CRYOGENIC GAS DISCONNECT JOINTS USED IN CRYOGENIC ACCELERATOR COLD-GAS DISTRIBUTION SYSTEMS*

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Abstract

Demountable gas disconnect joints are the preferred choice for assembly of cryogenic (20 K) helium gas manifolding systems used with linear accelerators being developed at Los Alamos. These joints must function in a vacuum vessel that operates at less than 1×10^{-6} torr while being routinely cycled from ambient temperature to 20 K and back to ambient temperature. The joints, which are used to distribute helium refrigerant gas at pressures as high as 450 psi, must also be capable of passing helium leak tests with a maximum leak rate of 5×10^{-7} std-cc/sec at operating conditions. For this application we have evaluated several forms of stainless-steel-to-stainless-steel and aluminum-to-stainless-steel flanged joints from several commercial manufacturers. This paper discusses the results of these evaluations and our experience in using some of the joints in a linear accelerator.

I. INTRODUCTION

Accelerator structures that operate at temperatures as low as 10 K require continuous cryogenic cooling inside a high-vacuum enclosure. The coolants may be liquid or cold gas cryogens, at flow rates of a few grams per second to 50 or more grams per second, at pressures of 250 to 450 psi; in our applications, cold helium gas is used as the coolant. The accelerator rf structures may be composed of many components that, because of their construction or their individual power losses or operating temperatures, must be cooled individually. The cryogen distribution piping and manifolding necessary to balance coolant flows to these structures are complex, difficult to fabricate, and difficult to assemble/install. Common practice has been to install the individual accelerator components and then hard-join the piping by soldering, brazing, or welding the joints.

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Operational demands require that the coolant joints maintain a leak rate of less than 5×10^{-7} std-cc/sec through many thermal cycles from room temperature to operating temperature, and that they disassemble for repair or modification of the accelerator components. In many accelerator systems, it is also necessary to join dissimilar metals, such as aluminum or copper (accelerator components), to stainless steel (cryogen piping). For these reasons, demountable joints have advantages over the common practice of hard joining.

Numerous demountable fittings and flanges are commercially available for vacuum, hydraulic, chemical, and industrial gas service. Little engineering data exists for use of these devices inside a vacuum chamber at 20 K, and no data was found for their use in joining dissimilar metals at 20 K. One application of a nonstandard nut/coupling fitting (Swagelok® with special ferrule) was identified[1], wherein the fitting was used on stainless steel tubing in a high vacuum chamber at temperatures of less than 20 K. Leak rates of less than 1×10^{-7} std-cc/sec (helium) were observed in this application. It is also known that liquid cryogenic fuel rockets make use of demountable fittings and flanges; however, no data was found on the leak rates inside a vacuum chamber or on their use in joining dissimilar metals.

We selected several commercially available fittings to evaluate their potential for meeting our requirements. These were the following (manufacturer of fitting selected and fitting name in parentheses):

- captured metal-gasket, sexless knife-edge, bolted stainless steel flange (Huntington/VAC-U-FLAT);
- captured metal-gasket, sexless double-knife-edge, bolted stainless steel flange (Crawford/CAJON-CF);
- nut/coupling/ferrule (Crawford/SWAGELOK);
- metal-gasket, nut/coupling, sexless, half-toroid seal (Crawford/CAJON- VCR);
- captured or self-energized (Helicoflex) metal-seal, sexless knife-edge, bolted aluminum and stainless steel flange (Hakudo/SMC ALFLAT);

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- captured metal truncated-conical-ring nut/ coupling (Stanley Aviation/ GAMAH).

Since the beginning of this initial evaluation, we have identified three more nut/coupling fittings that appear to be good candidates for our applications: ZT-Nut (Exel), Super JSK (Sanko-Kogyo), and Hiltap HTC4 Cryogenic Series (Hiltap Fittings LTD). In a private communication, Ishimaru[2] stated that the Super JSK (Sanko-Kogyo) fitting had been successfully used at 4 K without detectable leakage.

II. TEST CONFIGURATION

We modified a Balzers Model RCP 321 cryopump to use as a test chamber by removing the first- and second-stage adsorption arrays, leaving only the cold head and heat shield in the pump housing. This model refrigerator is designed to provide 6 W of cooling at 20 K. The disconnect joints were assembled and mounted in a clamping block, which in turn was fastened to the second stage of the cold head. A .005-in.-thick sheet of indium was placed between the mating surfaces to ensure good thermal contact. The clamping block also served as a mount for silicon diodes that sense the temperature and for electric heaters used to accelerate the warm-up period. With one end of the disconnect joint sealed, the other end was connected to a stainless steel tube used to pressurize the disconnect assembly from a regulated helium gas source. Figure 1 shows a typical clamping block with three 2219 aluminum Hakudo 34-mm O.D. flanges mated to three MDC 1-1/3" O.D. mini Del Seal® stainless steel flanges, each manifolded to a common helium pressurization line.

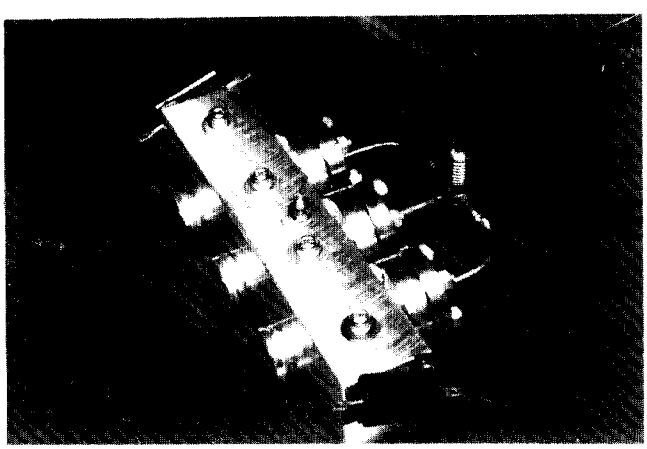

Figure 1 - Hakudo Aluminum "Mini" Conflat® Test Configuration

The top flange of the test chamber provided the vacuum seal, electrical feed- throughs, and ports necessary to interface with the helium gas supply, the vacuum- gauging system and the vacuum system. The test chamber was kept continuously under vacuum during the thermal cycling by a Leybold TMP 360 turbo pump. A helium leak detector was connected through a shutoff valve to a "tee" in the turbo pump foreline, which allowed round-the-clock monitoring of the integrity of the disconnect under test.

Controls for the thermal cycles were automated by means of a Balzers two- channel DTK 010 electronic temperature-measuring unit with high- and low-temperature set points. The compressor, the cooling water, and the refrigerator cold head each received a signal to start at the room-temperature set point and would remain active until the low-temperature set point (~20 K) signaled them to turn off. The cold head and compressor would then stop and the electric heaters would turn on and remain on until turned off by the room-temperature set point, re-starting the cooling cycle. A strip-chart recorder was used to indicate when the compressor was on or off, thereby providing a record of the number of cycles completed.

III. TEST PROCEDURE AND RESULTS

Each of the cryogenic gas disconnects was carefully assembled in accordance with the manufacturer's instructions or using standard Laboratory practices. Particular attention was given to cleaning the seals and the mating surfaces with alcohol and then inspecting them to ensure that they were free of fibers and any other contaminants. After the test disconnect(s) and clamping block had been installed on the cold head (Fig. 2), the top flange of the test chamber was set in place and the chamber was evacuated with the turbo pump to 5 x 10^{-6} torr. The pressurization line to the test disconnect(s) was then evacuated and back-filled with gaseous helium three

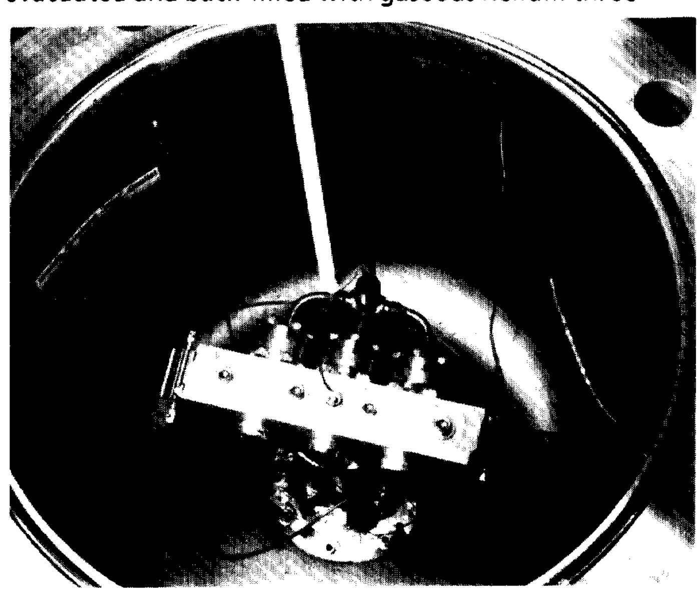

Figure 2 - Test Disconnects and Clamping Block on the Cold Head

times to ensure that most of the entrapped air was removed. Before the first cool-down, the test assembly was leak-tested under pressure to be certain that there was no evidence of leakage at room temperature. Cool-down was then initiated by turning the cryopump compressor on, initiating the control sequence described previously. Typically, the cooldown and warm-up times were nearly equal with the time required for one full cycle ranging from 3 hours for the small mass disconnects to 24 hours for the 6" Vac-U-Flat®.

Table 1 presents a summary of the nine different disconnects that were tested and the results. Leak tests with the helium leak detector were performed daily at the leak test pressure specified in Table 1. The tests were conducted at a variety of temperatures, from the lower extreme to room temperature and several temperatures in between.

IV. DISCUSSION OF RESULTS

All fittings and flanges tested, except the Crawford/Swagelok with standard ferrules, were found to have no leaks detectable with the helium leak detector used. We know from its use by others[1] in similar applications that Swagelok fittings with special ferrules are probably usable in our application. The Hakudo/ALFLAT aluminum flange, when mated to similar stainless steel flanges, was shown to be leak-tight after 100 thermal cycles. We also observed during testing operation that extreme care was necessary in handling and assembly of each disconnect type, to assure the absolute cleanliness of the components; this constraint is especially important in the assembly of the Hakudo/ALFLAT flanges.

Table 1 - Summary of Tests of Cryogenic Gas Disconnect Joints

Manufacturer/Designation	Type	Tube Size	Seal	Temp. Range	Leak-Test Pressure	He Lk. Det. Sensitivity	No. of Cycles	Test Results
Crawford/Cajon VCR®	Nut/Coupling	1/4"	Ag Plated Ni	R. T. - 11K	300 PSIG	1.9e-10 SCC/S	5	No detctable leaks.
Crawford/Swagelok®	Nut/Coupling	1/4"	SST Ferrule	R. T. - 25K	30 PSIG	5.0e-10 SCC/S	0	Lrg. leak @ 30 PSIG & 25K
Stanley Aviation/Gamah S-141	Nut/Coupling	1/2"	304 SST	R. T. - 25K	300 PSIG	4.0e-10 SCC/S	3	No detectable leaks.
Crawford/Cajon 1.33 CF	Bolted Flange	Up to 3/4"	Nickel	R. T. - 12K	300 PSIG	1.0e-9 SCC/S	5	No detectable leaks
Huntington/6"VAC-U-FLAT®	Bolted Flange	Up to 4"	Nickel	R. T. - 14K	400 PSIG	1.0e-9 SCC/S	5	No Detectable Leaks
Crawford/Cajon 2.75 CF	Bolted Flange	Up to 1-1/2"	Nickel	R. T. - 20K	450 PSIG	5.0e-10 SCC/S	28	No Detectable Leaks
Crawford/Cajon 1.33 CF	Bolted Flange	Up to 3/4"	Copper	R. T. - 26K	300 PSIG	7.0e-10 SCC/S	118	No Detectable Leaks
Hakudo/1.33 ALFLAT(2Ea.)	Bolted Flange	Up to 3/4"	Aluminum	R. T. - 22K	450 PSIG	5.0e-10 SCC/S	100	No Detectable Leaks
Hakudo/1.33 ALFLAT	Bolted Flange	Up to 3/4"	Helicoflex(Al)	R. T. - 22K	450 PSIG	5.0e-10SCC/S	100	No Detectable Leaks

V. CONCLUSION AND COMMENTS

We found that a convenient selection of demountable joints was available for use in accelerator design and construction. We also found that great care in assembly of the joints is necessary to assure that the joints will perform as expected. The identification of an acceptable aluminum-to-stainless-steel flange system, the Hakudo/ALFLAT, is very important for its application to high-performance lightweight accelerators, now being designed.

The GTA Accelerator currently being assembled makes considerable use of Crawford/CAJON VCR, Nut/Couplings, and Crawford/CAJON 2.75 and 1.33 CF Flanges. The GTA RFQ, which is cooled to 20 K by cold helium gas at 300 psi, has undergone more than 10 cool-down cycles from room temperature to 20 K without a detectable leak; 36 Crawford/CAJON VCR and 4 Crawford/CAJON 2.75 CF flanges (stainless steel to stainless steel) are used in this system.

References:

1. Westinghouse Large Superconducting Coil Project.
2. H. Ishimaru, TRISTAN Vacuum Group, National Laboratory for High-Energy Physics, Tsukuba, Japan. Private communication. August 1990.