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HYDROGEN TARGETS AT SLAC*

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Summary

Several types of hydrogen targets are used at SLAC. Some are multiple assemblies that allow the user to select liquid hydrogen, liquid deuterium or any of several solid targets. The most elaborate assembly build to date has a cell with circulating liquid hydrogen, a cell with circulating liquid deuterium, and an array of nine solid targets or holes. The target in use is selected by the computer. Target position is determined by encoders and verified by micro-switches. The operation of the fan circulating the hydrogen is monitored by a magnetic pickup coil. Forced circulation of hydrogen is used in other targets where the heat load is too high to allow stable operation with natural convection, or the length-to-diameter ratio is great enough to inhibit bubble free operation.

The simplest liquid hydrogen targets used at SLAC are directly connected to a reservoir of liquid hydrogen in a common vacuum tank. By connecting the fill line to the lowest point of the target and the vent line to the high point, the target will fill when the vent is open, and empty when the vent line is closed. A vacuum of 10^{-4} Torr or better is adequate for most targets.

If there is a need for deuterium or higher pressures of hydrogen, a heat exchanged circuit is added along with a container to hold the liquid while the target flask is empty. These targets are made of Mylar or Kaptan H film and are very much like those used in other laboratories. The reservoirs are filled from 1000 liter dewars through automatically controlled pneumatic valves.

For many of the experiments using the electron beam in the SLAC end station A, the targets are more sophisticated. Since beam heating is up to 10 watts per inch of hydrogen, fan forced circulation of the hydrogen is used. The first SLAC target using a fan was described in the proceedings of the 1969 Particle Accelerator Conference, (IEEE Transactions on Nuclear Science, Vol. NS-16, No. 3, June 1969, p. 631). The obvious advantage of the forced circulation is that heat input from any source will not cause boiling if the cell pressure is higher than the vapor pressure of the liquid. Our heat exchanger has about 150 square inches of area and is able to keep the circulating liquid within 1°K of the reservoir temperature.

The most complex target built here has a fixed vacuum tank and scattering chamber. The target reservoir assembly can be remotely adjusted through a vertical distance of 12 inches inside the vacuum tank. The top cover of the vacuum tank has a rotary seal that can be remotely adjusted through about 110° of angle. Both the vertical and rotary motions are actuated by air motors operating through appropriate gear reducers. The positions are monitored by Theta digital encoders to a least count of 0.0005" vertically and 0.001" horizontally at the target radius. Micro-switches also verify the positions where targets are.

This target system has a 3" diameter "flow thru" hydrogen target, and a similar deuterium cell. The cells are 1-1/2" high with the axis vertical. They are seamless aluminum cylinders with 0.003" thick walls. See Fig. 1. In addition to the two liquid filled cells are an assortment of solid targets which include a dummy cell. See Fig. 2.

Each liquid cell has two vapor pressure bulbs for monitoring temperature. The pressures are remotely indicated with potentiometer type transducers. The cell pressures are read in a similar way. With a digital voltmeter the pressure data can be read into the computer being used by the experimenter.

If desired, the target positions can be monitored by the computer. For the last three experiments using this target system the computer was programmed to be able to select the desired target and give beam permissive when it was in place.

During one of our recent high energy experiments, one of the LH_2 circulating fans (Globe Model 19A2105) failed. The fan failure was not detected immediately, resulting in some loss of valuable beam time. It was determined that a tachometer monitoring the pump speed would be of value. A proximity detector was tried with unsatisfactory results. It has decreased sensitivity at the cryogenic temperatures and a tendency to pick up and respond to the stray magnetic field of the fan motors. The inaccessability and remoteness of the fan and sensor precluded adjustment of the sensor once installed. The following design was then initiated: a hole was drilled in the rear of the fan housing. The rotor was extended 3/4 inch with a brass shaft. Mounted through and normal to the shaft extension is a 1/4" round bar magnet 3/4 inches long. The magnet strength was determined by measurement to be approximately 400 gauss at a distance of 3/32" from the magnet pole.

For a signal pick, one thousand turns of no. 38 magnet wire were wound onto a laminated steel U core. The core dimensions are: inside window — 1/2 inch with the laminated steel cross section being a 1/8 inch square. The core is mounted with the core window facing and centering on the LH_2 fan shaft extension. See Fig. 3.

When the permanent magnet is turned, the spatial flux distribution is roughly sinusoidal. From Lenz's law the voltage induced in the coil is:

$$V = N\frac{d\phi}{dt}$$

since

$$\phi = \beta A$$

and

$$\beta = \beta_{max} \sin 2\pi ft.$$

then

$$\frac{d\phi}{dt} = 2\pi\beta Af \cos 2\pi ft.$$

therefore

$$V = (N)(2\pi\beta Af) \cos 2\pi ft.$$

or

$$V = V_{max} \cos 2\pi ft.$$

and

$$V_{max} = 2\pi N\beta Af$$

where

N = no. of turns
ϕ = flux intercepted by the coil
A = cross sectional area of the core
f = frequency
β = flux density

Examining the result, it is apparent that the only variable in this relationship is (f) so:

$$V_{max} = k(f)$$

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From the above relationship it can be concluded that to measure the frequency one need only measure the voltage generated, and for most noncritical applications this would suffice. One problem that disallows the simple voltage measurement is that when the fan is overloaded or actually stalls, the motor windings create a sufficiently large magnetic field to induce a significant 60 cps voltage in the pickup coil. This would, of course, give an erroneous indication of fan speed. In fact, the device would be picking up the largest noise voltages when the fan is stalled.

To circumvent this problem, the output voltage of the pickup coil is shaped by the circuitry of Fig. 4. The coil voltage is directed to the noninverting input of a Fairchild μa 710 high gain voltage comparator. The inverting input is returned to a reference voltage. When the voltage from the tachometer pickup coil is greater than the reference voltage the output of the μa 710 will be + 3 volts, when less the output voltage will be zero. If the reference voltage is returned to ground, the circuit would simply act as a shaping circuit. By making the reference voltage adjustable, it is possible to limit the tachometer response to noise voltage at the expense of losing very low frequency response. The reference voltage is adjusted to a voltage higher than the maximum noise voltage expected. Since $V = kf$; the pickup coil voltage will at some frequency drop below the noise voltage setting and the tachometer will fail to respond. For our testing this turned out to be less than 60 rpm.

The circuitry has taken the sine wave output of the tachometer pickup coil and converted it to a square wave output whose period is the reciprocal of the frequency of the fan in Hz.

Once the voltage is in this form, there are several options as far as a readout is concerned. The voltage wave form can be displayed on an oscilloscope, or a frequency counter with a one minute gate would read out rpm directly. Some of the more sophisticated and expensive electronic counters have the capability for determining and displaying the reciprocal of the period which could also be used as a direct rpm readout. It is hoped that a frequency counter that will indicate rpm can be located, if not an in-house design may be initiated.

During the tachometer tests in liquid helium one of the Globe fans became quite difficult to start; it required approximately twelve volts to start rotation while the other identical fan would start with less than two volts applied. The bearings were changed and then the outside diameter of the impeller was reduced by 0.010" with no improvement. The problem was corrected by increasing the clearance between the rotor housing and the rotor by 0.002". After this operation, both fans and tachometer performed quite satisfactorily in liquid helium. Operation in liquid hydrogen will begin again in March 1971. Figure 5 is a graph of peak-to-peak coil voltages versus fan speed.

We have under construction now another target system using two hydrogen, two deuterium, and two dummy cells. These cells are horizontal aluminum cylinders. They are 3-1/2 in. diameter, and 6 in. and 12 in. long. The long cell is located above the short cell, with fluid pumped through the bottom cell, into the end of the long cell, and out the opposite end. Since there is no stringent requirement for minimum wall thickness, these tubes will have .010 in. walls, and .005 in. heads. In order to use all this with the existing actuators, both vertical and rotary positioning will be required. The targets and scattering chamber are designed to allow clear access from 0 to ± 90°.

In one other experiment, where the target cell had to be about 20 feet from the reservoir, it was expedient to use the fan to insure liquid at the target cell. Although we didn't need the full volume capability of the fan, it worked well when reduced down to 1/2 in. diameter.

Another class of targets that can use forced circulation of hydrogen are those which have a long length to diameter ratio and cannot be adequately insulated. Streamer chamber experiments prefer not to have any metal in close proximity to their high voltages. We have designed a target using no superinsulation. It will be about 8 mm diameter and 40 cm long. In addition to that it will be several feet from the reservoir. Although the fans previously being used might be adequate, we are testing a small centrifugal pump better suited for this work. Tests in liquid nitrogen have been completed, and work is in progress to build the hardware to run with hydrogen or helium. The pump should deliver about 2 liters per minute maximum flow at about 1.5 meters of LH_2 head when running at 3400 rpm. Our design will utilize an air motor drive capable of speeds up to 10,000 rpm. At the higher speeds, higher flow is possible with a pressure head up to 15 meters of LH_2.

In parallel with the liquid "pencil target" we are working on a high pressure gas target of the same general shape. At 10,000 psi the gas density will be about half liquid density. Our test vessels have not been able to hold that much pressure, but we are optimistic. If the high pressure can be contained with thin enough walls, several streamer chamber experiments will be somewhat less bulky than if a circulating liquid target is required.

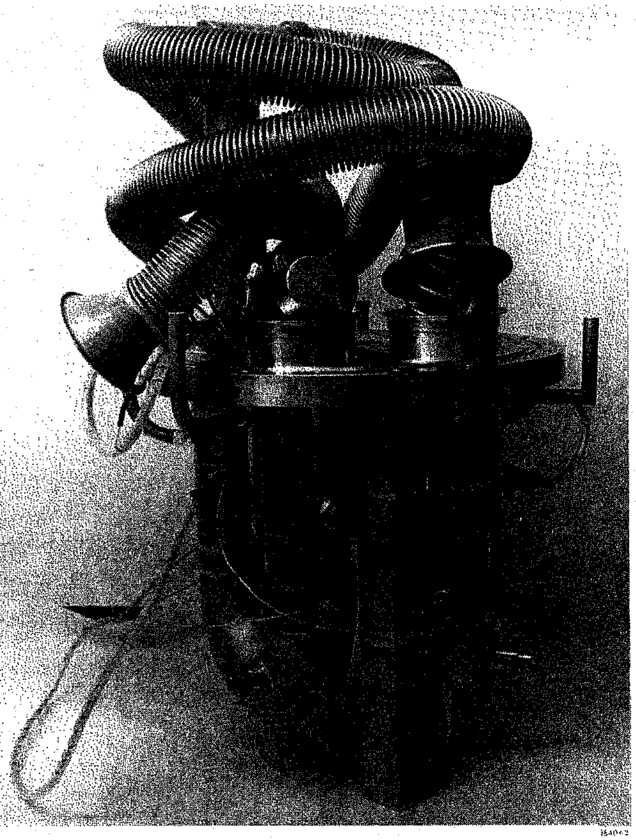


FIG. 1--Target-heat exchanger assembly before upper vapor pressure bulbs and fans were welded in.

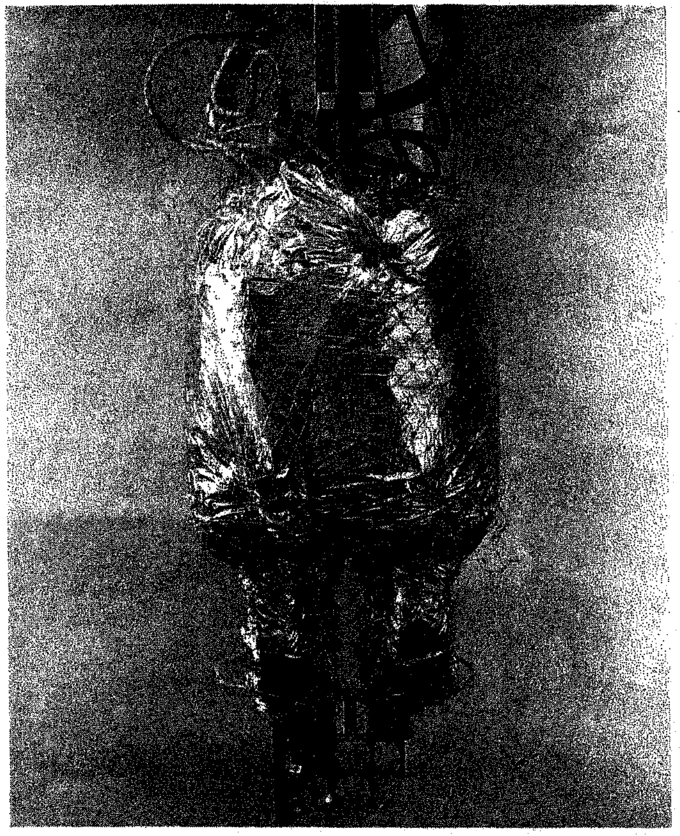


FIG. 2--Target-heat exchanger-reservoir assembly including two dummy cells and holder for eight solid targets. This view is from the beam input side.

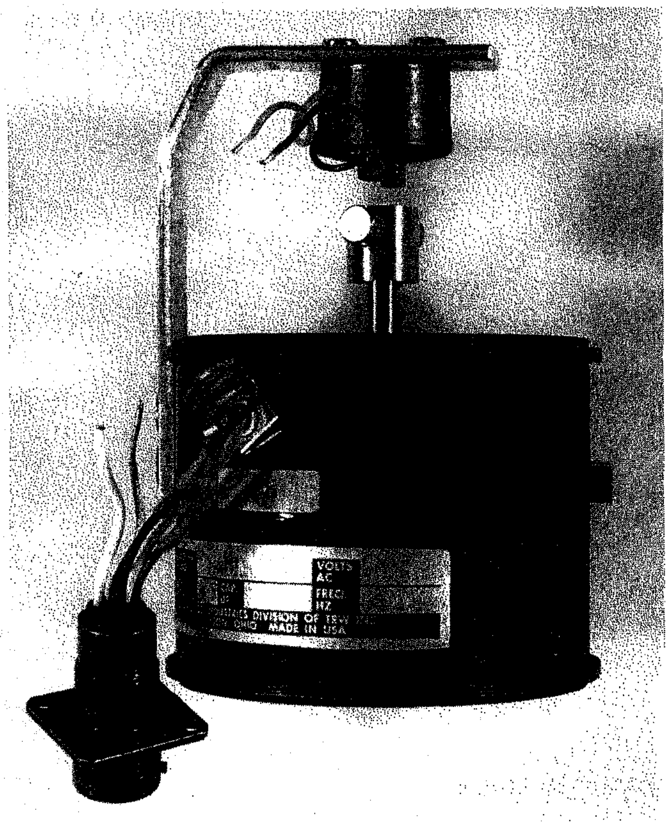


FIG. 3--LH_2 fan with extended shaft, magnet and pickup coil tachometer.

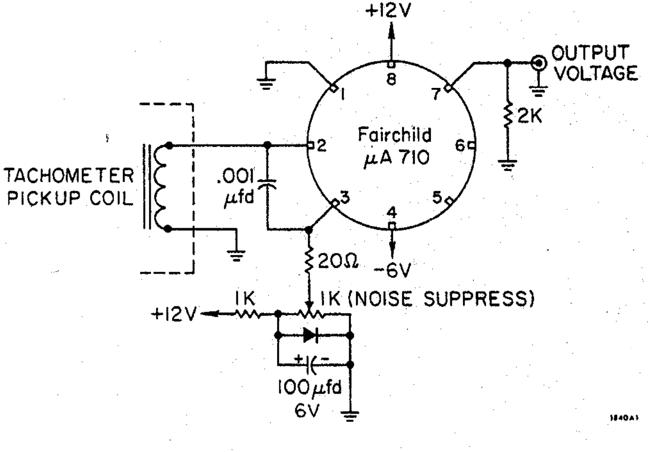
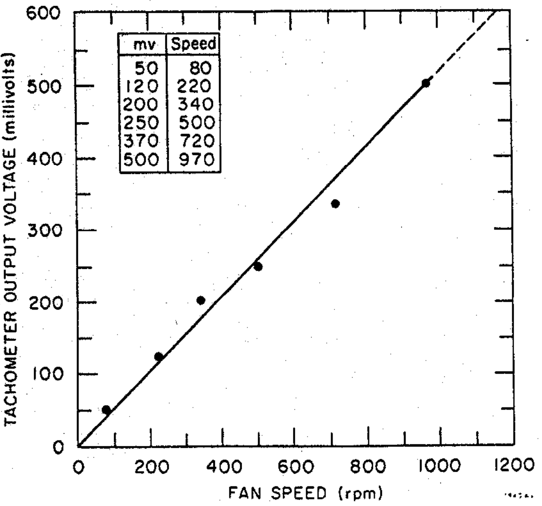


FIG. 4--Shaping circuit.



mv	Speed
50	80
120	220
200	340
250	500
370	720
500	970

FIG. 5--Voltage speed curve.