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A LIQUID HYDROGEN TARGET FOR SLAC'S 30 mA ELECTRON BEAM*

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Summary. A unique liquid hydrogen target capable of handling SLAC's high current (30 mA), high energy (20 GeV) electron beam is described. A small axial fan submerged in the liquid hydrogen circulates the liquid through the target cell and heat exchanger. Density variations as high as 10% due to beam heating were experienced in similar targets which did not employ this circulating technique. Experimental results show that in the circulating target these density variations were reduced to less than ± 1% with heat fluxes as high as 5 kW/cm^2 per cm of target length.

Introduction

Many of the experiments at the Stanford Linear Accelerator Center (SLAC) involve the use of liquid hydrogen targets. With the advent of higher beam currents at SLAC (25 - 30 mA peak) density fluctuations in the liquid hydrogen (LH_2) due to beam heating becomes a problem. Past experience with lower beam intensities has shown that the natural convection currents set up by the beam heating have been sufficient to circulate the fluid and maintain uniform density of hydrogen exposed to the beam.

Figure 1 shows a schematic of a typical SLAC liquid hydrogen target system. Bulk LH_2 is maintained in a reservoir above the target proper. Gaseous hydrogen is then condensed in the target cell by means of a heat exchanger which serves as both the top of the cell and the bottom of the reservoir. By maintaining the target cells at 35 psia some 3° K$^+$ of subcooling is made available to the condensed liquid in the target cell (LH_2 at 1 atm boils at 20.3° K; LH_2 at 2.3 atms boils at 23.5° K). The density variation of LH_2 under these conditions is some 1.5% per degree kelvin.

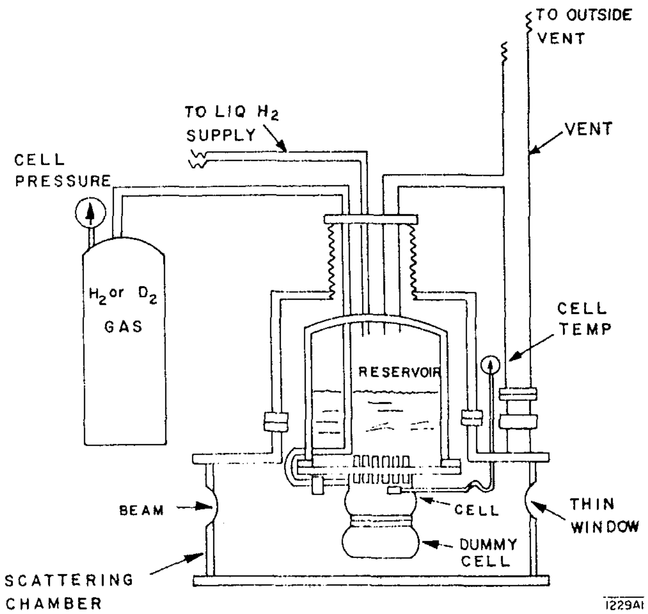

FIG. 1--Typical SLAC hydrogen target system.

The instantaneous energy absorbed by the target from the incident electrons at a current of 30 mA can be shown to be 8.6 kW/cm of target length. This heat is deposited over 360 pulses/sec of duration 1.5×10^{-6} sec or 0.013 watt-sec/cm/pulse. For a beam having a cross section of 0.25 cm^2 it can be shown that the temperature rise per pulse is greater than 0.15° K per pulse. For beams of smaller cross section the temperature rise is greater. Early last year when operating with a conventional target some tests were made at high currents and varying pulse rates. Some results of those tests are given in Fig. 2. Here is shown a typical normalized cross section vs repetition rate. Theoretically, this normalized cross section should be independent of rep rate. Microphones installed in the target indicated that sufficient beam current was available to cause boiling of the hydrogen. The resulting changes in the target density would produce the effect in Fig. 2.

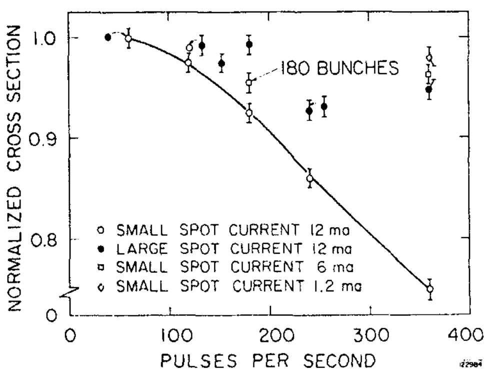

FIG. 2--Normalized cross section vs repetition rate.

The Natural Convection Target

On the basis of the results shown in Fig. 2 a target was designed to enhance the natural convection currents. It was hoped that the resulting convection current velocity would be sufficient to present a new slug of hydrogen to the beam for each beam pulse. Since our beam spot vertical size was 0.2 cm, the required hydrogen velocity for 360 pps was 72 cm/sec. The target shown in Fig. 3 had a flue in the center directly above beam line. The heated hydrogen was captured by the flue and directed to the top of the target and returned around the

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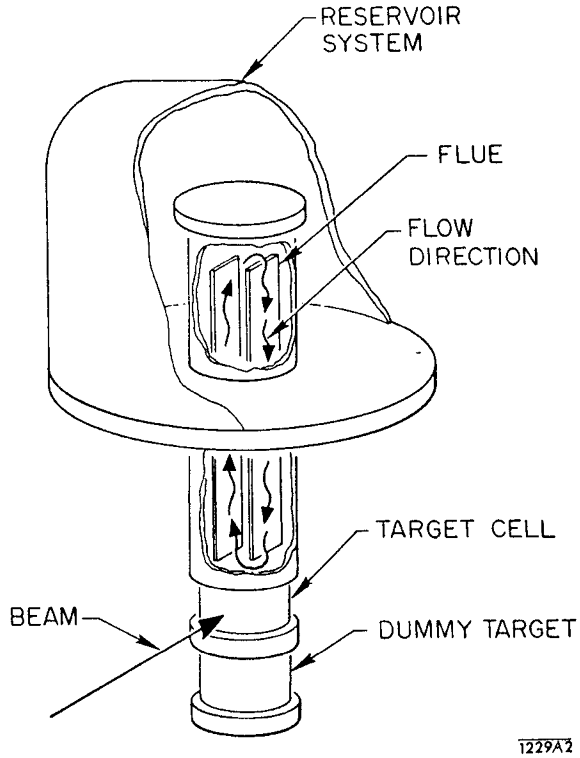

FIG. 3--Natural convection target.

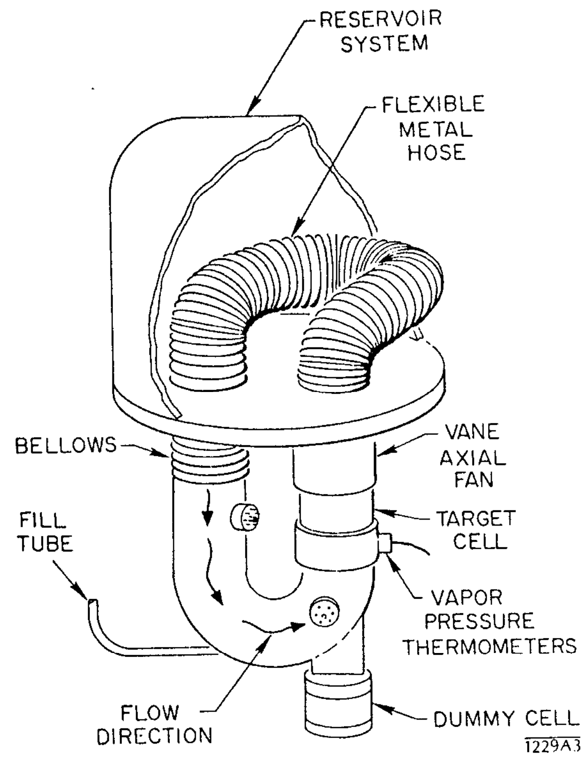

FIG. 4--Forced convection target.

sides as shown in the figure. Testing showed considerable improvement. Density fluctuations were reduced to 5%. This however, was not within the 1% accuracy required by the experiment.

Forced Convection Target

Rather than spend more time trying to further enhance the natural convection currents, a target incorporating forced convection was designed. This target shown in Fig. 4 consists of a "U" tube flow loop, heat exchanger, target cell and vaneaxial fan submerged in the liquid hydrogen. The target cell consists of a seamless 3 mil thick 3" diameter aluminum cylinder epoxyed into the flow loop. Immediately above and below the cell are vapor pressure thermometers. The fan, a Globe model 9A2105, 3 ϕ vaneaxial fan is submerged in the hydrogen with the target on the suction side. The flow loop is completed by a coil of flexible metal hose which acts as the heat exchanger. Various tests were run, the results of which are shown in Fig. 5. Previous results had shown that defocusing the beam reduced the density variations as would be expected since the total absorbed energy is spread over a larger volume of hydrogen. This is particularly true if the beam is defocused only horizontally rather than vertically. For this reason two tests were made, one with a horizontally defocused beam (area = 0.5 cm^2) and the other with a small beam spot (area .08 cm^2). Tests were made with the fan off and fan on for each beam spot size. Figure 5 shows that even without the fan this target was a much better target than had been run previously. It still, however, did not meet ± 1% density control required unless the fan was on. A series of runs were also made at varying fan speeds. No significant effect other than off or on could be detected. The density variations with the fan on, however, were reduced to less than 1%.

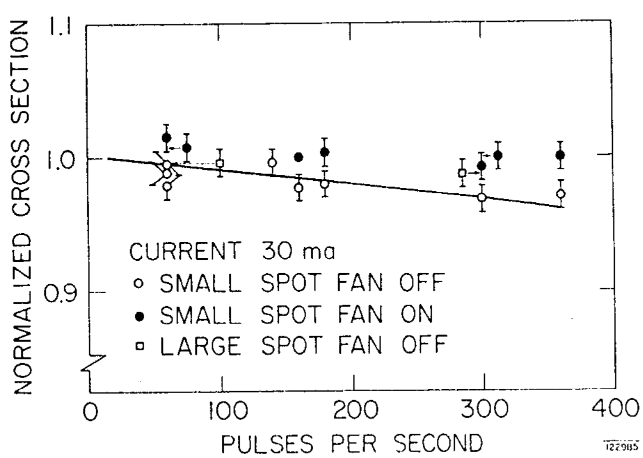

FIG. 5--Normalized cross section vs repetition rate.

In conclusion, it can be seen that where beam heating affects the target density, the forced convection target technique presented here is a significant improvement over conventional target techniques. The authors would like to thank all the physicists of Experimental Group A at SLAC, especially Drs. R. Taylor and D. Coward for making available the results of their target tests and also the shop personnel under R. Messimer and A. Johnston without whose help this target would not exist.