Explosion Potential of Neutral-Beam Source Cryopumps for TFTR

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Large cryopumps have become an integral part of all neutral-beam injectors being developed for major fusion experiments. As a joint effort between LBL and LLL, a cryopump has been constructed[1] as a test of the design for TFTR. Additional important purposes of the program are to investigate the compatability of the pump and a nearby neutral beam, and to determine whether a pulse of neutrons and gamma rays, such as will be characteristic of TFTR, will cause desorption of the condensed gas.

The explosion potential of the test cryopump became a paramount issue in the safety analysis required for the reactor experiment. The administrative limit for loading of the cryopump with normal hydrogen or deuterium is that amount of gas which will produce a partial pressure of 13 torr at a total pressure of 1 atmosphere, i.e. a 1.7% mixture by volume. At atmospheric pressure, combustion can occur for mixtures in the range 4.0-75%[2]. It is important to know whether, in a leak-up-to-air accident, when the partial pressure will range from 100% to 1.7%, an explosion can occur. For the test cryopump (250ℓ) loaded to the administrative limit, the energy of combustion would amount to 9.21×10^5 J, or 21.9 g of T.N.T. equivalent. However, for a TFTR beamline (73,000ℓ) the corresponding numbers are 2.69×10^7 J, or 6.39×10^3 g of T.N.T. equivalent.

Experiments by Eseff and Qinlan[3] on the combustion limits of hydrogen in air at various pressures shown that the upper and lower dilution limits draw together as the pressure of the mixture gets lower. Figure 1 reproduces their data, which was taken at ambient temperature, and also shows the leak-up-to-air trajectory as given by the expression, P in atm = $1.7/\%H_2$. It can be seen that the trajectory is everywhere in the non-combustion range.

Wolfe and Yurezyk[4] have done experiments on the limits of combustibility of H_2-O_2 mixtures. Figure 1 also shows their data, which was taken at 70°F (21°C) and at -320°F (-195°C). It can be seen that the trajectory is even further from the explosive area for gas mixtures at liquid-nitrogen temperatures than it is at ambient temperature.

Although the experiments described above, indicate that the administrative limit suffices to insure that combustion will not take place at any subatmospheric pressure, the paucity of the data and the fact that the experiments were not done with deuterium, both argued for further corroboration of the safety. Hence, it was decided to stage 2 different leak-up-to-air accidents (with the experimenters behind a suitable barricade). In the first, air was admitted to the system with the cryopump loaded to the administrative limit for deuterium. A hot-filament ion gauge was arranged to burn throughout the leak-up-to-air cycle. The liquid nigrogen supply was then valved off and air admitted to the system. In a 20-minute leak cycle, followed by 10 minutes at atmospheric pressure, nothing occurred to indicate that combustion had taken place. Reassurance was thus obtained for the safety of the reactor experiment. Next, the experiment was repeated with, in addition, a spark gap firing in the vacuum system at approximately 1-second intervals. Again, no combustion occurred during the leak cycle.

This, we believe, adds assurance to the safety of TFTR operations. It is highly desirable to valve off the supply of liquid gases to the cryopump once a leak occurs, since if large amounts of liqufd oxygen are allowed to condense on the cryopump surfaces, the trajectory is not as simple as that shown in Figure 1, and the likelihood of an explosion is unknown.

References

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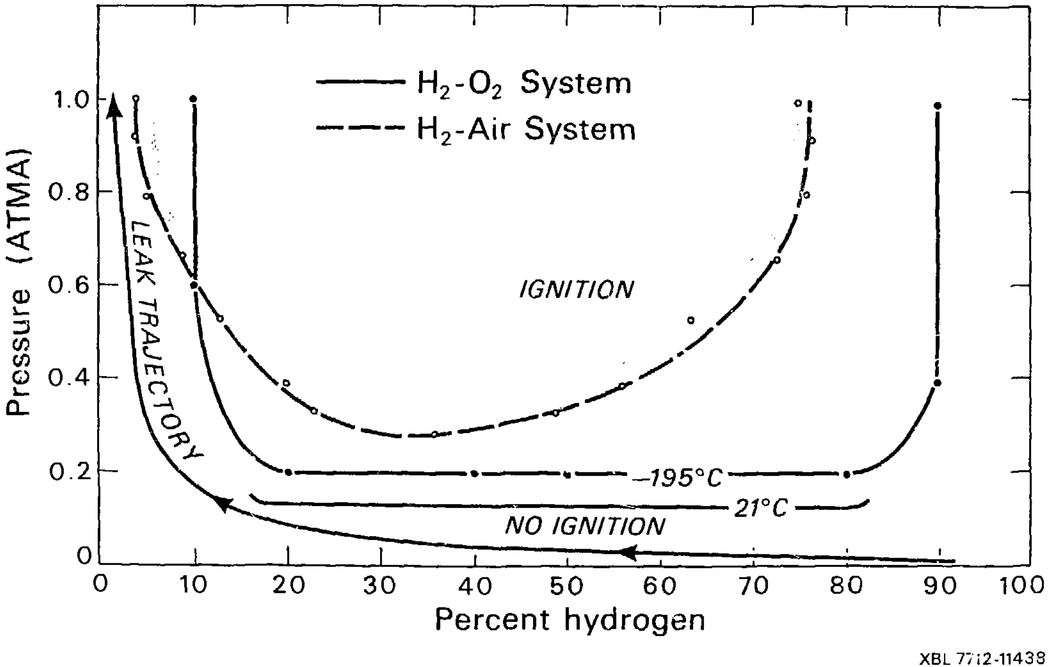
H2-O2 System
H2-Air System
IGNITION
NO IGNITION
LEAK TRAJECTORY
–195°C
21°C
Pressure (ATMA)
1.0
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
60
70
80
90
100
Percent hydrogen
XBL 7712-11438

Fig. 1