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Ice Targets for Use at NTOF

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ICE TARGETS FOR USE AT NTOF

by

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ABSTRACT

This report describes ice targets which were used during an experiment at the Neutron Time of Flight facility (NTOF) at LAMPF. Reasons for using the ice targets are given, and the construction, refrigeration system, and target preparation are detailed. Results of the research using these ice targets will be published at a later date.

WHY ICE TARGETS WERE USED

LAMPF Experiment 1123 sought to measure the $^{16}O(p,n)^{16}F$ differential cross section at a variety of angles.[1] The experimental method required two targets: one containing a mixture of ^{16}O and ^{18}O, and the other containing enriched ^{18}O, necessary for cross calibration. H_2O was chosen as the target material because natural hydrogen does not produce any significant (p,n) background. Enriched ^{18}O water was readily available at a cost of about $100/gram, and could easily be mixed with natural water to produce the desired isotope ratios. The targets had to survive the vacuum of the scattering chamber and a constant exposure to 25+ nA of 500 MeV protons for a period of two weeks, and target thickness had to be uniform, measurable, and constant. Ice targets proved to be ideal for these purposes.

CONSTRUCTION

Target design is illustrated in the accompanying figure. The ice target thermal frames were made from 1/8" (3.175-mm) copper stock, and measured 5" (127 mm) wide by 2.5" (63.5 mm) tall. Copper was chosen for its good heat conductivity. Centered in each frame was a 1.5" (3.8-cm) diameter hole, covered on both sides by a thin window material to hold the H_2O and minimize sublimation. Each frame had a fill hole which would accept a hypodermic needle, and a fill hole plug made from a 2-56 screw. During operation, two of these target frames were mounted on a 5" × 5" (12.7-cm × 12.7-cm) phenolic target holder, which was semipermanently bolted to the NTOF target ladder. The targets had to be mounted with gloved hands due to the low temperatures, so the mounting bolts and nuts were oversized to permit easy handling. The target holder had a groove for holding the cooling "finger" from a commercially available refrigerator in contact with the copper target frames. Phenolic has low heat conductivity, so the target holder also served to thermally insulate the targets from the ladder, reducing the cooling load.

Two different materials were used for

was used for the target which contained undiluted ^{18}O enriched water. This is a durable window material not likely to rupture and spill the expensive contents, but is thin enough to produce no significant background under the strong $^{18}O(p,n)^{18}F$ peak. Copper foil of 1/4-mil thickness (0.00635 mm) was also tested, but proved to be difficult to manufacture and too fragile for use.

The copper foil was soldered to the copper frames, one side at a time. The first side was attached using low-speed solder of a 50/50 tin/lead mixture. The frame was allowed to cool, then the second side was attached using high-speed solder of a 5/95 tin/lead mixture. This delicate process was carried out by a technician experienced in soldering techniques. A detailed description of a successful soldering process may be found in the LAMPF report LA-8109-MS (1979). The copper foil windows were tested by filling the targets with water, sealing the fill hole, then placing them in vacuum (unfrozen) for 24 hours. Losses were monitored by weighing the targets before and after use.

Aluminized mylar was used for the windows of the ^{16}O and ^{18}O mixed target. Physics dictated this decision: mylar is $C_5H_4O_2$, and only the carbon produces any significant (p,n) background. This background is almost entirely concentrated in the sharp gs $\rightarrow$ gs transition, which facilitates background subtraction. The thin aluminum coating, which is necessary to prevent degradation of the window in the proton beam, contributes almost nothing to background. The advertised thickness of the mylar was 1/4-mil (0.00635 mm), but the measured thickness was 3/10-mil (0.00762 mm). Experimentation found the best adhesive for attaching the windows to be Bi-Pax epoxy. First the mylar was pulled taut on a "mylar stretcher". The stretcher was similar to those commonly used to make windows for wire chambers. The copper frame was thoroughly cleaned with isopropyl alcohol (ethanol leaves a residue). The Bi-Pax epoxy was mixed, then placed in a small plastic boat in vacuum for 15 minutes to drive out air bubbles. The air-free epoxy was then transferred to a plastic syringe. A small bead of epoxy (0.5 mm radius) was drawn completely around the central hole of the target frame at a distance of 1/4" (6.35 mm) from the hole. The target was then placed on the stretched mylar, the weight of the target causing the epoxy to spread. The epoxy cured in 24 hours, and the entire procedure was repeated for the other side. Excess mylar was trimmed with a sharp razor blade. The mylar windows could not be tested in the same manner as the copper, since this would cause the windows to rupture. Instead, sample targets with mylar windows were tested by following the complete freezing procedure, and keeping them frozen in vacuum for 24 hours.

REFRIGERATION SYSTEM

The refrigerator used to keep the targets frozen was an FTS Systems, Inc., Flexi-Cool System FC-20-84-P2S. The refrigerator was factory-connected to a 5 foot (1.52 m) length of flexible stainless feed line, and a probe made of a 6 foot (1.83 m) length of 3/8" (0.953 cm) outer diameter flexible bellows tubing and a 36 inch (91 cm) length 3/16" (0.476 cm) outer diameter annealed copper "finger." There was a 2" length of 1/2" stainless tubing at the junction between the probe and flexible feed line, which was used for sealing the port where the tube entered the target chamber. The flexible bellows and exposed "finger" were wrapped with several layers of super-insulation. This system proved flexible enough to withstand rotation and vertical movement of the NTOF target ladder.

PREPARATION

Before mounting the targets in the scattering chamber, they were prepared as follows: first, the empty target was weighed. Then a calculated mass of H_2O with the appropriate isotopic mixture was added. (The calculation must account for the 8.5% expansion of water when it is frozen, and the fact that the isotopic mixture has a different mass than natural water. Great care must be taken to use the right amount of liquid, since too little would leave a void in the target, and too much would clog the fill hole, making it impossible to insert the plug screw.) Isotopic mixtures were 95.2 Atm% ^{16}O, 0.1 Atm% ^{17}O, and 4.7 Atm% ^{18}O for the primary target (although a later measurement suggests 5.2 Atm% ^{18}O), and 3.2 Atm% ^{16}O, 1.2 Atm% ^{17}O, and 95.6 Atm% ^{18}O for the undiluted enriched ^{18}O. The filled targets were then clamped between two thick aluminum plates, which had been surfaced with a layer of 5-mil (0.127 mm) mylar to prevent scratching of the delicate target windows. These plates assured that the front and back of the frozen cylinder of ice would be flat. The targets were then slowly frozen in a standard food-freezer for about 2 hours with the fill hole plug removed. The plug was inserted after the targets were frozen, with a drop of Leak-Lock applied to the threads to provide a good seal. The targets were transported in a styrofoam cooler kept cool with dry ice. Gloves were used to prevent frostbite while the targets were mounted in place in the scattering chamber.

SUCCESS OF OPERATION

The ice targets were successful in that they survived 14 days in vacuum with no measurable sublimation loss and no observed shape distortion. The refrigerator system maintained both targets at a nearly constant temperature of −65°C, as measured with a thermocouple held in contact with each of the copper frames. There was some difficulty in tuning the beam to pass through the 1.5" diameter hole in the targets while missing the copper frame entirely; this difficulty might have been alleviated if an oval hole with larger area were used instead. Because of beam halo scattering from the target frame, it was necessary to subtract a significant copper background from the data. Also, the targets were kept at temperatures so low that oil vapor was able to condense on the surfaces, despite the 4×10^{-5} torr vacuum in the scattering chamber. This made it necessary to subtract a carbon background caused by the oil from the data. Fortunately, background data were taken with a variety of targets, so the background subtractions were not difficult.

ACKNOWLEDGEMENTS

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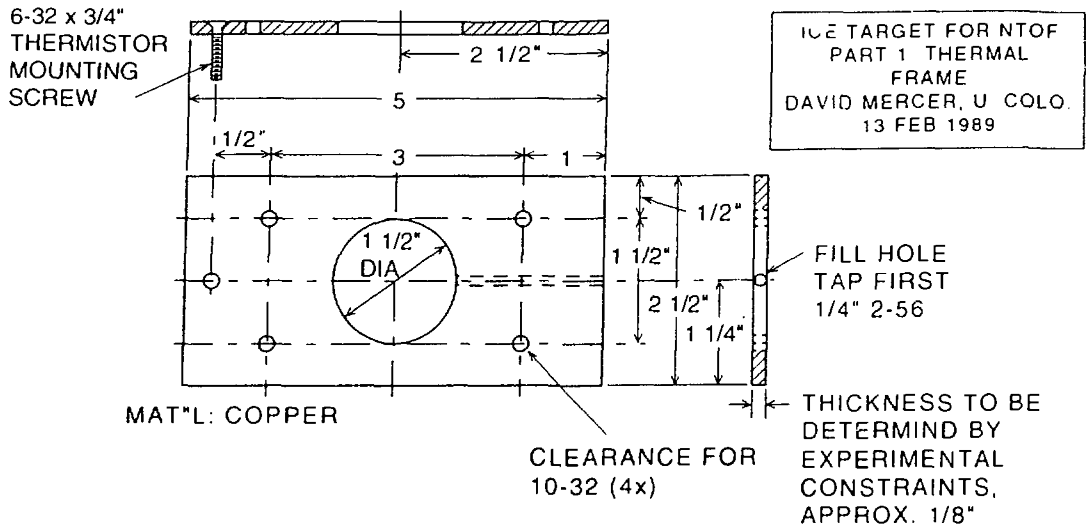
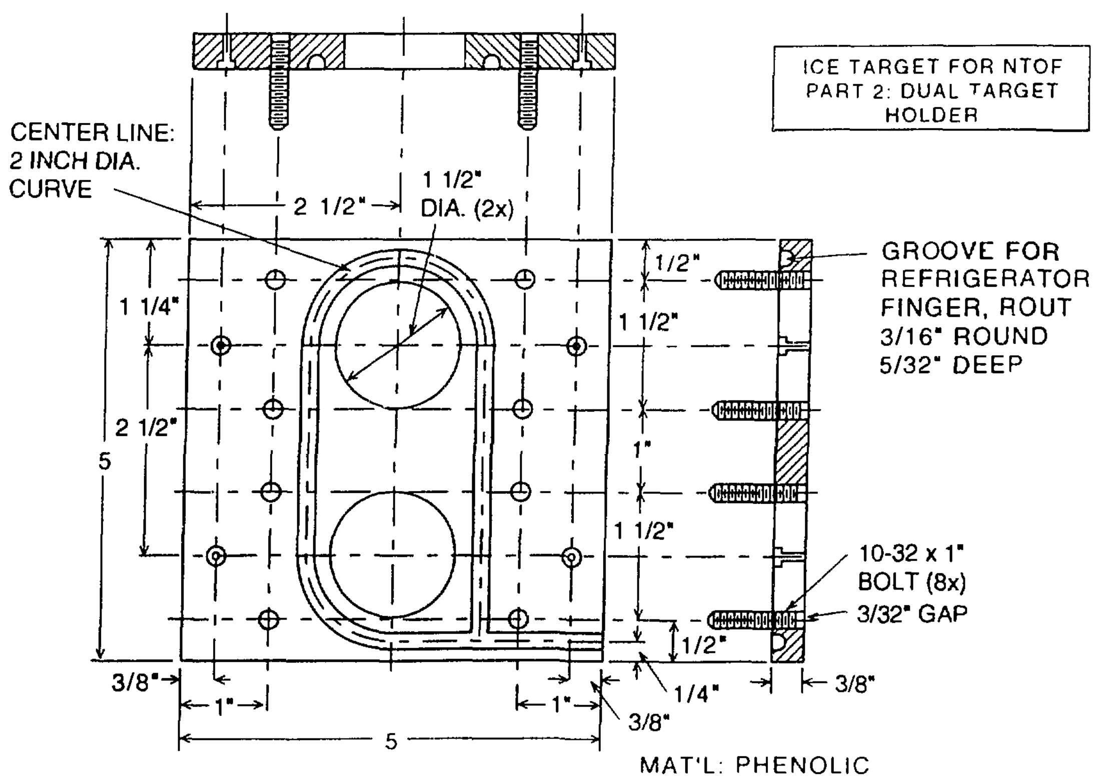

6-32 x 3/4"
THERMISTOR
MOUNTING
SCREW
2 1/2"
5
1/2"
3
1
1/2"
1 1/2"
DIA
1 1/2"
2 1/2"
1 1/4"
FILL HOLE
TAP FIRST
1/4" 2-56
MAT"L: COPPER
THICKNESS TO BE
DETERMIND BY
EXPERIMENTAL
CONSTRAINTS,
APPROX. 1/8"
CLEARANCE FOR
10-32 (4x)
ICE TARGET FOR NTOF
PART 1 THERMAL
FRAME
DAVID MERCER, U COLO.
13 FEB 1989


ICE TARGET FOR NTOF
PART 2: DUAL TARGET
HOLDER
CENTER LINE:
2 INCH DIA.
CURVE
2 1/2"
1 1/2"
DIA. (2x)
1/2"
1 1/4"
1 1/2"
2 1/2"
5
1"
1 1/2"
GROOVE FOR
REFRIGERATOR
FINGER, ROUT
3/16" ROUND
5/32" DEEP
10-32 x 1"
BOLT (8x)
3/32" GAP
1/2"
3/8"
1"
1"
1/4"
3/8"
3/8"
5
MAT'L: PHENOLIC