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LEAK CHECKING IN ISABELLE*

J. Briggs and H.J. Halama
Brookhaven National Laboratory
Upton, New York 11973

Introduction

The Intersecting Storage Accelerator (ISABELLE) consists of two rings having a circumference of 3.8 km each. In these rings superconducting magnets, held at 4 K, bend and focus the proton beam which is accelerated up to 400 GeV. Due to very different pressure requirements, ISABELLE contains two completely independent vacuum systems.[1] One, known as Beam Vacuum operates at 1×10^{-11} Torr and maintains a very clean environment for the circulating proton beam. Here only ion and titanium sublimation pumps are used to provide the vacuum. The other system know as Insulating Vacuum maintains superconducting magnet vessels at a pressure below 1×10^{-6} Torr. In this system all gasses except helium are cryocondensed on the cold surfaces of superconducting magnets and cryogenic circuits. Turbomolecular pumps pump the inadvertent small helium leaks.

The likelihood of a large helium background both in the MagCOOL area and in the ISABELLE tunnel severely limits the sensitivity of conventional leak detectors. In addition the refrigerator system and its cryogenic components may contain enough residual helium to make the use of ^{4}He for leak detection completely unusable. It should be realized, that leak detection in ISABELLE is one of the most important functions, since there are thousands of bellows and welds operating at 4 K and at 15 atmosphere pressure and that many welds can only be leak checked at room temperature. Leak rates are known to increase by 4 orders of magnitude when cooled from 300 K to 4 K. Thus our required 10^{-10} Torr liters s^{-1} sensitivity is essential for proper operation of ISABELLE and the methods and equipment which permit the location of such leaks in large systems have been developed and tested on the First Cell and the refrigerators. They produced a completely leak free system i.e. the helium background did not change when all pumps were closed for 24 hours. We will now discuss these methods and the equipment in more detail.

Equipment

All small volume components are leak checked in a conventional way with calibrated leak detectors having a sensitivity of 1×10^{-10} Torr liters (STP)/sec.
All welds to be used in cryogenic lines are first cold shocked with liquid nitrogen. For larger volumes a leak checking station is assembled from components shown in Fig. 1, to facilitate the pump down and to increase the sensitivity. In cases, where a large amount of water is present, as may be the case during the initial pump-down of components containing superinsulation, an additional LN_2 trap is used to reach acceptable sensitivity in a shorter time. The system to be leak checked is evacuated by the station shown in Fig. 1 with the valve V_2 open into the roughing pump. After a sufficiently low pressure for leak testing is reached, V_1 is opened and V_2 is closed so that the leak detector acts as the roughing pump. The entire gas thruput is intercepted by the leak detector.

The success of sensitive leak detection depends on low He partial pressure in the atmosphere which is $\sim 4 \times 10^{-3}$ Torr or 5×10^{-4}% by volume. Both in the ISABELLE tunnel and in the magnet test facility He partial pressure is likely to be much higher, which will demand leak and permeation free TMP and leak detector in locations where ^{4}He is used as a tracer gas. The tests showed that Balzer pump TMU-110 exhibited negligible permeation and leak rates and was therefore selected for the leak checking stations.

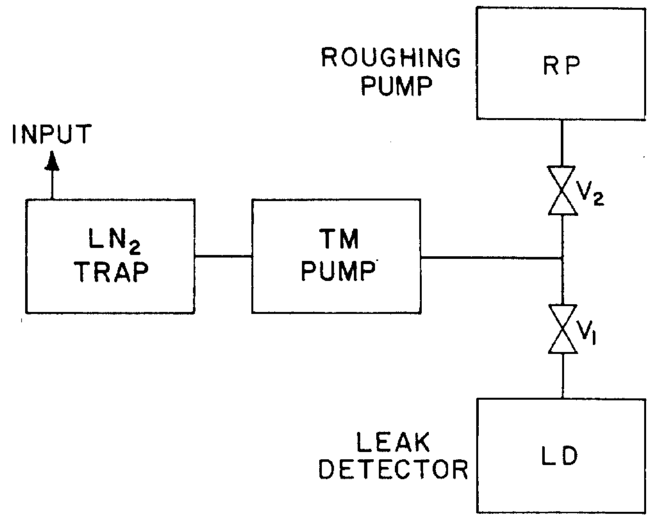

Fig. 1. Leak checking station.

The components which are contaminated with He require a different tracer gas. The most natural choice is a gas of similar molecular mass so that standard leak detectors can be easily modified for its use. ^{3}He or HD mixture with M = 3 AMU are best candidates. ^{3}He is a rare helium isotope and therefore correspondingly very expensive ($250.-per liter STP). This cost makes the use of ^{3}He for leak checking prohibitive. HD on the other hand can be produced very cheaply from the almost unlimited supply of deuterium left over at the BNL Bubble Chamber.

Since HD is not commercially available due to a limited demand for it, several methods to produce HD were investigated.[2] The method utilizing a titanium iron alloy (Ti $Fe_{.9}$ $Mn_{.1}$) as a catalyst has been selected.[3] An existing apparatus will shortly be in operation to produce large quantities of HD. We will also be able to supply other labs with HD, should they require it.

Mass 4 to Mass 3 Conversion

In most leak detectors the gas from a device to be checked is introduced through various components into the ionizer, where gas molecules are ionized by electron impact. All ions are then accelerated and focused by an aray of electrodes into a uniform magnetic field, B, which selects the wanted ion according to its kinetic energy,

$$eV_a = \frac{1}{2} mv^2 \qquad (1)$$

and the radius of curvature r due to B

$$r = \frac{m}{e} \frac{v}{B} \qquad (2)$$

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where V_a, m and v are accelerating voltage, mass and velocity of the ion respectively.

Combining Eq. 1 and 2, we obtain

$$rB = 2\frac{m}{e}V_a$$

Since in Veeco leak detectors r and B are fixed, the appropriate accelerating voltage V_a for ^4He is 270V and

$$V_a \text{ for } {}^3He \text{ and HD} = \frac{270}{3} \times 4 = 360V$$

This voltage is in good agreement with the experimental value of a clean ionizer.

To convert a Veeco MS-17AB from Mass 4 to Mass 3, the spectrometer ground lead on PC board "A" (see Fig. 34 in Veeco MS17 manual) is removed. At this point a 100 V stabilized adjustable voltage supply, Model IP-100 made by Hope Electronics is inserted as shown in Fig. 2. The adjustment of this supply provides the tuning for the Mass 3 peak. A toggle switch, T, is used for changing from Mass 4 (standard circuit) to Mass 3 operation. This same toggle switch can also be used to indicate by two indicator lamps for which mass the leak detector is tuned.

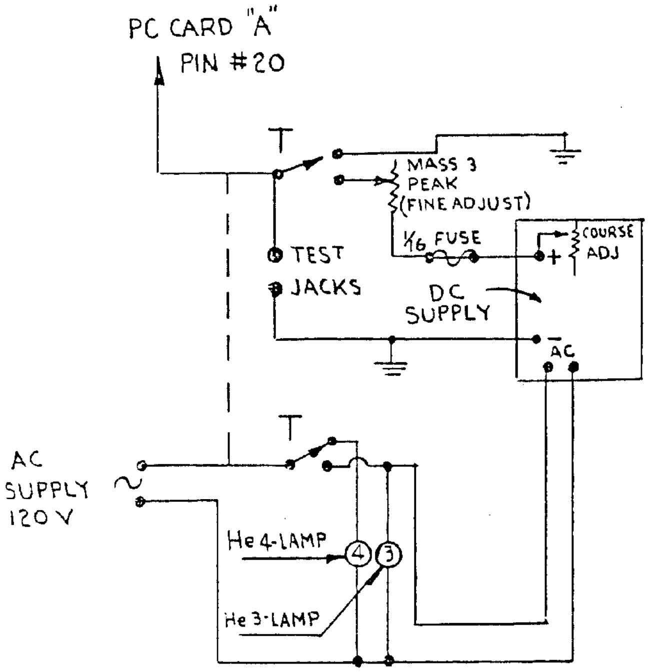

Fig. 2. Circuit of Mass 4 to Mass 3 conversion.

The instrument is tuned routinely for the normal Mass 4 peak according to the manufactures specifications. Once this is accomplished, T is switched to the Mass 3 mode and using an "HD leak", the leak detector is peaked by tuning the accelerator potential to the highest reading on the scale indicator. It should be noted that the use of HD mixture increases the sensitivity of the leak detector by a factor of 3 due to a higher ionization efficiency of HD as compared to that of He.

From a safety point of view the same precautions have to be taken as with hydrogen. The area has to be roped off and no smoking signs posted. It should be realized that during leak checking only a very small stream of gas is used, which completely eliminates the safety hazards.

Insulating Vacuum

One of the most stringent requirements of the system is that the vacuum leaks be kept to an absolute minimum, since many bellows and welds see supercritical helium at 4 K above 15 atmosphere pressure. The magnets are first assembled into the magnet Dewars and a leak test is performed after every weld. The Dewars containing magnets are insulated and mounted in the magnet vessel and the whole assembly is measured in the horizontal test stand to insure that the required magnetic properties, heat loads and leak tightness have been achieved. The completed magnet assemblies are then moved into the tunnel where 4 K helium supply and return lines are welded (Fig. 3) to complete the cryogenic circuit. After these welds have been cold shocked with liquid nitrogen, the fixture (developed by Briggs, Rosenka and Skelton), shown in Fig. 4 is clamped around them and then connected to a leak detector. The small volume of the fixture permits the location of leaks smaller than 1×10^{-10} Torr l s^{-1}.

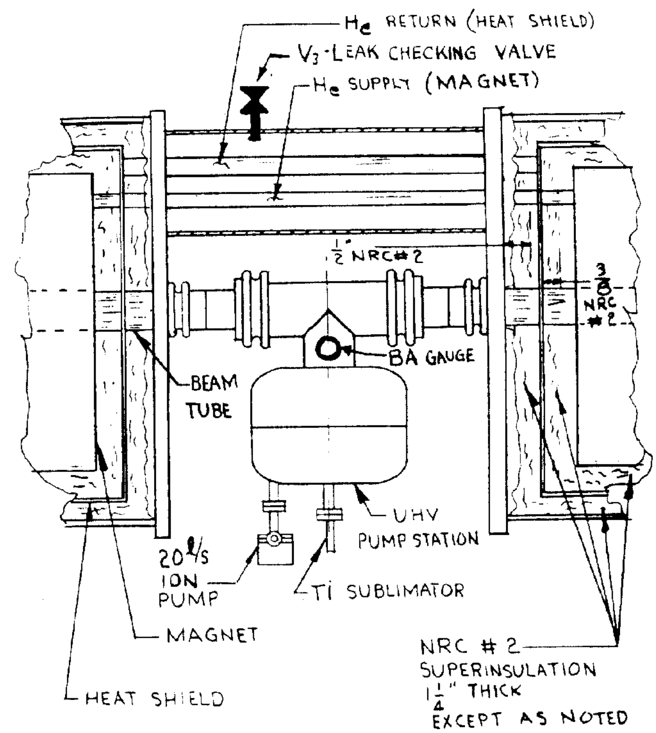

Fig. 3. Intermagnet section.

The fixture is first evacuated through the leak detector and when the most sensitive scale operation is reached the fixture is leak checked. Then the lines are pressurized to 200 psi with He + N_2 mixture. If no signal is observed on the most sensitive scale of the leak detector for 10 minutes the weld is passed. This method has been used on the First Cell and has produced a completely leak free system i.e., with all pumps valved off for 24 hours, no increase in helium background (10^{-9} Torr) was observed under operating conditions with T = 4.6 K and P = 150 psi. After the final leak check of helium carrying lines has been completed, the lines are insulated and a stainless steel envelope containing a valve, V_3, is welded over the intermagnet section (Fig. 3). The LC station (Fig. 1) is connected to this valve to accomplish the final leak test of the interconnect and the magnet vessels. If a helium leak developes in the magnet string during operation, several leak checking stations are connected to the interconnect valves V_3 along the suspected section and leak hunting is performed by the time of flight method. Refrigerator, transfer lines and lead pots are routinely leak tested using LC station and HD with excellent results. ^{4}He was found totally unacceptable as a tracer gas.

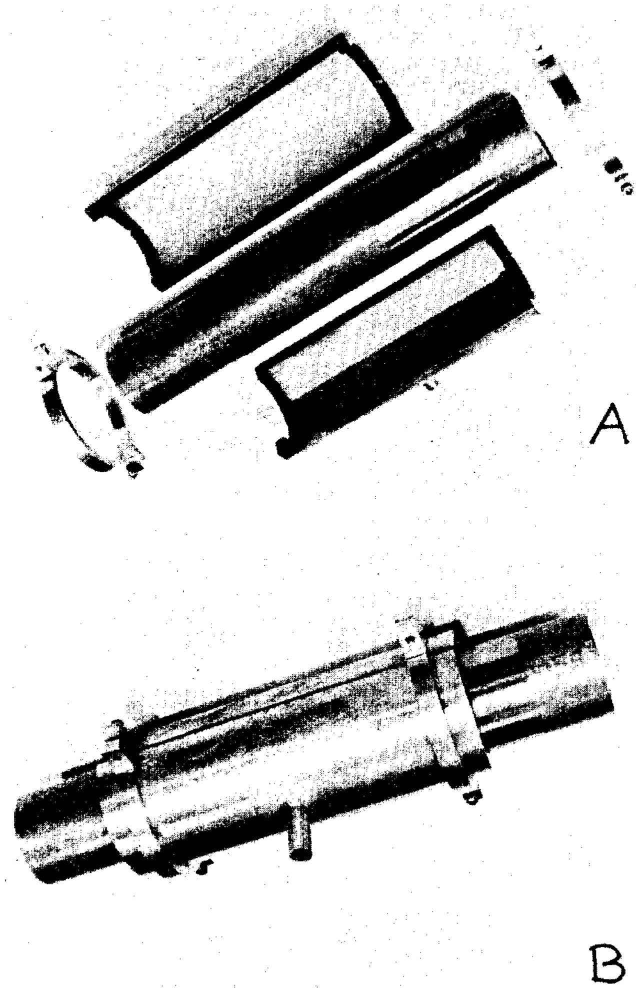

Fig. 4. The fixture for leak checking helium carrying lines. A open, B clamped on a pipe.

Beam Vacuum

Beam vacuum system[1] consists of beam tubes located in magnet vessels and UHV pumping stations, shown in Fig. 3, which are welded to the beam tubes, after the insulating vacuum interconnections have been completed. Since all the components have been leak tested before they were moved into the tunnel, only the welds need to be tested. This is done by evacuating 30-50 m long sections with leak checking stations. After maximum sensitivity operation is reached He or HD is used as a tracer gas; at the same time UHV stations are also leak checked.

The Beam Vacuum system has to be baked out to 300°C for proper operation of the machine. Should a small leak (> 10^{-9} Torr.ls^{-1}) open during or after the bake out, the leak is located by spraying argon gas on suspected places and by observing the output on the nearest BA gauge. This is a very powerful method as the ratio of air to argon pumping speed of the UHV pumping stations is $\sim$ 200 and argon sensitivity of BA gauge is high. Normal leak detection cannot be used after bake out, as it would contaminate the beam vacuum. A 40 m long prototype section of beam vacuum has been built[4] and both the above leak checking methods were tested. Pressures of < 1 x 10^{-11} Torr were routinely achieved.

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