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EXPERIENCE WITH Zr-Al GETTER PUMPS IN THE ISX-B TOKAMAK

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Abstract

Zr-Al getter pumps have been used in the ISX-B tokamak in connection with a series of pump limiter experiments. Experience with these pumps in this environment has revealed several problems that may limit their usefulness under typical tokamak operating conditions. Although the pumps perform satisfactorily while in operation with hydrogenic pumping speeds of 1-2 × 10^3 L/s at pressures of ∿10 mtorr, some unknown mechanism, on occasion, slightly activates pumps that had been previously passive. Such behavior precludes the use of any operations that require high hydrogen pressures in the torus. Additionally, discharge cleaning operations cannot be safely carried out after the pumps are fully activated. Continued use of the pumps eventually leads to destruction of two getter cartridges from hydrogen embrittlement.

1. Introduction

The pump limiter experiment on the ISX-B tokamak at Oak Ridge National Laboratory (ORNL) requires hydrogen pumping speeds of 1-2 × 10^3 L/s at the neutralizer plate. This is provided by two Zr-Al nonevaporable getter pumps located directly behind the limiter head (Fig. 1). Details of the pump limiter experiment and the rationale behind the choice of Zr-Al pumps have been given previously.[1] In this paper, we present a summary of our experience with the operation of these pumps in a tokamak

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environment with particular regard to several problems that arose in connection with their use.

2. Self-activation

When the getter pumps were first installed on the tokamak, they had been exposed to air and were in a passive state. The pumps are not normally operable until they have been thermally activated at high temperatures (400-700°C) for 10 to 15 min.[2] Prior to the planned activation of the pumps, it was discovered that a partial inadvertent activation had taken place. The torus had been filled with hydrogen to a pressure of 1 torr with all pumping systems valved off. The hydrogen pressure slowly fell, indicating some residual pumping action.

We confirmed that the Zr-Al pumps were responsible by backfilling the torus with a small amount of helium (which is not pumped by the Zr-Al alloy) and observing that there was no pressure drop with time. Later measurements indicated that the pumps were active and pumping hydrogen at about 1 L/s.

Initially it was assumed that the pumps had been accidentally heated to a temperature high enough to cause the activation. The normal discharge cleaning process does elevate the pump temperature, but measurements indicated that the maximum temperatures reached were less than 100°C — well below that required for pump activation. The activation cycle for the pumps (Fig. 2) indicates that for a passive pump the onset of pumping occurs between 350 and 400°C.

Another similar self-activation occurred when the torus was filled with hydrogen to a pressure of 13 torr for calibration of the Thomson scattering system. Examination of the pumps showed severe embrittlement, particularly in the regions near the windows in the limiter head. This effect can be seen in Fig. 3, which shows the getter cartridge, and closeups of a normal and an embrittled section, respectively.

A series of laboratory studies was carried out in an effort to identify the cause of the activation. A Zr-Al getter pump cartridge was installed in an instrumented vacuum test stand and exposed to various DC glow discharge plasmas in an attempt to achieve activation without external heating. Various electrode configurations, discharge currents, and gas pressures were tried; however, none activated the pumps, which implies that we did not successfully duplicate the conditions that led to the activation in ISX-B.

3. Discharge cleaning

Following the initial activation in the tokamak, the hydrogen pumped by the getter cartridges was thermally desorbed by slowly raising the temperature to 680°C in order not to swamp the main system turbopumps with the evolved hydrogen. This procedure fully activated both pumps. We expected the pumps to be passive during subsequent discharge cleaning by saturation of the getter surface with impurities removed from the walls by the discharge, as reported by the Princeton group.[3] In our case, this did not occur and large quantities of hydrogen were pumped during the overnight discharge cleaning. This gas load was measured during the next desorption cycle and found to be 4-5 $\times$ 10^3 L for each cartridge. This value is uncomfortably close to the hydrogen embrittlement limit of 20 torr•L/g or 6.6 $\times$ 10^3 torr•L.

Since then, discharge cleaning has not been performed in the tokamak with activated Zr-Al pumps for two reasons: (1) the hydrogen sorbed during any normal cleaning cycle will approach or exceed the embrittlement limit and (2) the time required to desorb that which would be pumped during a shortened cleaning cycle is excessive. One alternative would be to passivate the pumps, but it is not an attractive choice because this procedure requires a machine vent. Another possibility is to maintain the pump temperature between 500 and 600°C during discharge cleaning, but this procedure entails some degree of risk to the safety of the pump.

4. Pump limiter operation

Laboratory testing of the Zr-Al getter pumps prior to installation on ISX indicated pumping speeds of 1.2-1.8 × 10^3 L/s with flow rates up to 13 torr·L/s and at pressures up to 10 mtorr.[4] These measurements were carried out using the limiter head-pump configuration, as used in the tokamak.

Pumping speeds were obtained in the tokamak from pressure measurements with Schulz-Phelps gauges mounted in each limiter module and from gas feed rates into the machine. These measurements were made during ohmically heated (OH) plasma operation and involved two sets of experiments, one made with the passive pumps and one with the pumps activated. The gas flow into the tokamak was adjusted so that the line-averaged electron density was the same in the two cases, so that by assuming the increased flow as a consequence of the activated pumps, the pumping speed can be calculated. The results, corrected for the hydrogen gauge factor and the conductance of the extension tube for Schulz-Phelps gauges, are shown in Fig. 4 as a function of the line-averaged electron density obtained from microwave interferometer measurements. The pumping speed exhibits the expected flat behavior except at the lowest densities, where the difficulty of obtaining accurate pressure measurements introduces more error.

When the pumps are in operation, each getter cartridge sorbs a few hundred torr·L of hydrogen over a day of normal tokamak operation. This represents only a small fraction of the reversible sorptive capacity of 6 × 10^3 torr·L and can be easily outgassed.

5. Summary

We have found that for some unspecified reason the Zr-Al pumps self-activate in the ISX environment. Otherwise, the pumps maintain their normal operating characteristics. The self-activation is not compatible with those normal operating procedures which require backfilling the torus with hydrogen significantly above the pressures used in plasma operations. Under these conditions, hydrogen embrittlement can occur and result in destruction of the pump elements. Finally, with the pumps fully activated, the normal discharge cleaning in ISX cannot easily be carried out. The mechanism by which the pumps become accidentally activated has not yet been identified; also, it has not been possible to reproduce the effect in laboratory tests simulating the tokamak experience.

References

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3. R. J. Knize, J. L. Cecchi, and H. F. Dylla, J. Nucl. Mater., 103 & 104 (1981) 539.
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Figure Captions

Fig. 1. Details of the pump limiter module.

Fig. 2. Pumping speed for hydrogen and carbon monoxide as a function of temperature following deactivation of the pumps.

Fig. 3. (a) Photograph of the Zr-Al getter pump cartridge, (b) closeup of a normal getter surface, and (c) closeup of an embrittled getter surface.

Fig. 4. Corrected hydrogen pumping speed in ISX-B as a function of the line-averaged electron density.