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LEAKAGE OF WATER FROM GASKETED JOINTS PROPOSED FOR THE HWCTR PART I

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ABSTRACT

When mockups of typical gasketed joints proposed for the HWCTR were subjected to thermal and pressure cycling that simulated reactor operating conditions, the average leakage rate was less than 0.11 lb of water per year per linear inch of gasket. The joints were exposed to deionized light water and were cycled 100 times from about 70°C and atmospheric pressure to 250°C and 1000 psig.

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PART I

INTRODUCTION

A major phase of du Pont's study of power reactors concerns the design, construction, and operation of the Heavy Water Components Test Reactor (HWCTR). The HWCTR is a pressure vessel reactor that will be used to irradiate candidate fuel elements for power reactors. The reactor will be cooled and moderated by heavy water at an operating temperature of about 250°C; boiling will be prevented by pressurizing to about 1000 psig with helium in the gas space above the liquid level. Because of possible contamination of the operating area with tritium, an important consideration in the design of the HWCTR is the leakage of moderator from gasketed joints that seal closures on the reactor vessel. Leakage is also of economic importance in the evaluation of D_2O-moderated-and-cooled power reactors. Insufficient information exists in the literature for adequately estimating the vapor loss from such joints at the operating conditions of the HWCTR. An experimental study was therefore undertaken to determine the leakage of water from mockups of typical gasketed joints. This report describes the results of leakage tests in which gasketed joints were subjected to thermal and pressure cycling under simulated reactor conditions.

SUMMARY

The average leakage from mockups of typical HWCTR gasketed joints was less than 0.11 lb of water per year per linear inch of gasket during a 100-cycle test with deionized light water at a maximum temperature of 250°C and a maximum pressure of 1000 psig. The test gaskets, which were available commercially, consisted of two asbestos gaskets with stainless steel jackets and a spiral-wound gasket of stainless steel with an asbestos filler. Reproducibility of the leakage measurements was not determined because the leakage was much less than the value of 2 lb/yr/in. that had been assumed for design of the HWCTR. In a typical three-hour cycle, each joint was maintained at the maximum temperature and pressure for one hour; the balance of the time was for heating, cooling to about 70°C, and venting to atmospheric pressure.

DISCUSSION

BACKGROUND

In the design of the HWCTR, an enclosure is provided to house the reactor vessel and other associated process equipment and piping as well as to confine the release of radioactive material in the event of an accident to the system. During normal operation, the ventilating system for the reactor enclosure building is designed to

maintain a safe tritium concentration when the leakage of D_2O from all gasketed joints in the process system does not exceed 2000 lb/yr. Half of this total allowable leakage is assigned to the gasketed joints that seal closures on the reactor vessel. A leakage of 1000 lb/yr corresponds to an allowable leakage rate of 2 lb/yr of D_2O for each linear inch of gasket on the reactor vessel. The linear extent of each joint corresponds to the inner circumference of the gasket.

DESCRIPTION OF TEST EQUIPMENT

A typical test unit, shown in Figure 1, consisted of two 3-inch, 1500-psig pipe flanges joined together by a short section of pipe. Each unit, which was mounted vertically, was capable of testing two joints simultaneously, one at each flanged end. Thermal cycling of the test joints was accomplished with alternate streams of light water at 260 and 30°C and at a pressure of 1000 psig to the test units, as shown in the flow diagram of Figure 2. Helium was supplied to a vapor space maintained adjacent to those joints that would be exposed in the HWCTR to a D_2O vapor - helium mixture. Timers and timed relays operated valves that supplied the hot and cold water to the test units. In a typical cycle of about three hours duration, the joints were heated for one hour, maintained at the maximum temperature and pressure for one hour, and then cooled for one hour. At the end of each cycle all of the joints were vented automatically to atmospheric pressure.

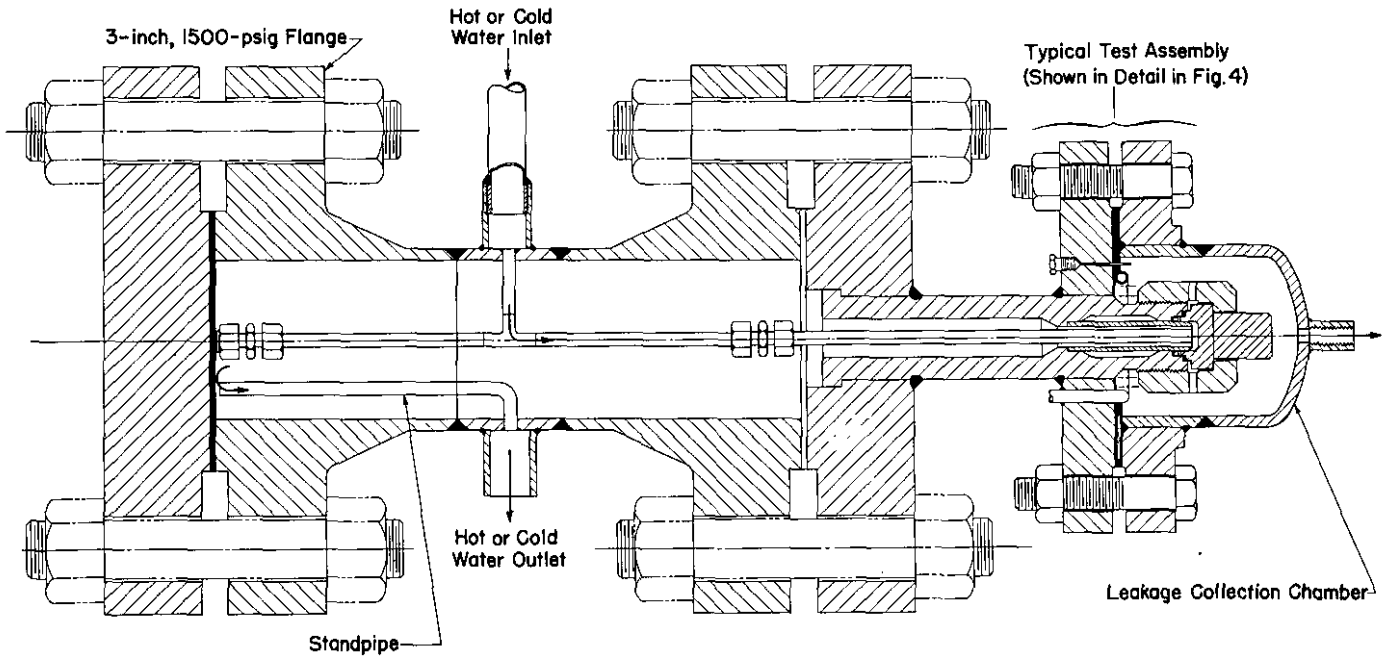

FIG. 1 TYPICAL TEST UNIT SHOWING GASKETED JOINT OF INSTRUMENT PIN IN LOWER TEST POSITION

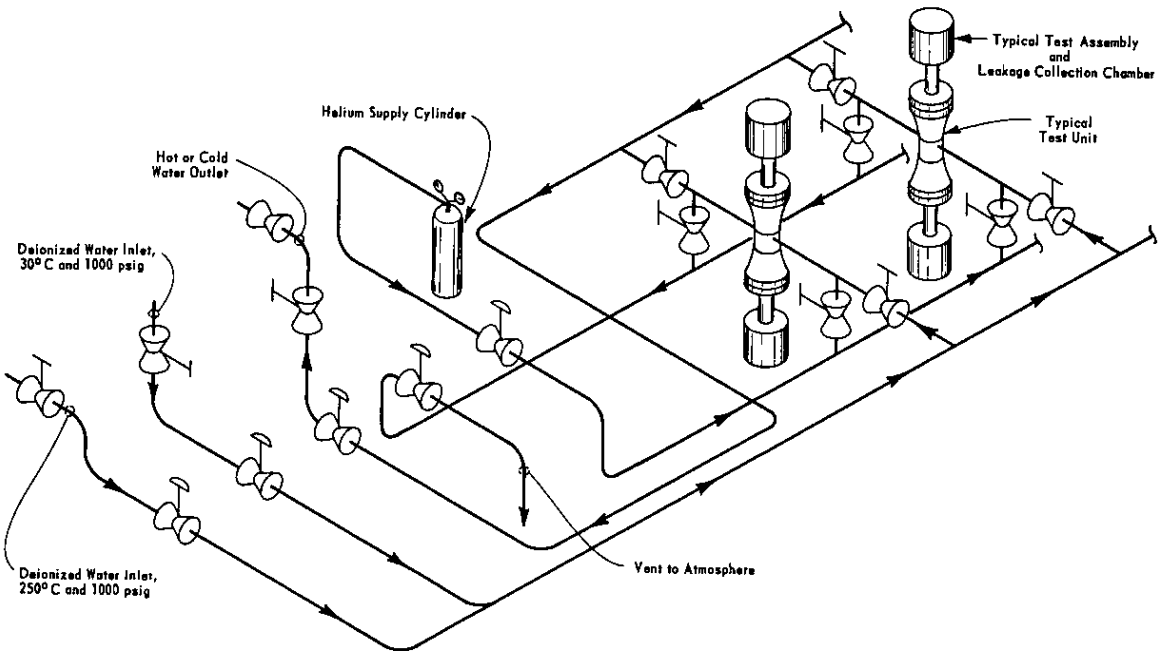

FIG. 2 FLOW DIAGRAM OF CYCLIC TEST FACILITY

As shown in Figure 3, light water leakage was collected by passing a metered flow of nitrogen of low water content through a sealed chamber that was built around each test joint. The nitrogen stream served both to vaporize any liquid leakage and to sweep out the total leakage from the chamber. The moisture contents of the supply and effluent nitrogen streams were determined by continuously passing metered sample flows through hygrometers. Each hygrometer was of the Keidel* type, essentially an electrolytic cell consisting of a film of phosphorus pentoxide between platinum wire electrodes. The electrical signal from each hygrometer cell was recorded at about one-minute intervals. Water leakage rates between 0.005 and 50 lb/yr could be detected within ±5% by this system.

The temperature of each test joint, as sensed by a thermocouple peened into the metal adjacent to the gasket, was recorded at one-minute intervals. The pressure was indicated by a Bourdon gage.

RESULTS

GASKETED JOINT OF AN INSTRUMENT PIN

The average leakage from a joint with a stainless-steel-jacketed asbestos gasket was 0.014 lb/yr/in. during a 100-cycle test under

*Keidel, F. A. "Determination of Water by Direct Amperometric Measurement". Anal. Chem. 31, 2043-48 (1959).

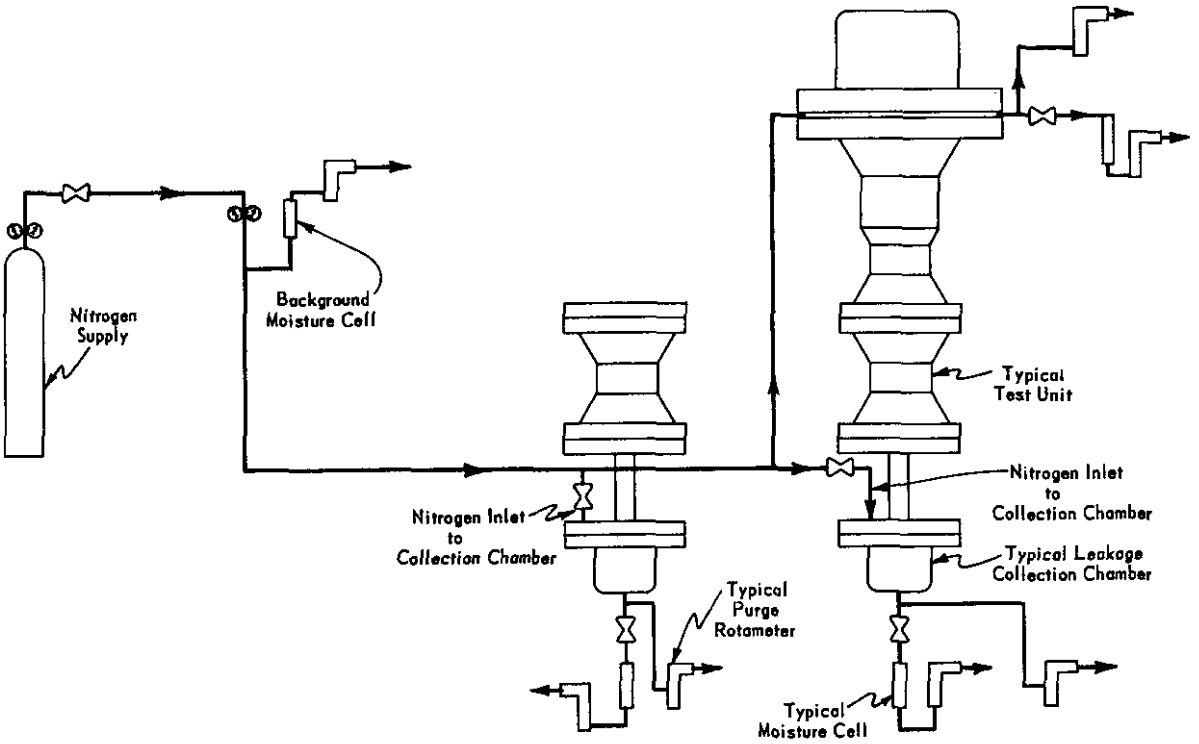

FIG. 3 FLOW DIAGRAM OF LEAKAGE DETECTION SYSTEM

the conditions specified above. The test gasket, which will be used to seal an instrument pin in the HWCTR, was 1 inch in OD, 3/4 inch in ID, and 3/32 inch thick, and was commercially available from the Johns-Mansville Company as Goetze No. 920, Type J. As shown in Figure 4, the gasket was compressed between two smooth faces of Type 304 stainless steel by a carbon steel nut. At the start of the test a torque of 600 ft-lb was applied to the nut; the torque required to remove the nut after completion of the cyclic test was 20 ft-lb. The initial torque of 600 ft-lb was selected after preliminary tests showed that the leakage exceeded the allowable rate when an initial torque of 500 ft-lb or less was applied to the nut. In these preliminary tests, the torque required to remove the nut after completion of only a few test cycles was found to be insignificant. The minimum and maximum leakage rates observed during the test were 0.0022 and 0.11 lb/yr/in., respectively. No significant difference was observed between the average leakage rates of the hot and cold phases of the cycle, as shown in Table I, or between the average rates at the start and end of the test.

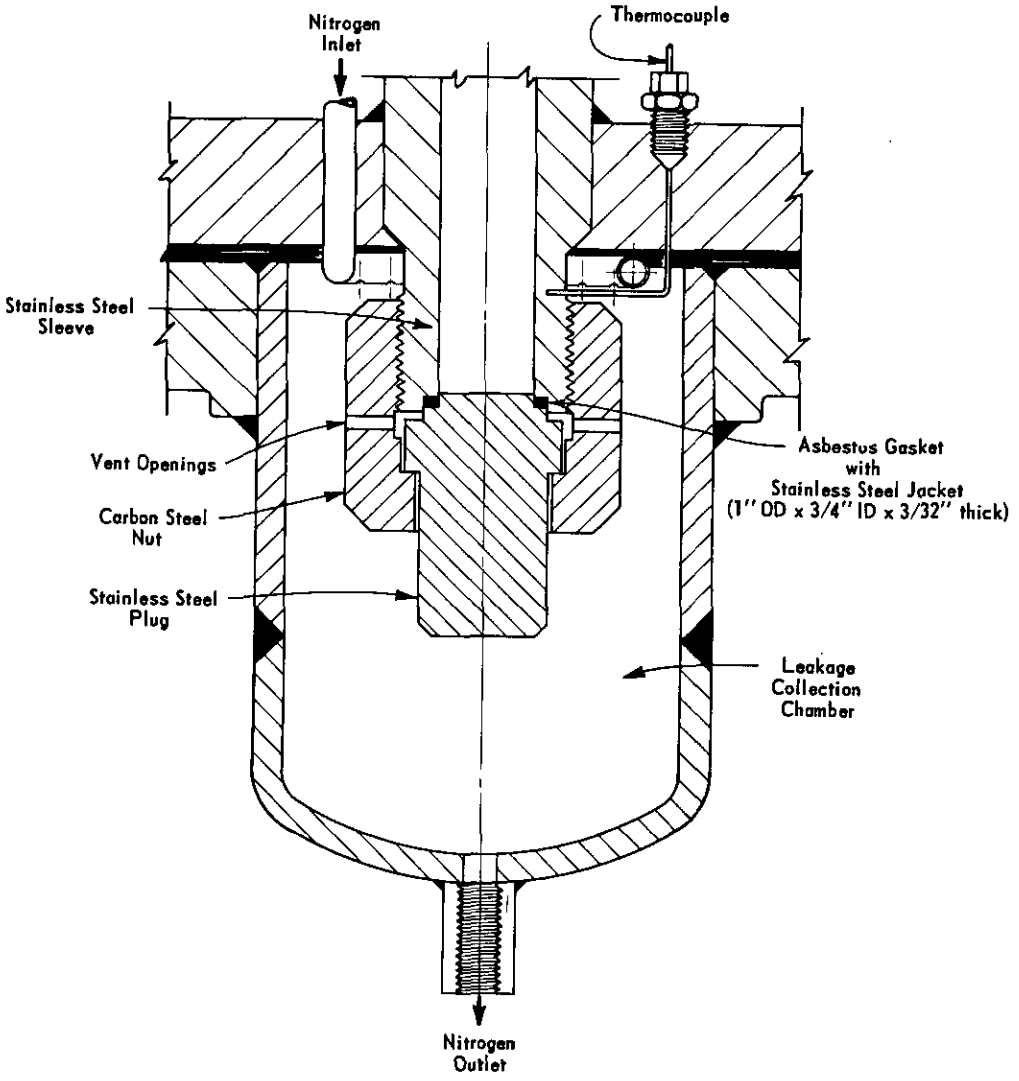

FIG. 4 TEST ASSEMBLY OF GASKET FOR INSTRUMENT PIN JOINT

TABLE I

Summary of Leakage Rates

Joint Description	Leakage Rate, lb/yr of water per linear inch of gasket				
	Average Rate During 100-Cycle Test	Average Rate Hot Phase	Average Rate Cold Phase	Minimum Rate	Maximum Rate
Jacketed asbestos gaskets					
Smooth sealing faces	0.014	0.013	0.015	0.0022	0.11
"V" Groove in sealing faces	0.014	0.016	0.012	0.0022	0.11
Jacketed asbestos gasket and "Swagelok" tubing fitting	0.003	0.004	0.0013	0.0013	0.12
Jacketed asbestos gasket and "Midlock" tubing fitting	0.10	0.13	0.026	0.0013	2.4
"Flexitallic" gasket	0.07	0.06	0.07	0.0004	0.3

The average leakage from a second joint, in which a "V" groove was machined concentrically in the center of each sealing face of stainless steel, was not significantly different from the leakage rate obtained for the test joint with smooth faces. Except for the "V" grooves, which were 1/64 inch deep and about 1/32 inch wide, the joint and test gasket were identical with those described in the previous paragraph.

COMBINED TEST OF INSTRUMENT PIN JOINTS

The combined leakage from the two nearby joints on an HWCTR instrument pin - the 1-inch-OD gasketed joint discussed above plus a tubing fitting, as shown in Figure 5 - was measured in 100-cycle tests with two types of tubing fittings. An average total leakage rate of 0.003 lb/yr/in. was obtained when a "Swagelok" tubing fitting was employed. The rate was 0.1 lb/yr/in. with a "Midlock" fitting. The leakage from the tubing fittings alone could not be determined by the difference between the total and 1-inch gasket leakages because the reproducibility of the gasket leakage measurements was not established. The "Swagelok" fitting, which was fabricated from stainless steel, sealed 3/8-inch-OD tubing; the "Midlock" fitting, which was also fabricated from stainless steel, sealed 1/4-inch-OD tubing.

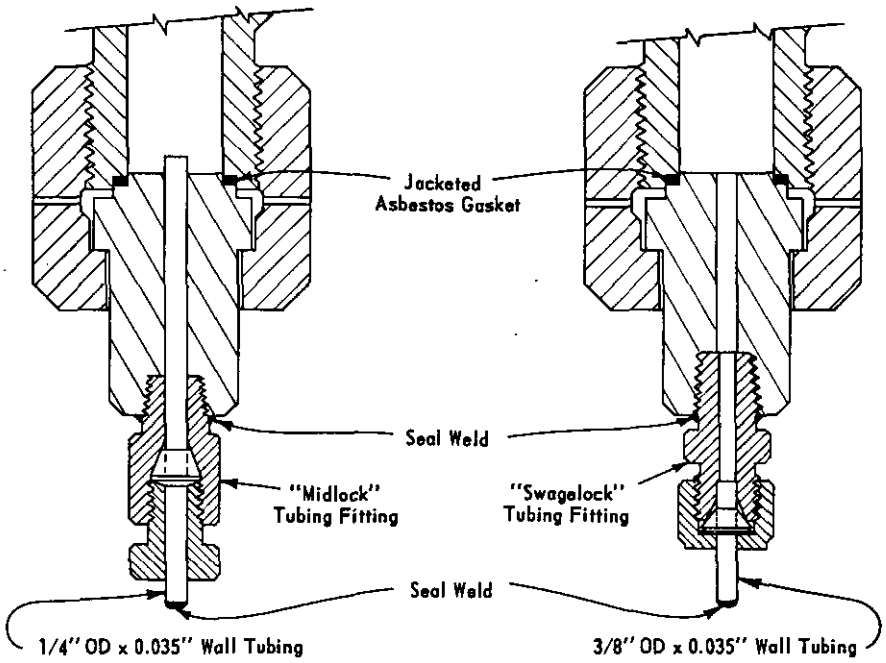

FIG. 5 INSTRUMENT PIN JOINTS

The variation in the leakage rates that were observed during the test is shown in Table I. The average total leakage rates for the hot and cold phases of the test were, respectively, 0.004 and 0.0013 lb/yr/in. for the joint assembly with the "Swagelok" fitting and 0.13 and 0.026 lb/yr/in. for the assembly with the "Midlock" fitting. The initial and final torques on the test joints were as follows:

	Jacketed Asbestos Gasket Torque, ft-lb		Tubing Fitting Torque, ft-lb	
	Start of Test	End of Test	Start of Test	End of Test
Test assembly with "Swagelok" fitting	600	180	50[a]	40
Test assembly with "Midlock" fitting	600	140	30[a]	25

(a) Manufacturer's recommended torque

GASKET JOINT FOR THE CONTROL ROD CLUSTER HOUSING

During a 100-cycle test, an average leakage rate of 0.07 lb/yr/in. was obtained from a mockup of a joint for the HWCTR control rod cluster housing that incorporates a spiral-wound, stainless steel gasket with an asbestos filler. The test assembly, which is shown in Figure 6, consisted of two 6-inch flanges, rated at 1500 psig, and

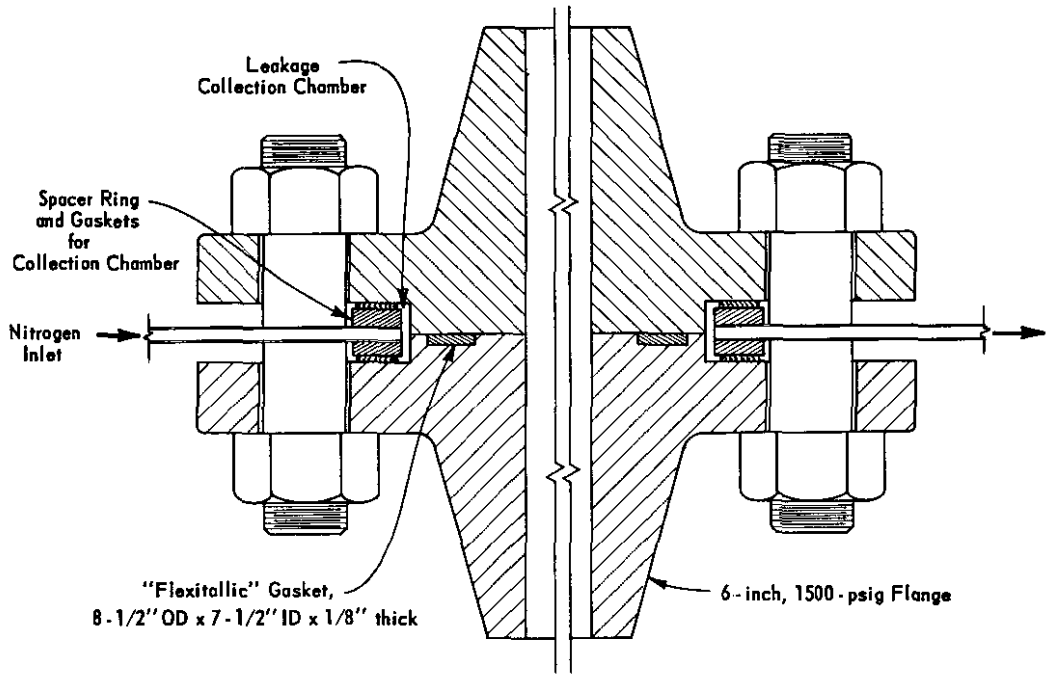

FIG. 6 TEST ASSEMBLY OF GASKET FOR CONTROL ROD CLUSTER HOUSING

a "Flexitallic" gasket. The gasket, which was 8-1/2 inches in OD, 7-1/2 inches in ID, and 1/8 inch thick, was compressed 0.025 inch between the smooth faces of the flanges. A groove that was machined in the face of one of the flanges retained the gasket. An initial torque of 600 ft-lb on each of the flange bolts was used to compress the gasket; at the end of the test a torque of 600 ft-lb still remained on the bolts. In the HWCTR, the joint will be exposed to a D_2O vapor-helium mixture, and consequently a similar mixture of H_2O vapor and helium was maintained on the joint during cyclic testing. As shown in Table I, the average leakage rates for the hot and cold phases of the test were 0.06 and 0.07 lb/yr/in., respectively. The minimum and maximum leakage rates observed during the test were 0.0004 and 0.3 lb/yr/in., respectively.

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