaks also exist.

Discussion

Many ideas were investigated and HRE experience reviewed before a firm design was chosen for the HRT leak detection system.

Tubing

An early decision was made to use 1/4" O.D. 0.065" wall - 347 stainless steel tubing and welded joints. This decision was based on an early materials procurement schedule, and the fact that the soldered connections and thin wall tubing used in the HRE were the source of several leaks within the system itself. During the subsequent development of the system the "leak detection" developed for "in-pile loop tests" was reviewed with H. C. Savage. The methods used on the in-pile loops are adaptable to the leak detection requirements of the HRT and have some advantages which should be considered in future designs. Stainless steel capillary tubing 0.080" O.D., 0.020 wall thickness is used and a special technique has been developed for making connections in this tubing.

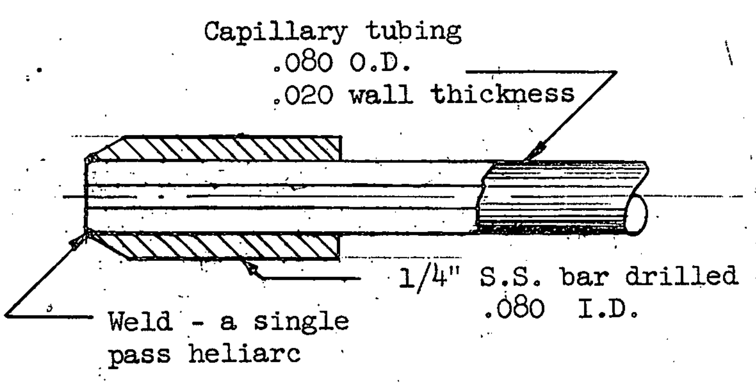
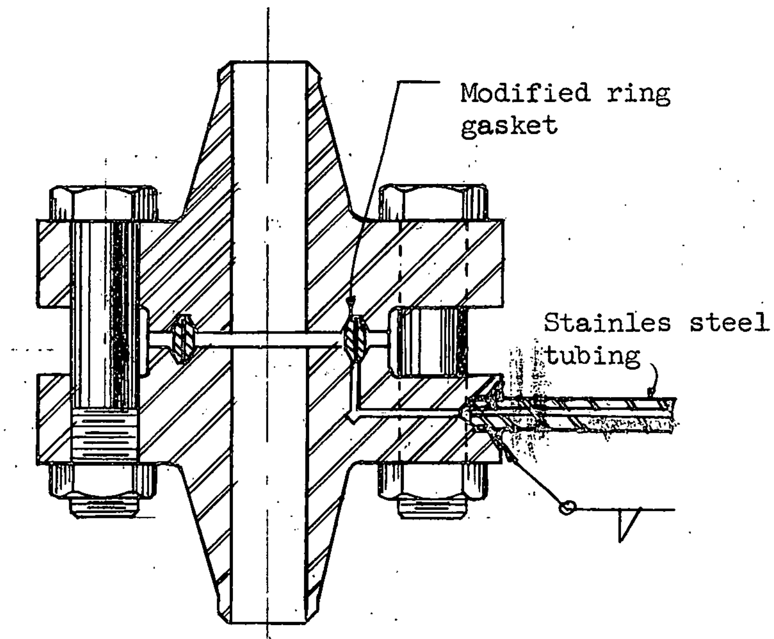


Fig. 2



Ring-Joint Flange Leak Detector
Fig. 1

The 1/4" O.D. bar shown in Fig. 2 can be threaded left hand to fit a high pressure autoclave fitting or socket welded into a flange. The capillary tubing is available in coils and can be run like wire, in trays, in conduit or "bundled". The principal advantage of the capillary tube is its flexibility and the ease with which it can be installed in the reactor cell, eliminating the necessity of installing the leak detector lines before other piping and equipment, as was found necessary with the long lengths of 1/4" tubing.

Valves

Valves of the Autoclave Engineers, Inc., 6000 lb class were specified, since these valves had been successfully used on component test loop detector lines. Kerotest valves with diaphragm sealed stems have plastic valve seats and are rated at 2000 lb. Hoke and other manufacturers of bellows sealed valves have not made valves for 2500 lb service. Hoke Valve Company claims to be developing a 2500 lb bellows sealed valve and in future designs the possibility of using a positively sealed valve should be reviewed.

Selection of D_2O

The use of a leak detection system pressurized to show a leak on the loss of pressure rather than on a rise of pressure was adapted for protection against contamination of the lines and the control room. This approach makes it necessary to use D_2O, which is compatible with both the fuel and blanket solution, for the leak detection system fluid.

Compressibility Calculations

Referring to Keenan and Keys tables of compressed liquids we find that on increasing the temperature from 100°F to 600°F at 2500 psi the specific volume increase is outside the limits of the tables, but by extrapolation it is found that the pressure increase for a confined liquid is in the range of 20,000 psi. $600^{\circ}F$ is the maximum temperature expected in the piping and heat exchanger flanges. The size of tubing and bends in the piping effectively prevent thermal currents within the leak detector fluid, therefore, the high temperature is assumed to be confined to the metal contact volume within the body of the flange or vessel. The temperature of the tubing inside the cell should not exceed 135° to 150° F. This would account for a temperature rise in the range of 90° on initial start up after flooding. Referring to Keenan and Keys tables and using a rise of 100° from $100^{\circ}F$ to $200^{\circ}F$ we find the pressure increase for a confined liquid again exceeds the limits of the table and extrapolation indicates the pressure rise would be approximately 10,000 psi. The temperature of the header system in the control room is effectively stationary. Rough calculations of the systems combining the three ΔT conditions indicate that the high-pressure-system pressure will increase from the initial 2500 psi cold state to over 5000 psi at operating temperatures. This increase in pressure must be relieved by "bleeding off" the excess D_2O created by expansion as the system is heated up.

The low-pressure-system pressure increase will be much lower; however, the low pressure system has a rupture disc which will fail at 1000 psi and this system must be watched very closely during warm up to prevent breaking the rupture disc.

The specific volume increase for:

A temperature increase from $100^{\circ}F$ to $600^{\circ}F$ at 2500 psi = 0.00701 ft^3/lb.

A temperature increase from $100^{\circ}F$ to $200^{\circ}F$ at 2500 psi = 0.00062 ft^3/lb.

The specific volume decrease from 2500 lb to 2000 lb = 0.000025 ft^3/lb at $100^{\circ}F$

= 0.000099 ft^3/lb at $600^{\circ}F$

The exact volumes of liquid hold up in the flange annuli vary depending on dimensional tolerances and the spacing between flanges. Plan dimensions have been used to determine the volume of D_2O in various portions of the system.

The Volume of D_2O in Leak Detection System

Fuel System Location Description	Low(500 psi)Pres. System in^3	liters	High(2500 psi)Pres. System in^3	liters
	Volume of Holdup			
Flanges	8.9		43.4 14.7	
Heat Exchanger			4.738	
Pump	———		4.800	
	8.9	.14	77.638	1.27
Pipe in tank	121.2	1.99	323	5.29
Pipe in shield and control room	54.6		108.0	
Headers	96.0		249.0	
	150.6	2.47	357.0	5.85

Sub Totals:

Low pressure system	=	280.7 in^3	=	4.6 liters
High pressure system	=	757.6 in^3	=	12.4 liters
Fuel total				17.0 liters

In a like manner the volumes in the blanket system are:

Sub Totals:

Low pressure system	=	440.1 in^3	=	6.02 liters
High pressure system	=	476.6 in^3	=	6.53 liters
Blanket total				12.55 liters
Pressurizing header (filled to vent line)	=	73.8 in^3	=	1.21 liters
Total system	=	2029 in^3	=	30.76 liters

In case of a leak at a flange the high temperature volume would be replaced and the loss would be reflected in the lower temperature volume of D_2O. For the fuel high pressure system which is the largest, with 12.4 liters:
2.4×10^{-5} ft^3/lb = specific volume change from 2500 psi to 2000 psi at 70°F; 12.4 liters at 2.21 lbs/liter = 27.4 lbs; and 2.4×10^{-5} ft^3/lb x 27.4 lb x 2.832×10^4 ml/ft^3 = 18.6 ml loss required to drop the pressure to 2000 psi.

The high pressure leak detection system is to be pressurized to 2500 psi and the pressure alarm signal actuated at 2100 psi. The variation of pressure with volume is nearly linear at these temperatures and pressures, therefore, a loss of approximately 15 ml at constant temperature will set off the alarm. Since the specific volume change for temperature variations is greater than for pressure changes, a large pressure drop has been selected.

The greatest objection to the leak detection system as designed is the effect of this large specific volume change due to temperature particularly at higher temperatures. Cooling the temperature of the flanges from 600°F to 100°F at 2500# the volume decrease is

$$7.01 \times 10^{-3} \times 1.27 \times 2.21 \times 2.832 \times 10^5 = 532 \text{ mil}$$

which is 35 times the volume required to set off the alarm and 45% of this volume decrease occurs in the first 100°F. The system will alarm on cooling down without a leak. It should also be noted that tests on stainless steel oval ring gasketed flange joints indicate that leaks are most likely to occur on cooling down, and may tighten up on reaching a steady state.

Care should be taken to maintain a pressure on the flanges during the cool down of the flanges and equipment. A search for leaks would not be profitable until a steady state has been reached, but maintaining a pressure on the leak detecting lines will maintain in-leakage and prevent spreading contamination.

For the low pressure fuel system which is the smallest with 4.6 liters: 2.3×10^{-5} ft^3/lb = specific volume change from 500 psi to 100 psi at $70^{o}F$; 4.6 liters at 2.21 lb = 10.15 lb; and $2.3 \times 10^{-5} \times 10.15 \times 2.832 \times 10^4$ = 6.6 ml loss required to drop pressure to 100 psi. The low pressure leak detection system is to be pressurized to 500 psi and the pressure alarm signal actuated at 100 psi and will require approximately 6.6 ml loss of fluid at constant temperature.

Method of Applying Pressure

Several pumping schemes were considered, the most promising being:

(a) The Scott and Williams hydro-pulse pump, a motor operated, bellows pump with a positive seal. Reliability of this pump is very good. This type of pump has been extensively used as a homogenizer in industry.

(b) Sprague, air operated hydraulic pump is a piston type of pump which uses rubber O ring gaskets. Experience with this pump indicates that it tends to stick in operations which heat the unit. The oil used to lubricate the pump cylinder may also contaminate the D_2O. It has the advantage of variable speed operation which will hold a given pressure dependent only on the flow demand.

(c) The use of the purge pump with either a separate head - which would be a custom built unit - or with a tie connection in the line with check valves was considered. J. S. Culver concluded the dual use would work; however, it was his opinion that a separate pump in the $1,000.00 class would pay for itself in savings realized by the reduction of maintenance and lost time.

Since the leak rates are small and flow rates are correspondingly small, a solid liquid system was selected to give a large pressure drop on the loss of a small volume of liquid. For these same reasons it was decided to use the already existing oxygen supply system as a pressure source instead of a pump.

A separate vessel was selected so that D_2O could be charged into the system at atmospheric pressure and a vent arranged to maintain a yapor space upon full charge. It was assumed that oxygen from the high pressure system could be used to develop 3000 lb pressure. Since the oxygen will be initially injected into the low pressure system the O_2 generator installation will be deferred and a 0.6 cf/min high pressure air compressor (2500 psi) has been purchased to supply pressure to the leak detector header in lieu of the O_2 generator.

To minimize the dilution of D_2 in the D_2O, dry (instrument) air should be connected to the suction side of the compressor.

Bellows Leak Detectors

The bellows seals on the stems of the remotely operated valves in the fuel and blanket streams are potential leak points. The bellows are made of 3-ply stainless steel and tests to failure indicate that the probability of a leak is remote. The valves as purchased have a bonnet around the bellows with a packing gland at the stem. Pressurizing this bonnet to 1000 psi on the high pressure valves was considered. This required connecting each valve bonnet to a header in the shielded control cubicle where a differential pressure cell would actuate an alarm. The possibility of a leak in the packing gland being greater than a leak in a bellows upon failure cast doubt on the reliability of the "detection".[1] Another serious objection was the contamination

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1. Billings, A. M., Memo to J. E. Kuster, "Packing Gland Leakage in HRT High Pressure Valves, May 1, 1956.

which would be carried in to the control cubicle, since this is a rate of rise system and process fluid would flow into the leak detection lines on failure.

The design adopted relies on the cell space monitrons to signal a rise of activity in the containment cell in case of a bellows leak. Each valve is provided with a 1/4" O.D. stainless steel tubing connection from the valve bonnet through a disconnect at the top of the cell (just under the roof plug) to a valve in the valve bay in each half of the cell. This will permit all valves to be checked for leaks by removing the roof plugs in one location for either the blanket or fuel sides. In the event of activity rise indicating a system leak the reactor fluids will be transferred to the storage tanks and the system pressurized with an inert gas. By removing the roof plugs over the valve bay, all valve bellows could be checked for leaks by opening the valves connected to the valve bonnets in succession and watching for bubbles in the shielding water. A special high pressure disconnect was developed for lines to the heat exchanger, let down heat exchanger, pressurizer bleed valves and the circulating pumps. All other disconnects are autoclave standard high pressure connections.

In future designs consideration should be given to replacing the packing at the valve stem in the bonnet of the remotely operated valves with a bellows so the bonnet can be pressurized. This will serve a duel purpose in reducing the pressure differential on the system seal bellows during operation, and in providing a positive leak check (with the possibility of providing the additional protection of in-leakage in case of a bellows failure).

Testing

The pressurizer, header and tubing shall receive a 1500 psi test with helium and a helium leak detector check made on all welds. A hold test for

10 to 15 minutes should be made to assure all leaks are repaired. When the flange and equipment connections are completed, the system shall be filled with D_2O and a pressure test 1-1/2 times the operating pressure shall be applied and repeated, if necessary, until the system is tight.

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