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William G. Graham and Lawrence Ruby

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Radiation-Induced Degassing of Cryopumps

William G. Graham and Lawrence Ruby

Lawrence Berkeley Laboratory
Berkeley, California 94720

The possibility of radiation-induced degassing of cryopumps is important in connection with fusion reactors utilizing neutral-beam injectors. Calculations[1] in the case of TFTR, based on 20 MW of D-T fusion power and thermally isolated cryopanels made of copper, considered 2 important cases: No streaming radiation visible to the cryopanel, giving a (combined neutron and gamma) heat load of 4.6×10^{-4} W/cm^3 in the panel; and streaming radiation visible to the cryopanel at a further distance from the torus, giving a heat load of 1.7×10^{-3} W/cm^3 in the panel. In the former case, the transient temperature rise was estimated as 1 K/s, and in the latter case, as 7.3 K/s. The latter-case result predicts that the portion of the cryopump affected would be degassed during a 0.5-s pulse, since the vapor pressure of deuterium at 8 K is 8×10^{-4} Torr. More recent calculations[2] employing continuously-cooled stainless-steel cryopanels of the type actually used in TFTR, and assuming a heat load of 1.34×10^{-2} W/cm^3, predicted that the temperature rise in the panel would only be 0.029 K during a 0.5-second pulse. Neither of the calculations attempted to evaluate the possible effects of individual neutron or gamma-ray interactions.

A small test cryopump[3,4] has been constructed at LLL. One purpose to which the test cryopump has been put is to investigate a possible radiation-induced degassing effect. No satisfactory simulator exists for the radiation pulse characteristic of a magnetic-confinement fusion reactor, and so a conveniently available pulsed source of neutrons and gamma rays has been used for the initial study. This source is the TRIGA Mark III Reactor at the University of California, Berkeley.

A dry exposure room, measuring about 3.5 m on a side, allows the irradiation of large objects either in a pulsed or a continuous mode. Figure 1 shows the cryopump installed in the Exposure Room of the Reactor.

The pulses produced by the reactor had a half width of about 12 ms. The maximum fast-neutron fluence on the cryopump was about 2×10^{11} cm^{-2}, the thermal-neutron fluence 3×10^{9} cm^{-2}, and the gamma-ray dose 6×10^{3} rad. The tests were usually performed by supplying 2 TRIGA pulses to the cyropump. The first pulse was fired with the cryopump unloaded with deuterium. Then, the cryopump was filled with the administrative limit[4] of deuterium. With the loading completed, the second pulse was then fired. The cryopump was instrumented with both a nude and a glass-enclosed vacuum gauge. Each was powered from a special power supply capable of a 1 ms response time. Additional instrumentation consisted of temperature measuring devices on the liquid-nitrogen-cooled and liquid-helium-cooled surfaces of the cryopump.

The pressure-gauge response of the system to the TRIGA pulses is shown in Fig. 2. With an unloaded cryopump, an apparent pressure pulse is produced which is only slightly longer than the reactor pulse itself. In separate experiments, it was found that a similarly appearing pulse is produced by a completely sealed-off vacuum gauge. However, as can be seen from the Figure, with a deuterium-loaded cryopump, a very much larger pressure pulse was produced, which had a long exponential tail, characteristic of a re-pumpdown of the system. The pumping speed, as computed from the exponential, is about half that observed previously when the cryopump was subjected to D_2-gas pulses, in the absense of radiation. Additional experiments were run with the core of the reactor retracted somewhat into the pool, in order to change the mix of gamma rays, thermal neutrons, and fast neutrons so as to preferentially depress the latter. Progressive retraction of the core caused the degassing effect to be reduced, and finally to disappear entirely. Monitoring

of the neutron and gamma fluences was accomplished by exposing high-purity foils and TLDs, respectively. Data on neutron and gamma fluences for the various core positions will be presented, as well as an explanation of the possible outgassing mechanism.

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CAPTIONS

Figure 1: Cryopump in Reactor Exposure Room

Figure 2: Cryopump Response to a Reactor Pulse

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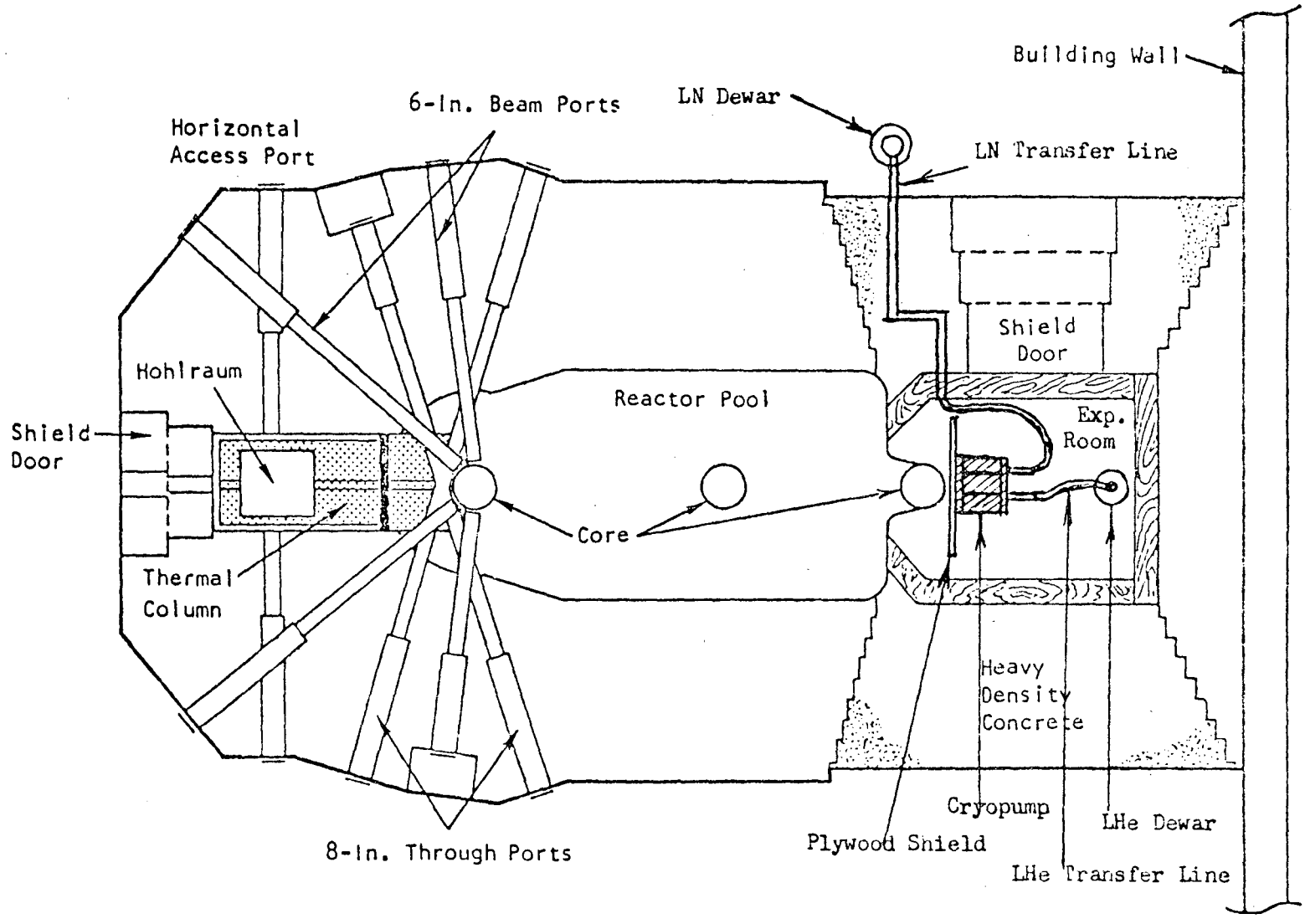

Fig. 1

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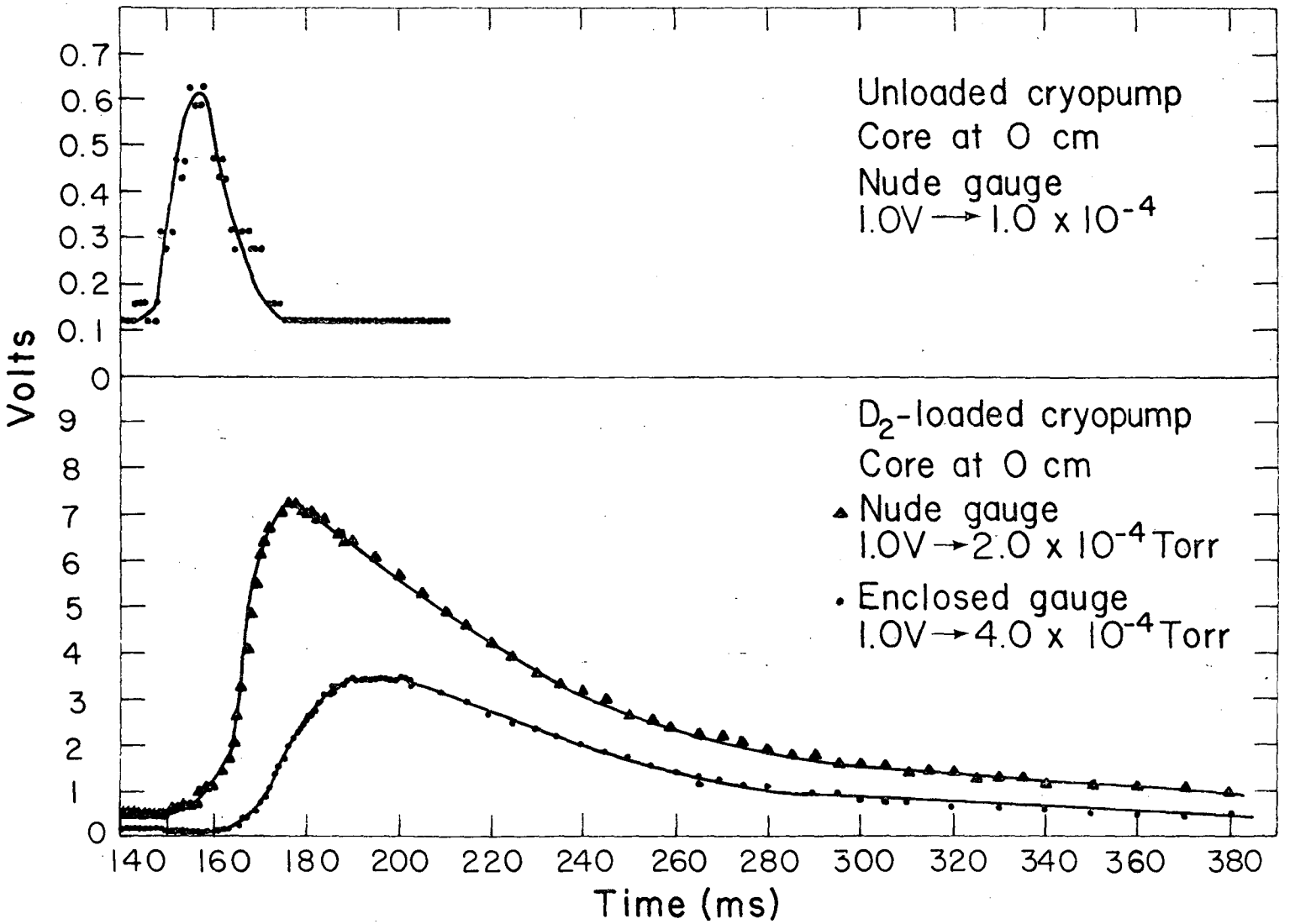

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Fig. 2

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