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Abstract

A liquid propane chamber is described, with special reference to some of the construction and design problems.

A brief summary of its operation in the 6.2-Bev neutron beam is given.

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Introduction

A propane bubble chamber was designed and built along the same general lines as previously reported chambers.[1,2,3] There are, however, some significant differences. (a) Our chamber was designed to fit into an existing magnet with a pulsed field of 22,000 gauss.[4] (b) This is a diaphragm-type expansion chamber similar to that reported by D. A. Glaser and D. C. Rahm[2] and the University of Washington.[5] (c) A dark-field illumination system is used, the components of which occupy no more than one inch in vertical direction. (d) A secondary pressure vessel, provided with an external vent, is used for safety in case of window failure.

The Chamber

The chamber size and shape were determined by three factors: the 6-in. magnet gap, the 19-in. diameter of the hole in the top pole, and the strength of the glass used for the top and bottom of the chamber (Fig. 1).

We did not wish to assemble the chamber in the magnet, therefore a unit was designed that could be preassembled. The chamber and heat shield are assembled and lowered into the gap through the top pole.

The thickest available Herculite for windows was 1.25 in., therefore all stress calculations were made on the basis of the published figures for this material.[6]

A modified rectangular shape was found to be the most desirable for our purposes, since we wished to have a maximum track length along the beam direction. The maximum inside dimensions of the completed chamber are 13 in. long, 6.5 in. wide, and 3.25 in. deep. The body was machined from a solid block of nonmagnetic stainless steel, and the walls are 2 in. thick and polished on the inside.

The chamber was originally designed with four free pistons in one side wall for the expansion mechanism. These were similar in design to the piston used by J. Steinberger,[3] but they were magnesium rather than micarta. The pistons were actuated by nitrogen pressure controlled by a commerical three-way pilot-operated 0.75-in. solenoid valve.[7] Both "O" rings and "quad" rings were tried on the pistons, but their lifetimes were only on the order of a few hundred cycles. The system was then changed to one using a single 1/8-in. Hycar diaphragm. The diaphragm is supported in the expanded position by a plate in which are drilled 250 1/16-in. holes for the passage of the nitrogen.

So that there will be no clamping load on the windows, they are assembled in their frames in such a way that when they are bolted to the chamber there is a minimum of one mil of clearance between them and the chamber body. Lead and various eutectic alloys were tried unsuccessfully in an effort to find a suitable material for distributing the load from the glass to the frame. The material finally used was epoxy resin No. 828[8] with Curing Agent D. This mixture cures at 65°C. The assembly technique was as follows. The window was placed in the clamping frame and string packing inserted between the window and the frame at the beginning of the 45° bevel. The assembly was then bolted to the chamber with several 1-mil shims between the body and the glass. (The "O" ring was not in place). The window was weighted down so that the shims were snug, and the gap between the window and frame was filled with the resin, which was then cured.

The window-clamping ring was machined from Hastelloy type B stainless steel, since this material has a coefficient of thermal expansion as close to that of the glass as it is possible to obtain for a material not affected by a pulsed magnetic field. Too great an expansion difference would either overload the glass or allow it to move too far away from the O ring seal.

The Secondary Pressure Vessel

For safety reasons it was decided to place the chamber in a secondary pressure vessel that was provided with a vent to the outside of the building. Since the lower half of this vessel also acts as a heat exchanger, the vent is covered with a 2-mil disk of aluminum that would rupture on a slight increase in pressure. The upper portion of the pressure tank is the upper pole piece, which is bolted to the upper yoke of the magnet, and the two sections are sealed with an O-ring gasket. By using the magnet as part of the pressure vessel we were able to save gap height by making the bottom of the pressure vessel thin, since it is supported by the bottom pole. (See Fig. 2)

The upper portion of the hole in the top pole piece was sealed with a plug in which two optical flats were inserted to provide openings for the camera.

The Thermal System

The chamber is heated by a water bath inside the lower portion of the secondary pressure vessel. This bath, in turn, is heated by copper tubes through which flows temperature-controlled water from an external pumping system. The circulating water is heated by immersion calrod units controlled by a mercury switch accurate to 0.01°C.

The Optical System*

The illumination is provided by a pair of G.E.F.T. 922 flash tubes. Each tube is placed in a semicircular length of brass tubing lined with aluminum foil and wound in a spiral with 50-mil bare copper wire. This wire and the tubing act as the tickler electrode. An air blast is directed along the lights to provide cooling and to prevent possible accumulation of propane vapor around the lights. The light from the flash tube is directed into the top edge of a piece of 0.25-in., lucite about 12 in. long that serves as a light pipe. The edge of the lucite directly

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* The "Venetian Blind" method of illumination was suggested by Prof. Harvey White and first used in a form suitable for low temperatures by Parmentier and Schwemin on a 2 1/2 inch hydrogen bubble chamber.[1]

below the flash tube was cut and polished at a 45° angle to direct the light along the length of the lucite. From the light pipe the light enters the diffuser plate, which is another piece of lucite provided with a sand-blasted area directly below the bottom window of the chamber. This piece of lucite, as well as the light pipe, is vacuum-coated with aluminum except directly under the chamber, and then wrapped with tape to protect the surfaces. This provides maximum reflection. Directly above the diffuser plate we installed a "venetian blind" to provide a black background for the camera. This was constructed by cementing together lucite strips, 1/16 by 6 in., in five sections. In the first section the lucite pieces are at a 23° angle to the normal and each succeeding section is at a 3° smaller angle. The final section is at an 11° angle. These sections are cemented together in one piece and then cut into nine strips 3/4 in. wide at right angles to the 1/16-in. lucite pieces. Alternate strips are inverted and turned end for end. This provides even illumination and illuminates both ends of the chamber. The final assembly is baked at 60°C for several hours before final machining and polishing. The thickness of the final assembly is not greater than 3/4 in. The cement was made by dissolving scrap lucite in ethylene dichloride and adding black spirit dye.

The chamber is photographed by a steroscopic camera with 90-mm lenses placed on top of the secondary pressure vessel. The camera is provided with a third lens that records on the same film the picture number, the run data, and the field current.[4]

Operation

The chamber has been run with a vapor pressure as low as 295 psi and as high as 340 psi with tracks of good quality throughout. The lower pressures seem to give slightly better results in track quality, since the bubbles do not grow so rapidly as they do at higher temperatures.

We have operated the chamber for several days at the Bevatron in the 6.2-Bev neutron beam.

The expansion valve is given the signal to open at time zero and closed 7 to 11 milliseconds later. The pressure signal from the transducer is displayed on an oscilloscope (Fig. 4), and the beam injected into the chamber at the point of minimum pressure. The lights are flashed about 2 msec after the last of the beam has arrived. Pictures taken with this light delay show differences in ionization of the various particles very well (Fig. 5). Light delays on the order of 0.5 msec are used for bubble-counting techniques.

It was found necessary to use 300 volts on the expansion valve, rather than its rated maximum of 150 volts, in order to get reliable operation at the rapid recompression times required for the present cycle rate of 10 per minute.

Acknowledgments

Dr. Wilson, M. Powell contributed many helpful suggestions and criticisms. Vincent Romano did the major portion of the engineering. Dr. William B. Fowler, Dr. Earl C. Fowler, and Richard Lander were responsible for the work and alterations during the Bevatron experiments. The electronics were designed by Donald Lundgren. This work was done under the auspices of the U.S. Atomic Energy Commission.

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Legends

Fig. 1. Schematic

Fig. 2. Chamber

Fig. 3. Typical oscilloscope trace

Fig. 4. Typical picture

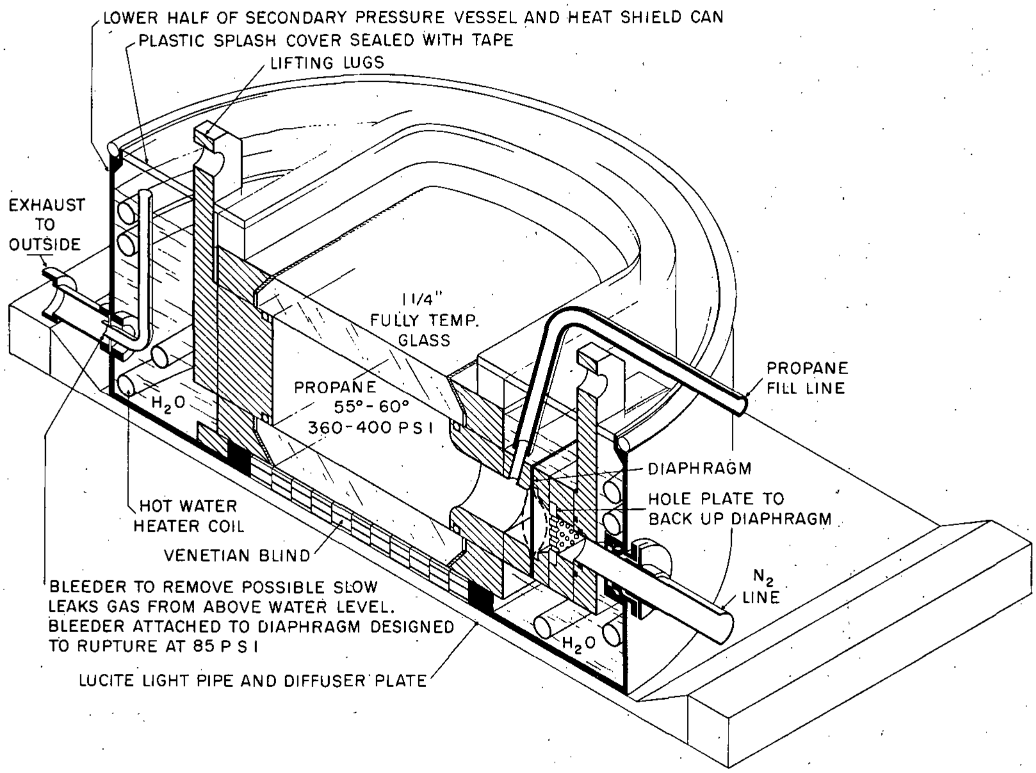

Fig. 1. Schematic

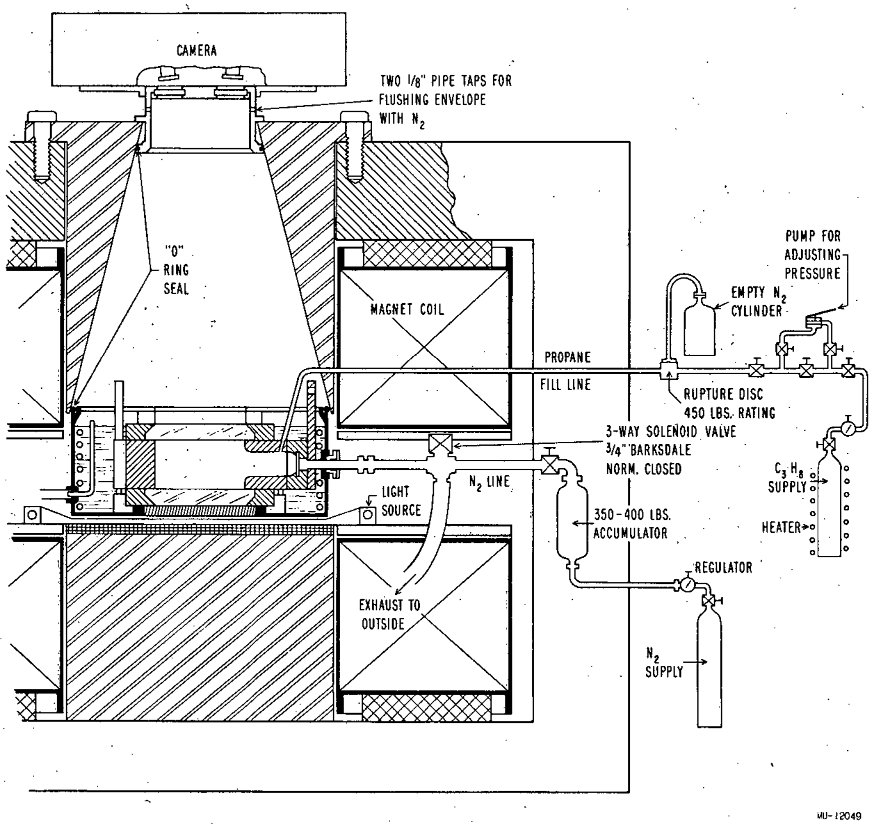

Fig. 2. Chamber

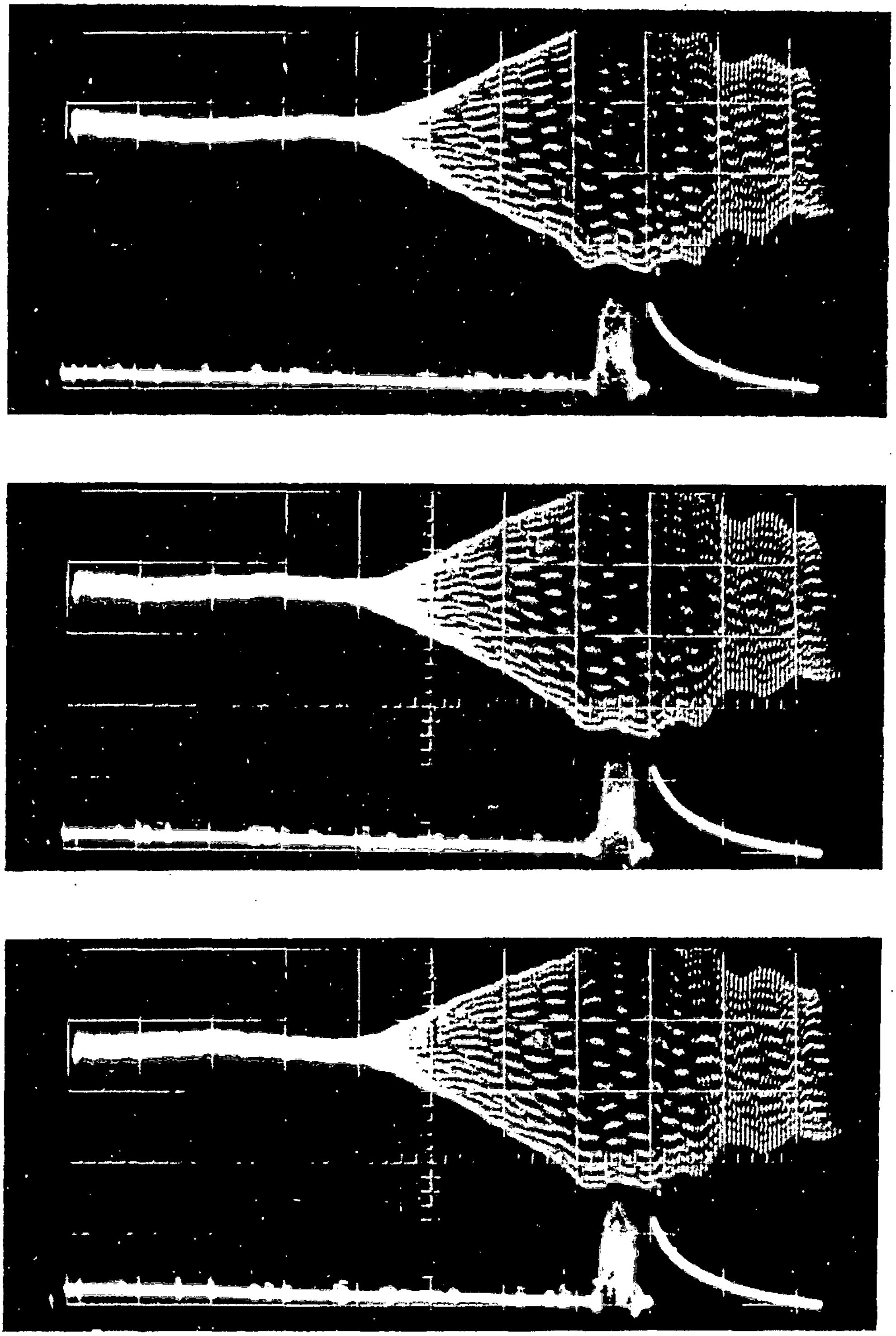

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Fig. 3. Typical oscilloscope trace

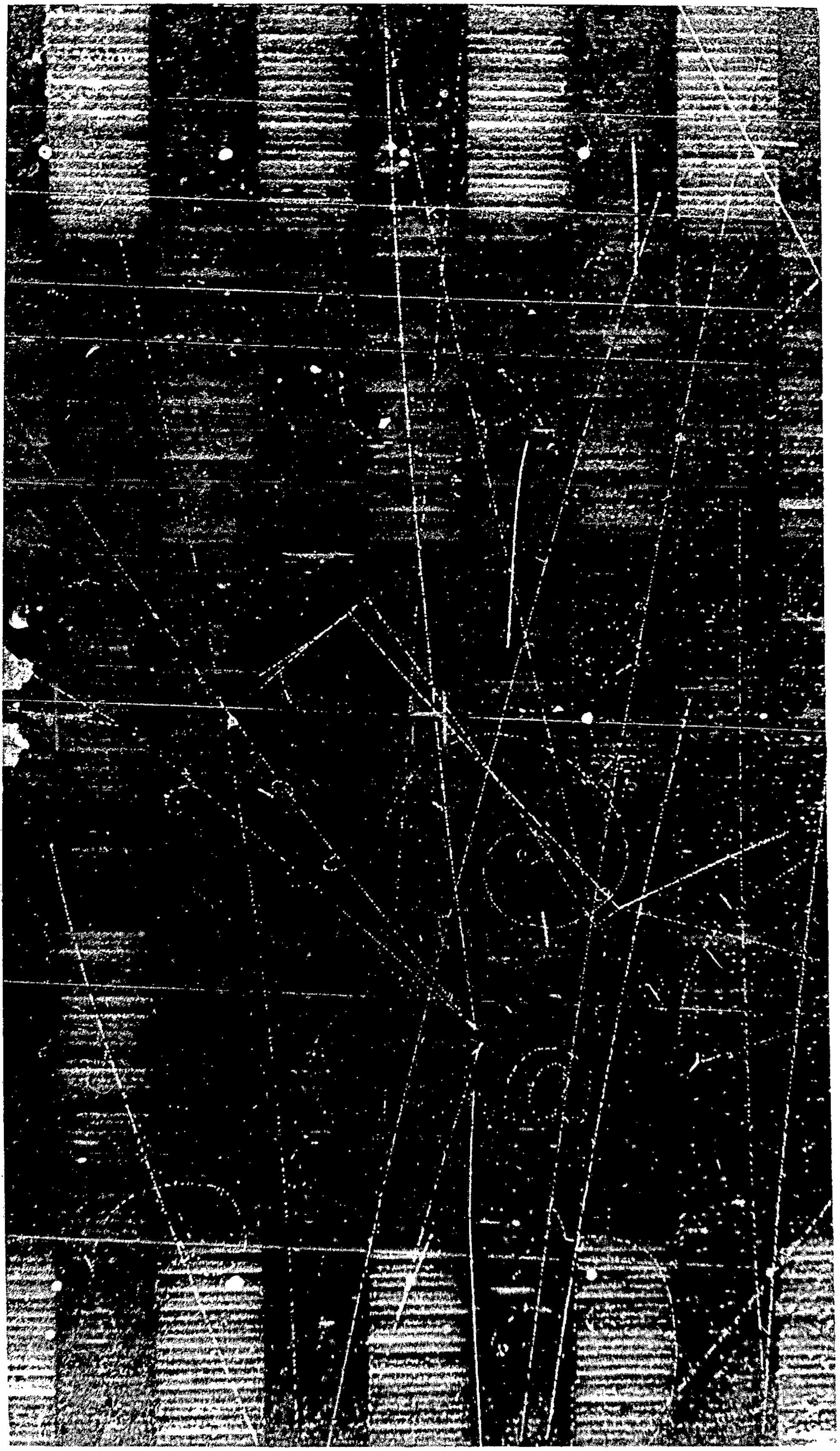

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Fig. 4. Typical picture