HYDROGEN TARGETS

Most high energy physics experimenters at Fermilab require liquid hydrogen or deuterium targets for particle interaction studies or for hadron filtering. The simple nuclear structure of hydrogen permits clearer interpretations of interactions than is possible using denser materials. Deuterium is used as a neutron target in which case the proton-induced reactions must be subtracted. To provide a dense and efficient target the hydrogen or deuterium is used as a liquid. Hydrogen liquifies at 20°K (-423°F) and deuterium liquifies at 23°K (-417°F). With minor adjustments to the equipment, both fluids can be used alternately in Fermilab targets.

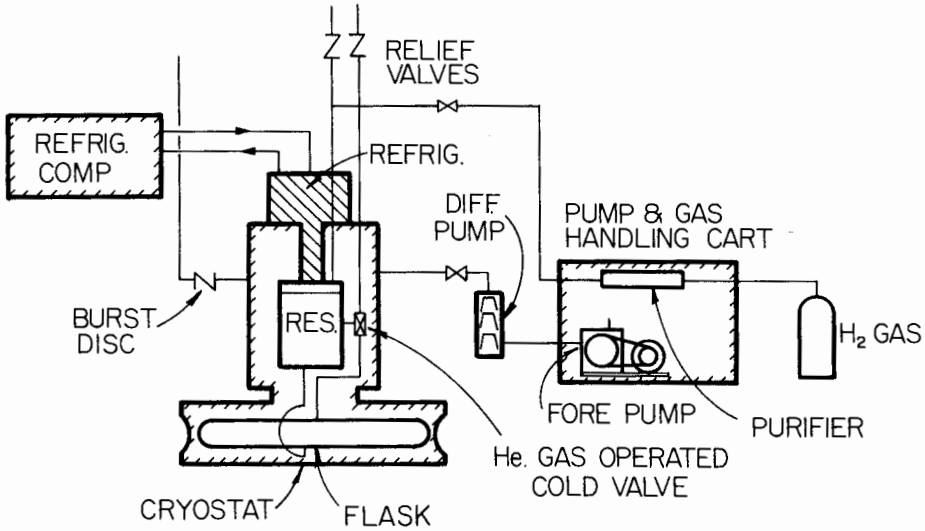
All Fermilab cryogenic targets are refrigerated, since refrigerated targets contain the minimum amount of liquid hydrogen. Only the liquid required to fill the flask is needed, since the refrigerator continuously recondenses the boil-off gas. Transporting liquid hydrogen in the experimental areas is eliminated, and target venting requirements are greatly reduced. Surveillance is minimized because the smaller inventory of hydrogen is more easily controlled. Personnel are necessary only for occasional monitoring and for start-up and shut-down operations.

A typical refrigerated liquid hydrogen target system consists of a Mylar or thin metal cylindrical hydrogen flask, suspended in an evacuated cryostat to insulate the liquid from room temperature. A mechanical refrigerator removes heat incident on the flask from the ambient environment. The target flask and cryostat are usually custom designed to meet the specific experimental requirements. Modularization and standardization of ancillary

equipment reduces the amount of custom work required. Operation is also simplified, since the control console contains the same equipment arrangement and flow diagram for all targets. The diagram on page 11 shows the typical target system piping and components for a single-flask target having less than a 6-liter flask and a refrigerator load of less than 10 W at 20°K. An open cold valve connects the flask to a reservoir when there is liquid in the flask. This valve is closed when the liquid is temporarily moved into the reservoir for taking background data. The hydrogen can remain in the reservoir up to four hours before it must be returned to the flask.

Target systems containing both liquid hydrogen and liquid deuterium are more complicated since they usually have three identical flasks. The two liquid-filled flasks are physically moved aside to collect "target empty" data by substituting an evacuated flask. These systems are several times more expensive, since the refrigeration equipment is duplicated and a specially designed manipulator and readout indicators are necessary.

Targets are designed for experimenters by Research Services Department, Cryogenics Group. The flask, cryostat, and support hardware are specified in the agreement for each experiment. Standardized Fermilab equipment available for assignment include 20°K refrigerators of several types and capacities, a cart-mounted pumping and gas handling unit and a control console containing readouts for pressure, liquid level, and vacuum, in addition to a graphic control panel. Special safety requirements for the target system such as venting, inerting and safety interlocking, are considered very early in the design. Additional equipment, such as hydrogen



Schematic diagram of a typical Fermilab cryogenic target system incorporating a small, single-flask target. The flask contains the liquid hydrogen or deuterium used as a target in an experiment.

gas detectors, inerting system modules, and fire and draft sensors are available to implement these requirements. The completed target system is assembled for testing in Laboratory 3 in the Village. Rigorous testing of each target is performed before the target is prepared for installation in an experimental area. Large target systems, those having a liquid capacity of more than 30 liters, may be tested in an outdoor area adjacent to Lab 3 which has utilities for remote target operation.

Each target installation is reviewed by a subcommittee of the Laboratory Safety Committee to eliminate hazards peculiar to the location of the target system. The experimental area Department Head reviews the findings of

the Cryogenic Safety Subcommittee and authorizes the Cryogenics Group to fill and operate the target. If the target or support equipment is modified, the complete installation is reviewed again.

The Cryogenics Group operates all Fermilab targets and has first-line responsibility for the systems. Upon request, the experimental group is authorized to operate the cold valve for "target empty" runs or for target manipulation when a system is so equipped.

A number of interesting and cryogenically significant target systems have been used at the Laboratory and others are being commissioned or are in the design/fabrication stage.

The total cross section experiment (#104) used the largest refrigerated target system built to date. With a total liquid inventory of 300 liters, approximately that of the 30-inch bubble chamber, housed in vessels with thin Mylar windows, and located in a poorly ventilated area, this system presented a technical and safety challenge. The target is of the three-flask type; the 50-liter inventory of LD_2 dictated a deuterium recovery system. Installed in a nitrogen gas-filled room, the system met demanding safety criteria. A round-the-clock operator was provided when the target contained liquid. The system operated uneventfully for several months of data taking.

As part of the broad-band photon facility in the Proton Area, a 100-foot-long liquid deuterium vessel is installed between the poles of sweeping magnets. The function of this filter system is to attenuate neutrons and provide the clean photon beam desired for photo-production experiments (#87). The LD_2 flask is approximately one inch in diameter and the system contains about

32 liters of liquid deuterium. A portion of the deuterium can be emptied into a liquid reservoir to obtain background data or to utilize the unattenuated neutron beam. The filter is installed in the Proton-East underground hall. This location required that special venting be installed. The cryogenic system ran almost continuously for about six months as the experimenters accumulated their data. Several other dual fluid targets have been used and the three-flask target system shown on page 14 for Neutral Hyperon #8 has recently been commissioned.

At this writing, the installation of the small target in Proton-West for Particle Production #284/Photon Search #95 is nearly complete. The flask for this target is unusual in that it is only one centimeter in length and 5 inches in diameter, with flat windows. The life of the flask, limited by radiation damage as it is traversed by the high-energy proton beam, can be prolonged by remotely moving the flask. The target for another Proton Area experiment, Particle Search #300, is under test in Lab 3. The flask is mounted at the end of a 20-foot-long cryostat within one of the Proton-East target box drawers.

There are at present eight liquid hydrogen targets installed in the experimental areas, including five in the Meson Area and three in the Proton Area. Another ten systems are in various stages of design, fabrication, or testing, including two for Proton, seven for Meson, and one for Neutrino.

As part of the improvement program to update equipment to provide greater reliability to the user, an improved computer monitoring system is being designed which will permit continuous monitoring of all target equipment

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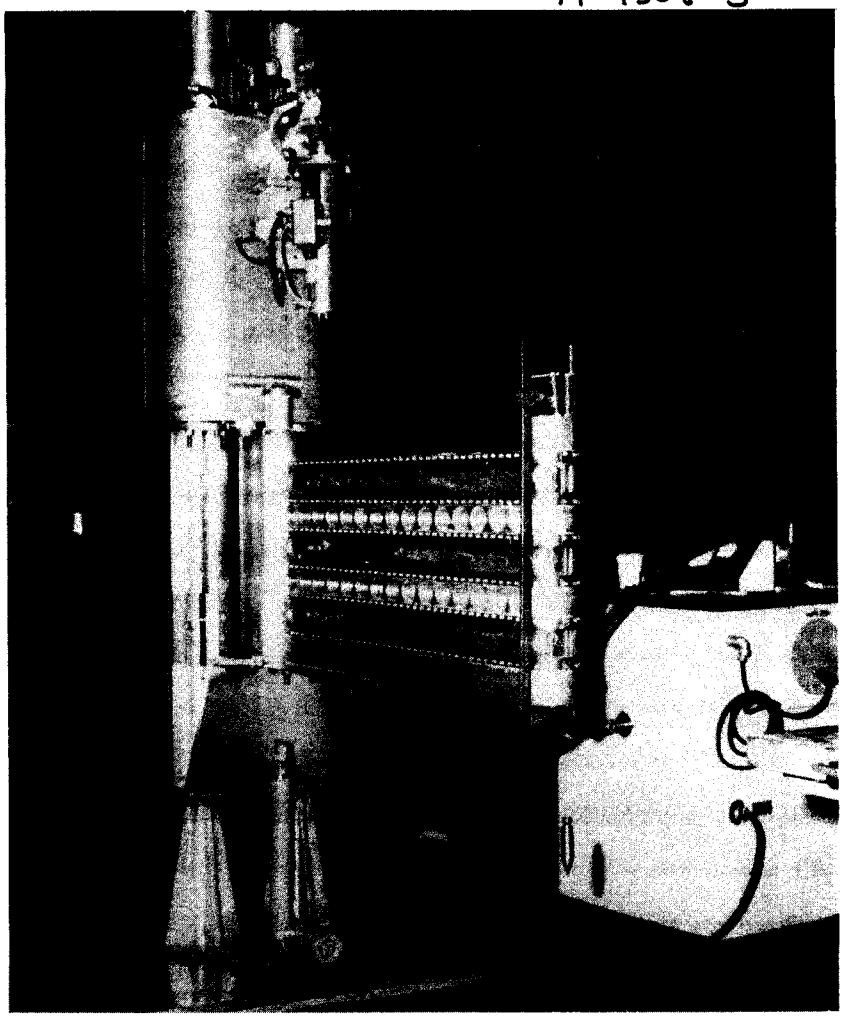

The three-flask target for Neutral Hyperon # 8 under test in Laboratory 3 prior to its installation in the M2 beam line in the Meson Area. Each flask has a capacity of approximately 1 liter; the upper one is filled with hydrogen, the center one is empty, and the lower one is filled with deuterium. The two refrigerators needed are housed in the container above the target. At the base of the target is the jack mechanism--manipulator--used for vertical positioning.

via telephone link to other parts of Fermilab. Additional circuitry will permit remote restarting of equipment after a power failure and some additional control of target functions. Targets will be continuously monitored from a common point; abnormal parameters will sound an alarm and alert personnel. This system should increase surveillance, while keeping the manpower requirement to a minimum. Down time due to unnoticed operational changes should be eliminated.

The installation and operation of target systems would be impossible without the cooperation and continuing efforts and assistance of engineers and technicians from all the experimental area departments.

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