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November 6, 1950

Berkeley, California

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Abstract

A description is given of a target in which liquid hydrogen was bombarded with x-rays from the Berkeley synchrotron. The liquid hydrogen, in a stainless steel flask, was surrounded by an evacuated jacket containing a heat shield maintained at the temperature of liquid nitrogen. The liquid level was indicated by a counterweighted float system.

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Introduction

As a part of the program of investigating mesons produced by x-rays from the Berkeley synchrotron it was desired to bombard hydrogen. It was necessary that the hydrogen be extremely pure and dense and it was important that the walls of the vessel be as thin as possible in order to avoid degradation and scattering of the incident x-rays and emergent mesons. These requirements were most easily met with liquid hydrogen.

Construction

The essential components of the target were a flask to contain the liquid hydrogen, a refrigerated shield surrounding the hydrogen flask to minimize heat transfer by radiation, a vacuum jacket to provide thermal insulation, and a liquid-level monitoring system, as shown in Figures 1, 2, and 3.

The hydrogen flask was made entirely of stainless steel, fabricated by "heliarc" welding. The horizontal section was made of 2 inch diameter tubing with a wall thickness of 0.035 inch. The end caps were made by drawing hemispheres from 0.030 inch flat sheet and then machining the central 1-3/4 inch diameter area to a thickness of 0.005 inch before removing from the drawing die. This method of fabrication gave a minimum thickness of material in the region traversed by the x-ray beam, yet permitted the weld to the cylindrical section to be made between parts of comparable wall thickness. One of these caps was tested to failure at a pressure of 1000 pounds per square inch, which corresponded to development of the full tensil strength of the material. A section of 4 inch tubing above the beam-line section provided a substantial reservoir for storage as well as a large liquid-gas interface to allow gas bubbles to escape without liquid entrainment. A section of 2 inch tubing above the reservoir provided a long thermal leakage path. Stainless steel was chosen for the flask material because it is easily fabricated, retains a highly reflecting surface finish, and because it does not accelerate the ortho-para conversion of hydrogen.

The upper portion of the refrigerated shield consisted of a liquid nitrogen filled tank formed from two coaxial stainless steel cylinders by welding in radial spacer bars at the open top and welding vacuum tight a flat ring to form the bottom. A 1/8 inch thick copper plate was soft-soldered to the bottom and to this a semi-cylindrical shield of two layers of 0.005 inch copper was attached with screws. The ends of this horizontal section were covered with two layers of 0.001 inch aluminum foil. The hydrogen flask was thus entirely surrounded by a surface which was almost all at the temperature of boiling nitrogen.

The vacuum jacket was split into two parts for assembly. The upper portion consisted of a cylinder welded into a rectangular cover plate. The internal system was suspended from and in thermal contact with the outer tank only at the top. The lower portion of the vacuum tank consisted of a flanged rectangular box at the bottom of which a 0.015 inch thick semi-cylindrical section of stainless steel was attached by silver soldering. At either end 2 inch diameter ports were cut coaxially with this semi-cylindrical section. The ports were closed with gasketed caps which were made from hemispheres drawn from 0.005 inch stainless steel sheet, and furnace brazed to stainless steel flanges. These end caps were made removable to permit inspection of the assembled target.

The level of the liquid hydrogen in the reservoir was monitored with a float system. This system was chosen because of its simplicity and inherent reliability. A counterweighted system was required because of the extremely low density of liquid hydrogen, 0.07 gm/cm^3. A 24 inch length of pyrex pipe was attached to a header on the top of the hydrogen flask and a 1-3/4 inch diameter pulley was mounted in the top flange of this pipe. A hollow aluminum float and a counterweight were hung from the pulley with a 0.005 inch diameter molybdenum wire. The float was designed to displace 4 grams of liquid hydrogen when fully submerged and the counterweight was made 2 grams lighter than the float. There was thus a net driving force of 2 grams available in either direction. This was sufficient to overcome any friction in the pulley bearings but it was discovered that when a slight kink was accidentally introduced into the cable it would not pass over the pulley with this driving force. For this reason the counterweight was made of steel so that it could be driven manually with a small magnet held against the outside of the pyrex pipe. The length of the cable was adjusted so that the traversal of the pyrex pipe by the counterweight corresponded to the traversal of the 24 inch long reservoir section in the hydrogen flask by the float.

The jacket was evacuated to a pressure of 10^{-6} mm of mercury by a conventional oil-diffusion pump system with a speed of 10 liters per second. This vacuum while obviously better than necessary to eliminate thermal conduction in the gas was extremely useful in establishing the vacuum tightness of the system.

Charging System

When a good vacuum had been obtained in the main vacuum jacket the system shown in Figure 4 was evacuated to a pressure of less than 100 microns of mercury. This was done with the transfer dewar removed and the end of the transfer tube sealed with a rubber cap. The system was then filled with helium to a net positive pressure of 5 p.s.i. and the liquid nitrogen shield was filled. This preliminary preparation was usually made some hours before the liquid hydrogen was received.

When the system was ready to charge the cap was removed from the end of the transfer tube, Valves 2 and 3 were opened, the transfer tube was inserted into the dewar, and the header on the dewar was sealed. During this time air was prevented from entering the system by the helium escaping from the end of the transfer tube. Valves 1 and 5 were then opened, Valve 2 was closed, and helium was forced into the header of the dewar, driving the liquid hydrogen through the transfer tube into the hydrogen flask. When the flask was filled, Valve 5 was closed and Valve 2 was opened, thus providing a bypass to vent the header of the dewar into the main exhaust system.

The target was emptied by blowing out the liquid nitrogen shield and filling the vacuum jacket with helium to atmospheric pressure.

Some precautions are worth noting. The pyrex pipe and all rubber lines in the system were provided with internal wires securely connected to grounded conductors at the ends in order to drain electrostatic charges produced by the flow of the hydrogen gas. The transfer tube was vacuum-jacketed and this jacket extended well into both the dewar and the hydrogen flask. The end of the transfer tube in the hydrogen flask was terminated just above the top of the reservoir section. This allowed the gas which came out of the transfer tube to separate and escape without throwing liquid hydrogen up the column.

Performance

The target proved to be economical in use. With the flask properly chilled the loss of liquid hydrogen during charging amounted to about 3 liters and the subsequent evaporation rate was about 2 liters per day. Since the shelf life of the charge in a 25 liter dewar is only about 3 days it would seem that in any future design one should make the reservoir section of the liquid hydrogen flask large enough to take the full charge.

The target has been employed in a variety of experiments. It has been used with the Berkeley synchrotron by Cook[1] and Bishop[2], et al. in the study of positive mesons and by Steller and Panofsky[3] in the study of neutral mesons. It has been used with the 184-inch cyclotron by Peterson[4] in the study of mesons produced by high-energy protons and by Chamberlain[5], et al. in proton-proton scattering experiments.

Acknowledgments

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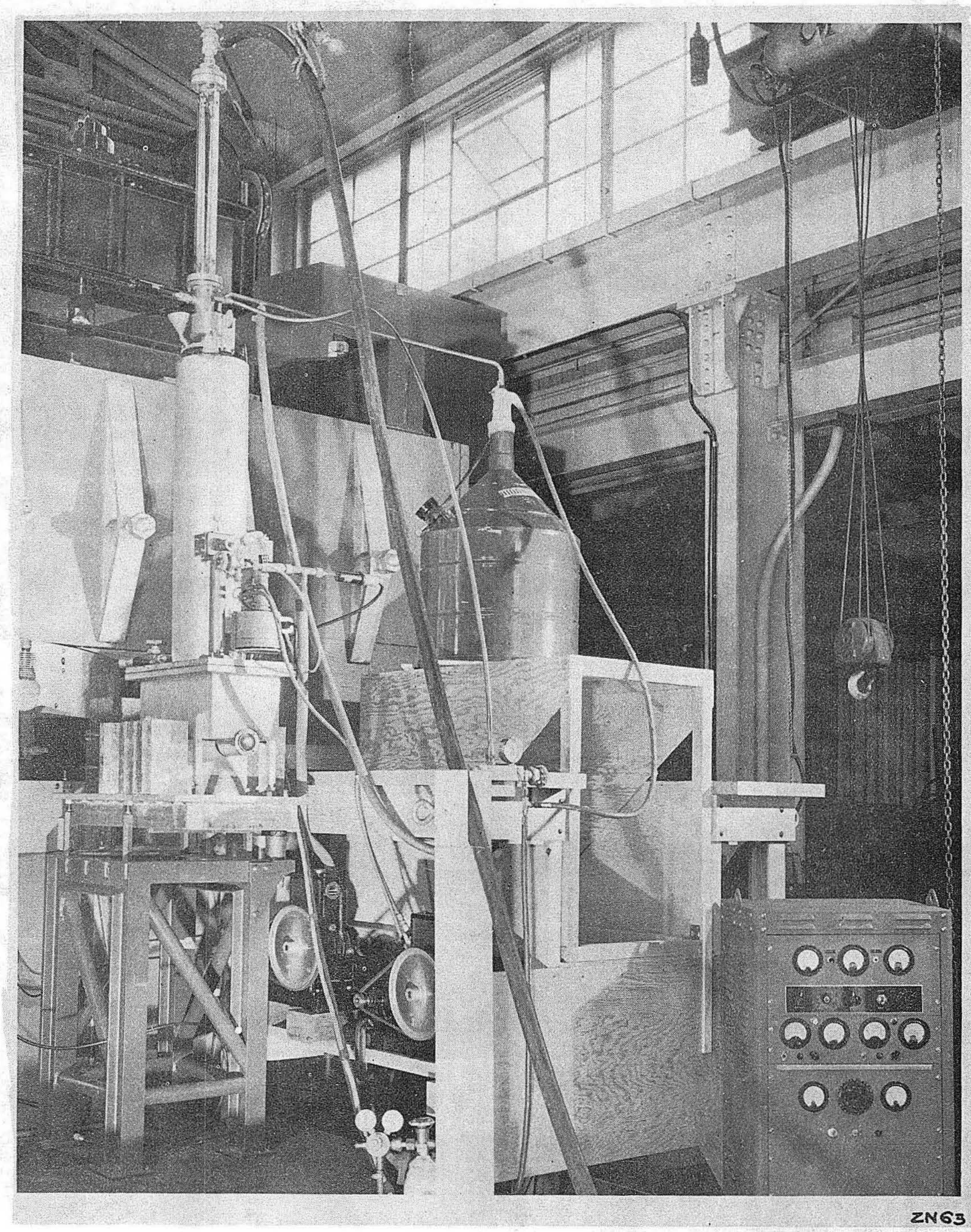

Fig. 1
Liquid Nitrogen Target in use
with the Berkeley Synchrotron

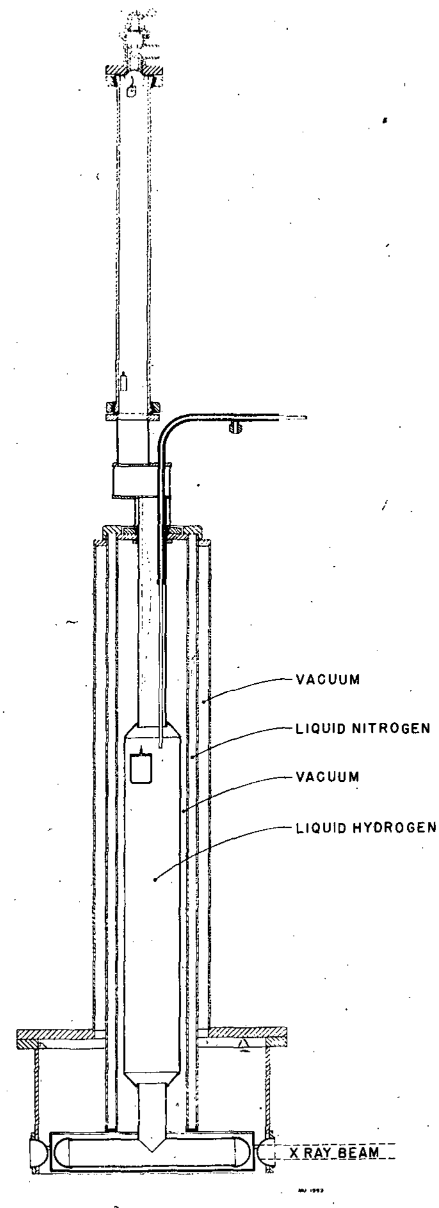

Fig. 2
Cross Section of Target

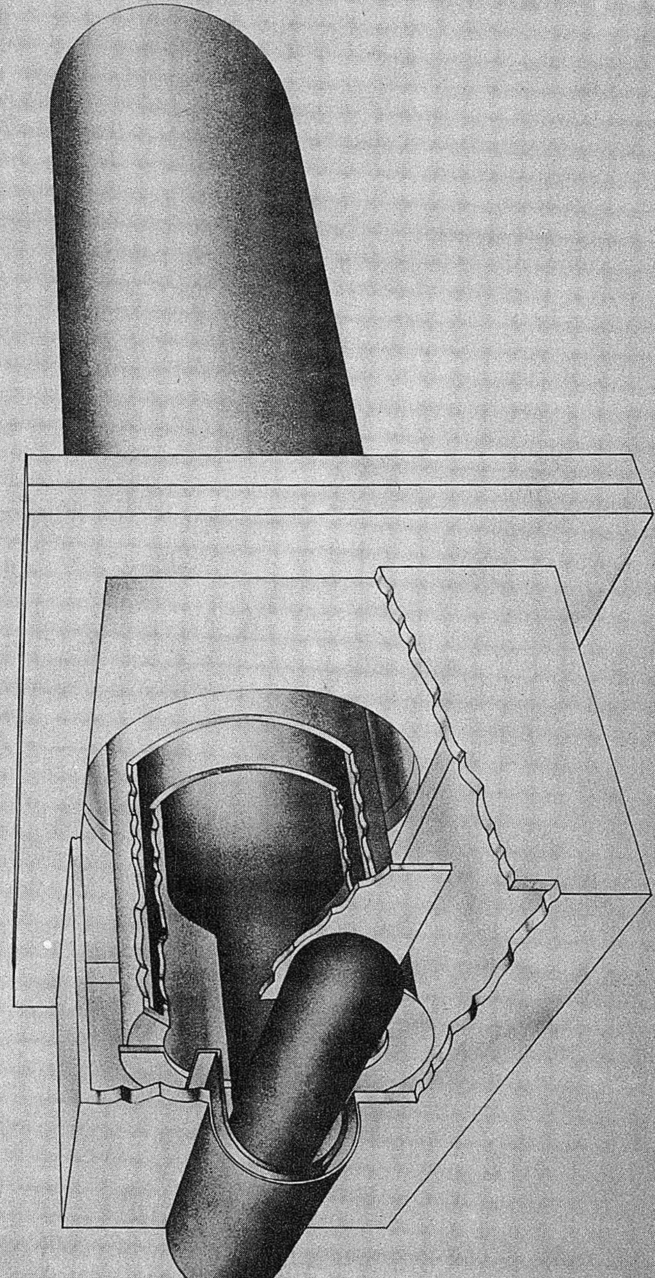

FIG 3
Cut-Away View of Target

ZN 64

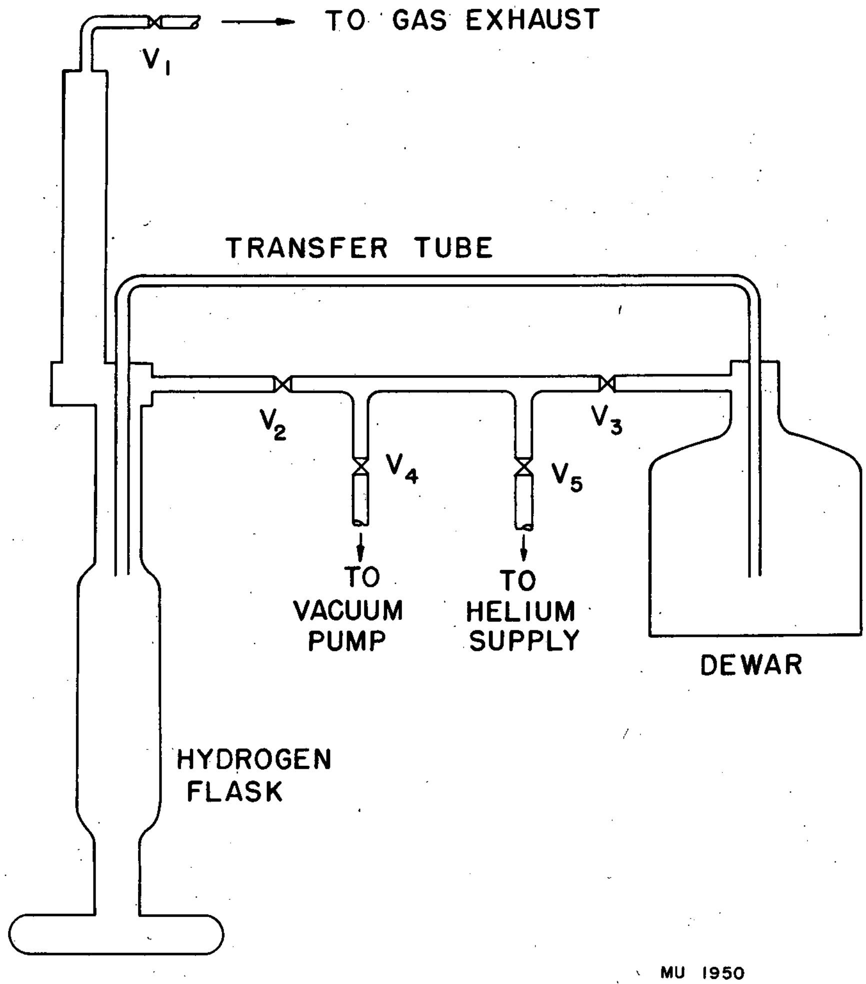

Fig. 4
Charging System