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FINAL REPORT

MEASUREMENT OF NEUTRON SPECTRA IN LIQUID HYDROGEN

prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Contract NAS 3-6217

by

GENERAL ATOMIC

DIVISION OF

GENERAL DYNAMICS

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

July 17, 1966

Contract NAS 3-6217

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I. INTRODUCTION

This Final Report describes the research program performed under Contract NAS3-6217 for the Advanced Development and Evaluation Division, NASA-Lewis Research Center. The work is, in effect, a continuation of the research performed under Contract NAS3-4214 which has been described in report NASA CR-54230 (GA-5750).

The purpose of the program was to measure differential angular energy flux spectra in liquid hydrogen in the fast, intermediate, and thermal neutron energy regions and compare these angular flux spectra with the predictions of the one-dimensional transport theory code GAPLSN. Angular flux spectra were measured in a simple two-dimensional geometry represented by a cylindrical cryostat of liquid hydrogen (LH_2) with a small spherical isotropic fission source externally located on the axis of the cylinder.

The experimental facility, which was used in these measurements, is described in Section II. The angular flux spectra were obtained by time-of-flight techniques using a high-intensity pulsed source of neutrons generated by the General Atomic electron linear accelerator (Linac). The experimental techniques are described in Section III. Data reduction and results comprise Section IV. Calculations were performed for each measurement using the transport theory code GAPLSN. Section V discusses and presents the measured and theoretical results.

Appendix A contains the checkoff lists which were used for each set of measurements, and operational and emergency procedures. Appendix B is the tabulated data for each of the measured spectra in the liquid hydrogen.

II. EXPERIMENTAL FACILITY

2.1 GENERAL ATOMIC LINEAR ACCELERATOR FACILITY

The General Atomic electron linear accelerator (Linac) is a three-section, high current, L-band machine. Its characteristics are summarized in Table 2.1. Beam conditions for these experiments were: 28 ± 1 MeV, repetition rates from 15 pps for the thermal neutron measurements to 360 pps for the intermediate and fast neutron measurements, peak currents to 1500 ma, and pulse widths from 20 nsec for the fast neutron measurements to 4.5 μsec for the thermal neutron measurements.

The General Atomic Linear Accelerator Facility is shown in Fig. 2.1.

2.2 LIQUID HYDROGEN FACILITY

The liquid hydrogen facility is actually a complete facility within the Linac facility. The liquid hydrogen cryostat is located in the experimental room as shown in Fig. 2.2, the LH_2 control console is in the data lab area (see Fig. 2.1), the "bottle farm" and LH_2 supply dewar are located in the back area as shown in Fig. 2.2.

A major effort on this program was the setup, or more accurately the resetup, of the liquid hydrogen facility, since the facility had been used before on Contract NAS 3-4214. This setup was necessary prior to doing any time-of-flight neutron spectral measurements in liquid hydrogen (LH_2).

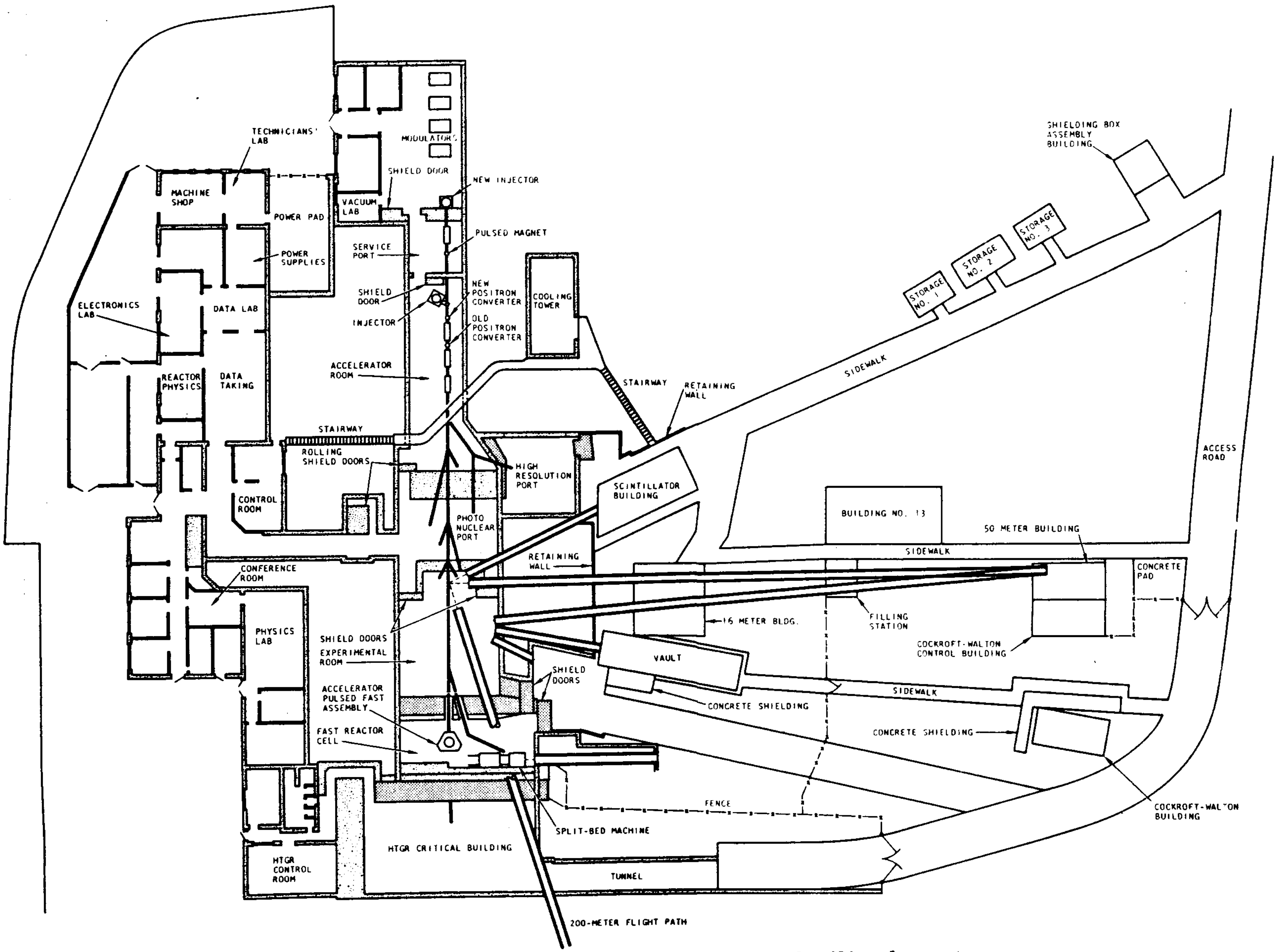


Fig. 2.1--Linear accelerator facility layout

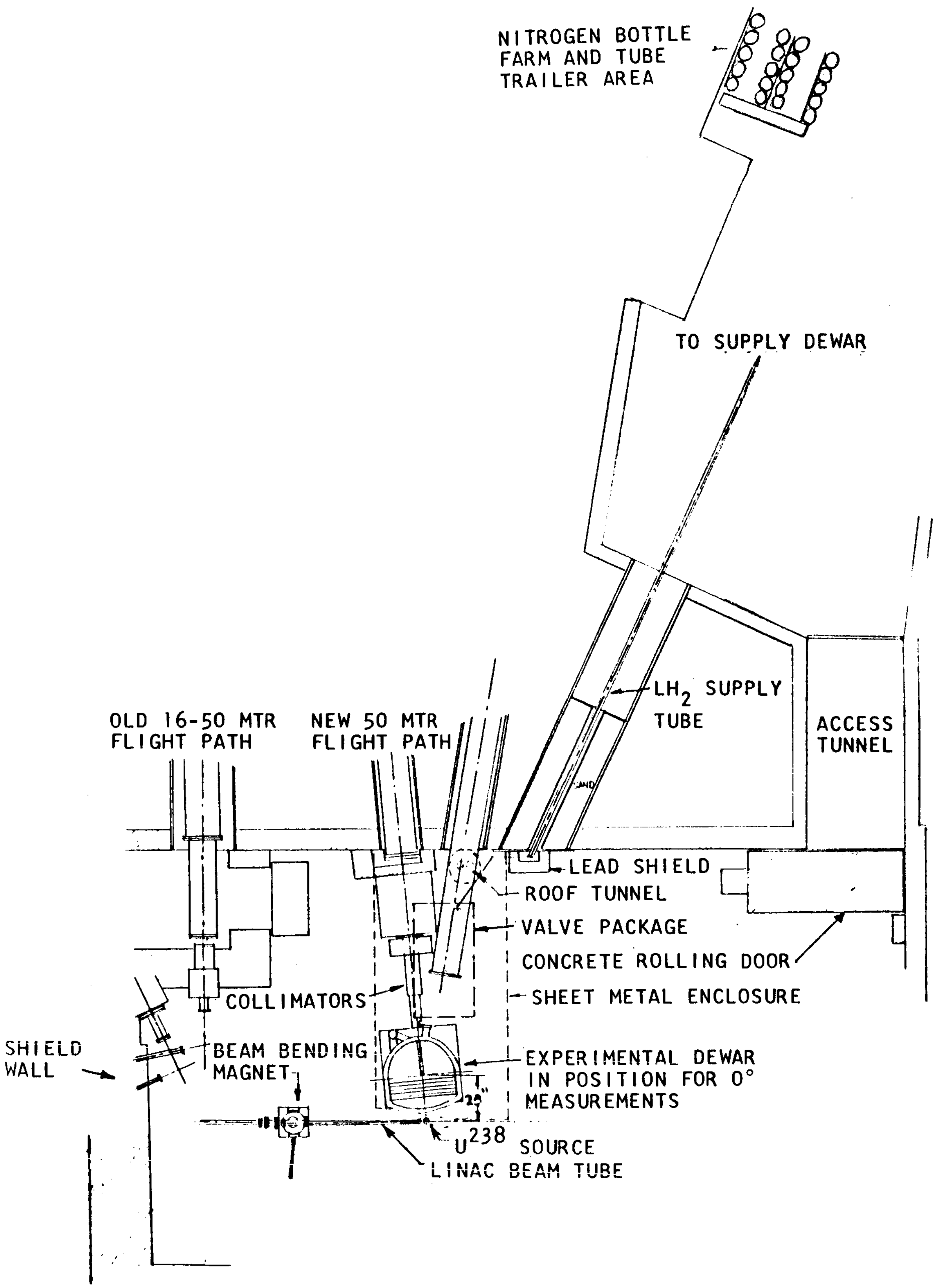


Fig. 2.2--Plan view of the liquid hydrogen facility

The liquid hydrogen facility has been described in detail in Ref. 1 and therefore the following sections will only give a general description of the various components of the facility and give in detail the problems, tests, and modifications that were necessary to reinstate the LH_2 facility for use in the present measurements.

The liquid hydrogen facility is composed of the following components:

1. Liquid hydrogen cryostat
2. Liquid hydrogen cryostat support system
3. Sheet metal enclosure
4. Connections from the liquid hydrogen cryostat to the valve package
5. Valve package
6. Vacuum jacketed transfer lines from the valve package to the liquid hydrogen supply dewar
7. Gas cylinders or tube trailer and the associated plumbing for distributing the gaseous nitrogen or gaseous helium (commonly referred to as the bottle farm).
8. Remote control liquid hydrogen console
9. Liquid hydrogen supply dewar.

2.2.1 Liquid Hydrogen Experimental Cryostat

Design details of the LH_2 experimental cryostat are shown in Fig. 2.3. The LH_2 experimental cryostat is the "heart" of the LH_2 facility. It contains 160 gallons of liquid hydrogen when completely filled. It is compartmented in such a way as to vary the thickness of hydrogen which the fast neutrons must penetrate before escaping by the probe tube down the flight path

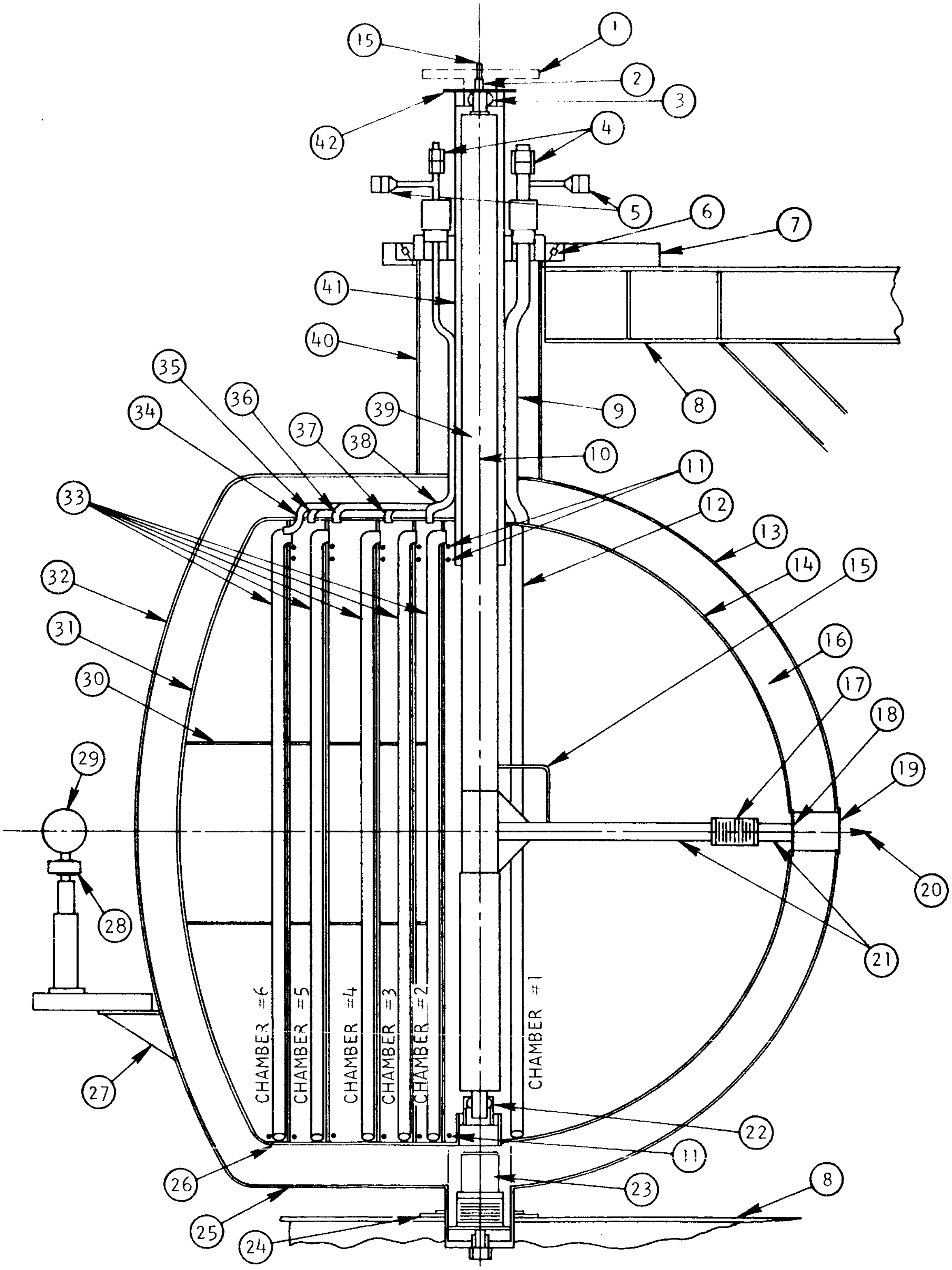


Fig. 2.3 -- LH_2 dewar design details

FIGURE 2.3 LEGEND

1. Alignment plate
2. Alignment plate bearing surface
3. Upper probe pivot spherical bearing
4. Vent line fittings
5. Liquid level sensor fittings
6. Dewar rotation tapered roller bearing
7. Yoke bearing seat
8. Yoke arm
9. Chamber No. 1 vent tube
10. Probe pivot axis
11. Liquid level sensors
12. Fill/dump tube
13. Outer hemispherical head
14. Inner hemispherical head
15. Probe evacuation tube
16. Super insulation and vacuum space
17. Probe tube bellows
18. Inner head window
19. Outer head window
20. Neutron flight path axis
21. Probe tube
22. Lower probe pivot spherical bearing
23. Retractable transportation stabilizer
24. Guide plate
25. Outer shell cylinder
26. Inner shell cylinder
27. Source location bracket
28. Source/Linac beam tube guide
29. Fast neutron source
30. Baffle stay rod
31. Inner torospherical head
32. Outer torospherical head
33. Chamber-to-chamber LH_2 transfer tubes
34. Chamber No. 6 vent tube
35. Chamber No. 5 vent tube
36. Chamber No. 4 vent tube
37. Chamber No. 3 vent tube
38. Chamber No. 2 vent tube
39. Invar probe pivot tube
40. Outer neck tube
41. Inner neck tube
42. Angle indication scale

to the detector. The cryostat is insulated by 90 layers, each of which is composed of aluminum foil and glass fiber paper. The multi-layered (super) insulation is between the inner and outer dewar and it is under vacuum. During the fifteen months between the end of the last contract and the start of the present contract, the vacuum had, of course, deteriorated. To perform the pumpdown required building a vacuum system composed of a vacuum valve, forepump, diffusion pump, vacuum readout system, and flexible bellows. Numerous safety measures with backup precautions were necessary to insure against such things as cracking the oil in the diffusion pump and contaminating the multilayer insulation space. The multilayer insulation contains numerous interstitial spaces and constitutes an excellent trap for various gas molecules. The Buna-N "O" rings in the vacuum valve attached to the LH_2 cryostat were replaced prior to pumpdown since the cryostat had been in a high radiation field area for over 15 months and these "O" rings could have sustained radiation damage. Pumpdown of this multilayer insulation space required several weeks to obtain a 1.8×10^{-5} mm of Hg vacuum which was satisfactory and as good as during the experimental work conducted under Contract NAS 3-4214. This vacuum proved to be more than adequate since the boiloff rate was so low that it was not detectable over a period of about ten minutes on a pressure gage that read from 0 to 50 in. of water.

2.2.2 Liquid Hydrogen Cryostat Support System

A lack of rigidity in the original dewar support system caused misalignment problems during the 1964 series of LH_2 experiments under the previous program. These problems occurred mainly during rotation of the dewar when a change in the center of gravity would shift the weight of the assembly on the support table and cause the probe tube pivot centerline to go out of plumb. The design of the aligning and locating devices made it difficult and time consuming to realign the dewar. Also, the single cantilever cryostat support was not rigid enough and the weight of the liquid hydrogen in the dewar would visually affect the dewar position. Therefore, a new two-column dewar support was designed and constructed to eliminate the difficulties inherent in the older system. The new support system is shown in Fig. 2.4. The LH_2 experimental cryostat and support system are shown together in Fig. 2.5. One of the main advantages of the new system is its rigid attachment to the floor. By bolting the large diameter support columns directly to the floor, the mislocating tendencies of the previous rail-mounted table were eliminated. The two-column cantilever support system limits any weight-induced deflection to a vertical direction so that the probe pivot tube is freed of any cocking tendency. Prior to the transfer of the dewar from its old support to the new, the new system was tested by hanging a 4000-lb load on the support; only a small vertical deflection was observed for this load which was almost twice the load placed on the support system by a dewar filled with liquid hydrogen. The support system was also loaded with a 1000-lb weight, which approximates the weight of the dewar filled with liquid hydrogen. Only a 0.028-in. deflection was observed with the 1000-lb load. Thus, the 80 lb anticipated weight

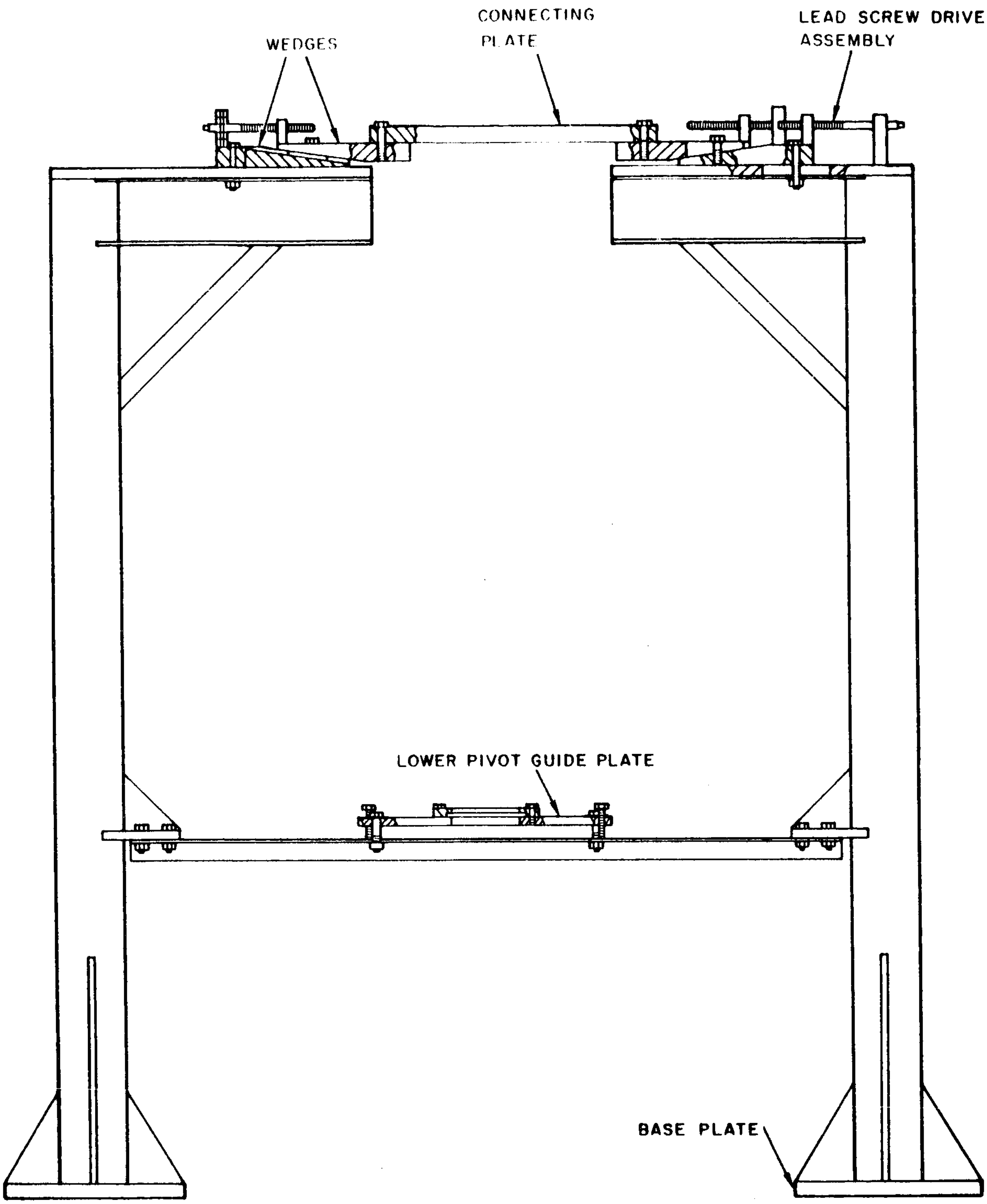


Fig. 2.4--Liquid hydrogen support structure. Lateral movement is provided by the lead screw drive assembly

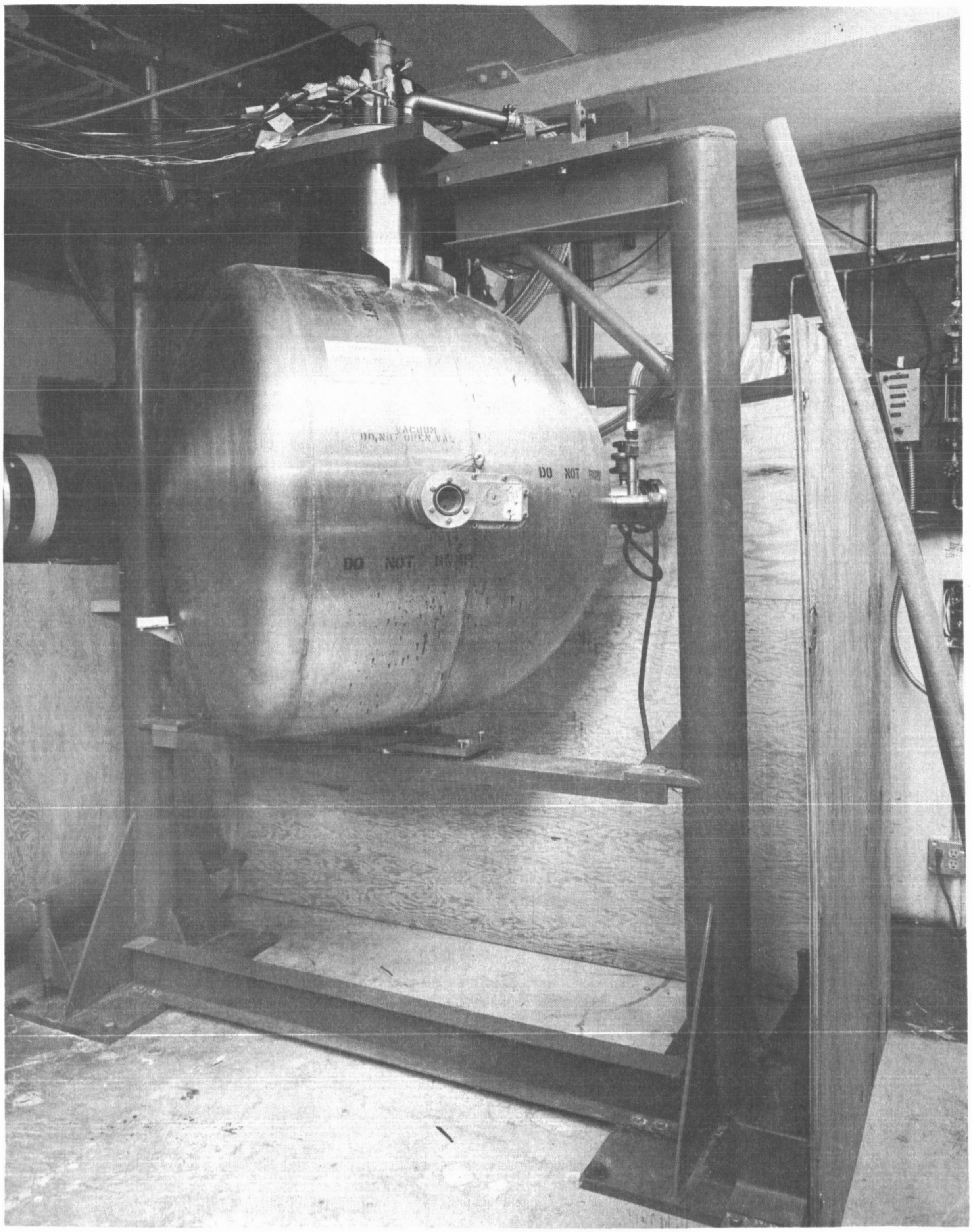


Fig. 2.5--Liquid hydrogen cryostat support system

change between an empty dewar and one filled with LH_2 caused a negligible amount of deflection in the vertical direction.

The Timken bearing originally supplied by Cryogenic Engineering Company (Cryenco) was retained at the top of the dewar, while the lower trunnion was fixed and used as a rotation locking point. This lower trunnion had been free in the Cryenco design and it was relatively easy to move the dewar out of horizontal alignment and plumb. In the new system the vertical trunnion axis is restrained and it is almost impossible to move the dewar out of plumb.

Wedge plates are used at the top of the support to provide the necessary horizontal adjustment.

During actual operation, it was observed that rotation of the dewar did not disturb the plumb of the probe tube pivot; initial alignment was relatively easy and fast and subsequent checks of the alignment showed no shifts.

Mobility of the LH_2 experimental cryostat and support system is obtained by two removable screw-on wheeled carriages one of which is shown in Fig. 2.6.

2.2.3 Sheet Metal Enclosure and Work Platform

On the previous contract (NAS 3-4214), the dewar and valve package area were enclosed by walls made of conducting plastic (velostat) to isolate this area from the rest of the experimental room and to provide rapid air changes in the areas where a hydrogen leak would most probably occur.

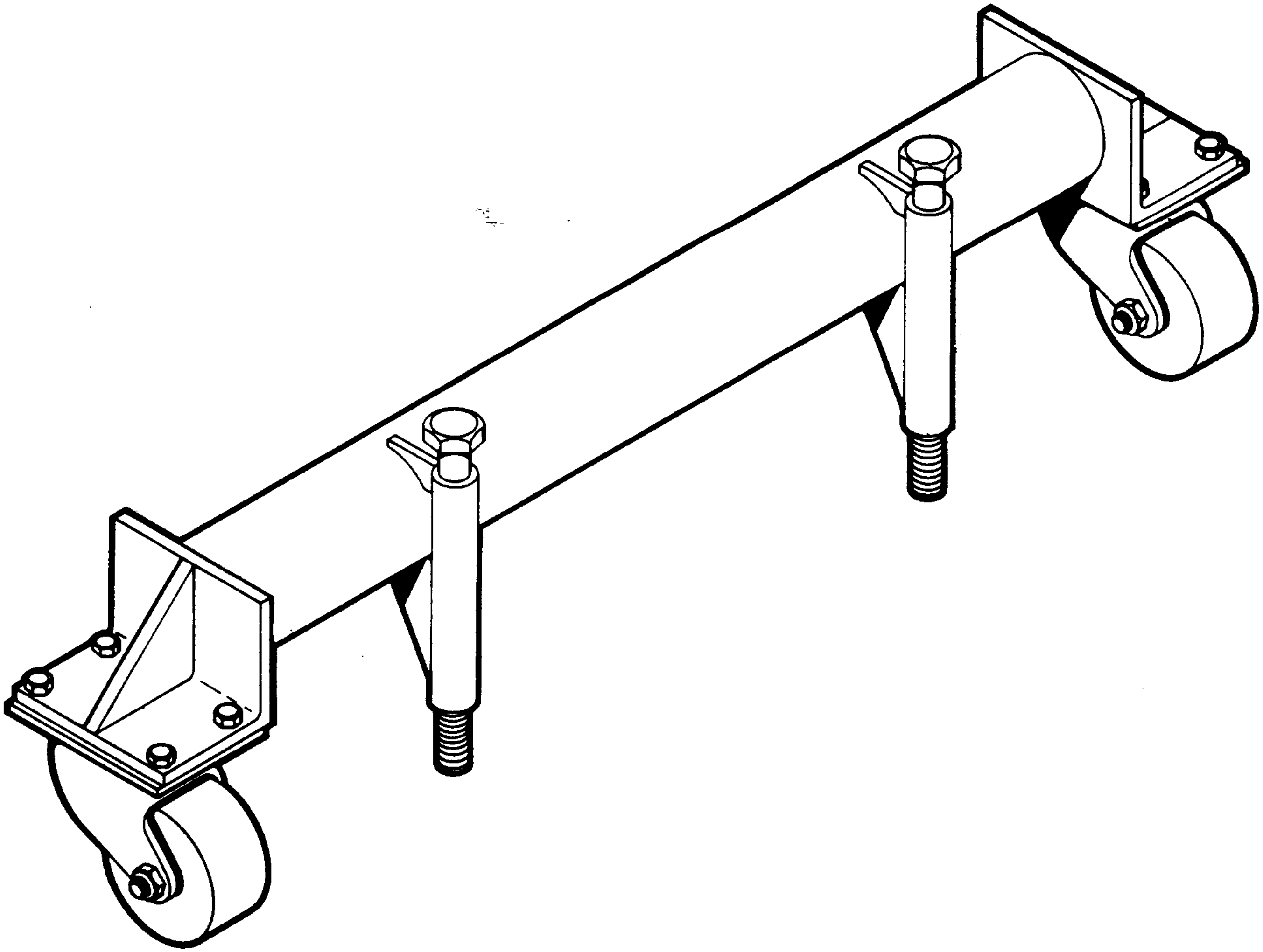


Fig. 2.6--Screw-on wheeled carriage for moving the liquid hydrogen cryostat and support system

It was believed that a sheet metal enclosure following the outline of the original plastic walls would provide a safer, more satisfactory structure. Therefore, 0.040-in. aluminum sheeting was used to enclose the area; however, the conducting plastic was retained in some areas to provide flexible ports for the uranium source and pure air entrances. Clear mylar sheets were used to cover ports in the aluminum walls through which TV cameras monitored conditions at the vent lines, background plug, and the LH_2 cryostat top area. The enclosure is shown in Fig. 2.7. The concrete floor inside the enclosure was covered with aluminum sheets and all areas enclosed by the sheet metal enclosure were grounded so that the resistance was less than one-fifth of an ohm between any of the parts.

A large work platform, (not shown in Fig. 2.7) 6.5 ft off the floor, was erected between the dewar and the valve package to allow easy access to the valve package and the upper area of the dewar. This platform permitted us to set the dewar angle without disturbing the dewar alignment, and it also provided a point of support for the vent lines.

An 18-in. diameter flexible duct was used as the air intake supply (see Fig. 2.7) for the sheet metal enclosure. Coming from this duct are two 4-in. diameter "elephant trunk" ducts which purge the areas enclosed by the roof support columns on either side of the sheet metal enclosure. The exhaust for this enclosure is an 18-in. diameter duct through the 1-ft thick concrete, 8-ft thick dirt ceiling of the experimental room. A special explosion-proof motor and static-free pulley belt were installed for use

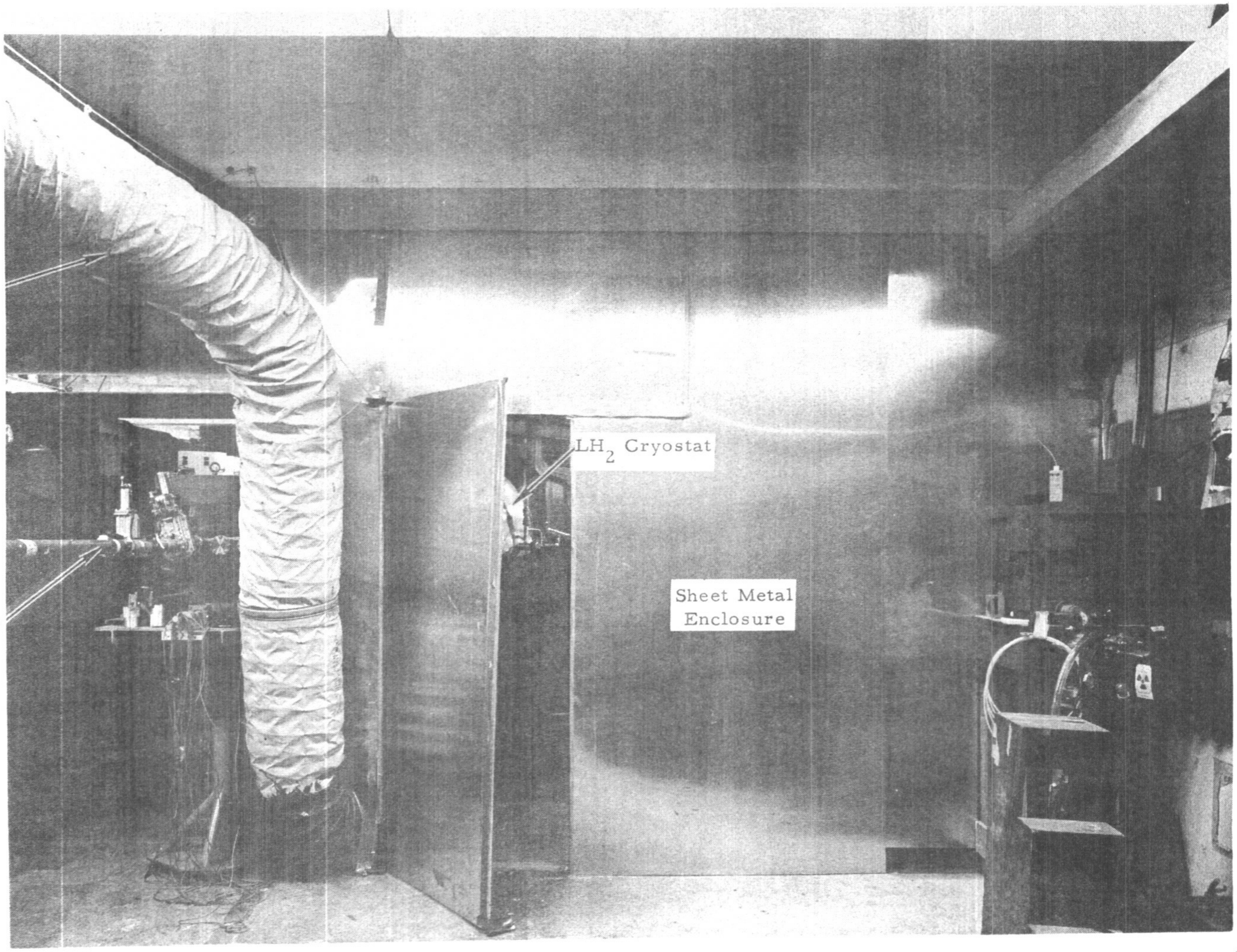


Fig. 2.7--Sheet metal enclosure showing flexible ducting for intake air supply

on the exhaust system for the LH_2 experiments. The exhaust system is generally used for the entire experimental area, and by restricting the volume of air exchange to the sheet metal enclosure a rapid air change was achieved.

2.2.4 Connections from the Liquid Hydrogen Cryostat to the Valve Package

The following are the connections from the LH_2 experimental cryostat to the valve package:

1. Five 1/2 in. diameter nonvacuum jacketed vent lines. One from each of chambers 2 to 6 as shown in Fig. 2.3.

2. One 2 in. diameter nonvacuum jacketed vent line from Chamber 1 (see Fig. 2.3).

3. Nonvacuum jacketed annulus relief line which relieves the pressure between the inner and outer dewar in case of an emergency.

4. One vacuum jacketed line which serves as both the fill and dump line.

The vent lines were checked with a helium leak spectrometer prior to use. It was found that a number of pinhole leaks were present in one of the flexible vent lines. This was due possibly to excessive short radius bending caused by rotation of the cryostat during the previous contract period. Although only one vent line was found to have pinholes, the integrity of the other lines was suspect, therefore, five new 1/2 in. diameter vent lines were made to replace the original lines. The new lines were made 6 in. longer than the original lines to allow more flexing freedom. In actual operation, the new, longer lines proved to be much easier to handle and allowed greater freedom during dewar rotation.

2.2.5 Valve Package

The valve package and the associated gas, vacuum, and transfer lines had to be completely cleaned before being placed in service. The valve package contains ten valves which see LH_2 or cold gas. These valves are electro-pneumatic remotely-operated extended stem valves with the dump and fill valves vacuum jacketed. They are of the metal-to-metal seal type. The valve package also contains three remote-operated solenoid warm gas valves for emergency purge. Directly connected to the valve package from two different locations remoted 30 and 60 ft. respectively are gas lines containing both remote-operated solenoid gas valves and throttleable hand valves for purging, evacuation, operation of the pneumatic valves, and remote readout of the pressure-vacuum of the system. Also connected to the valve package is a 40 ft. dump line, a 40 ft. vent line shown in Fig. 2.8 and a 40 ft. transfer line.

The valves which control the flow of cryogenic liquids or gas must be in proper working order. The liquid hydrogen system must also be free of all matter which would jam or clog the valves and flow passages. The system must be dry and free of water since ice formed during the LH_2 or LN_2 runs could lodge in the valve seats. Care was taken to ensure that no dust or foreign material had entered the valve package and gas lines by sealing all connections during this inactive period. This, of course,

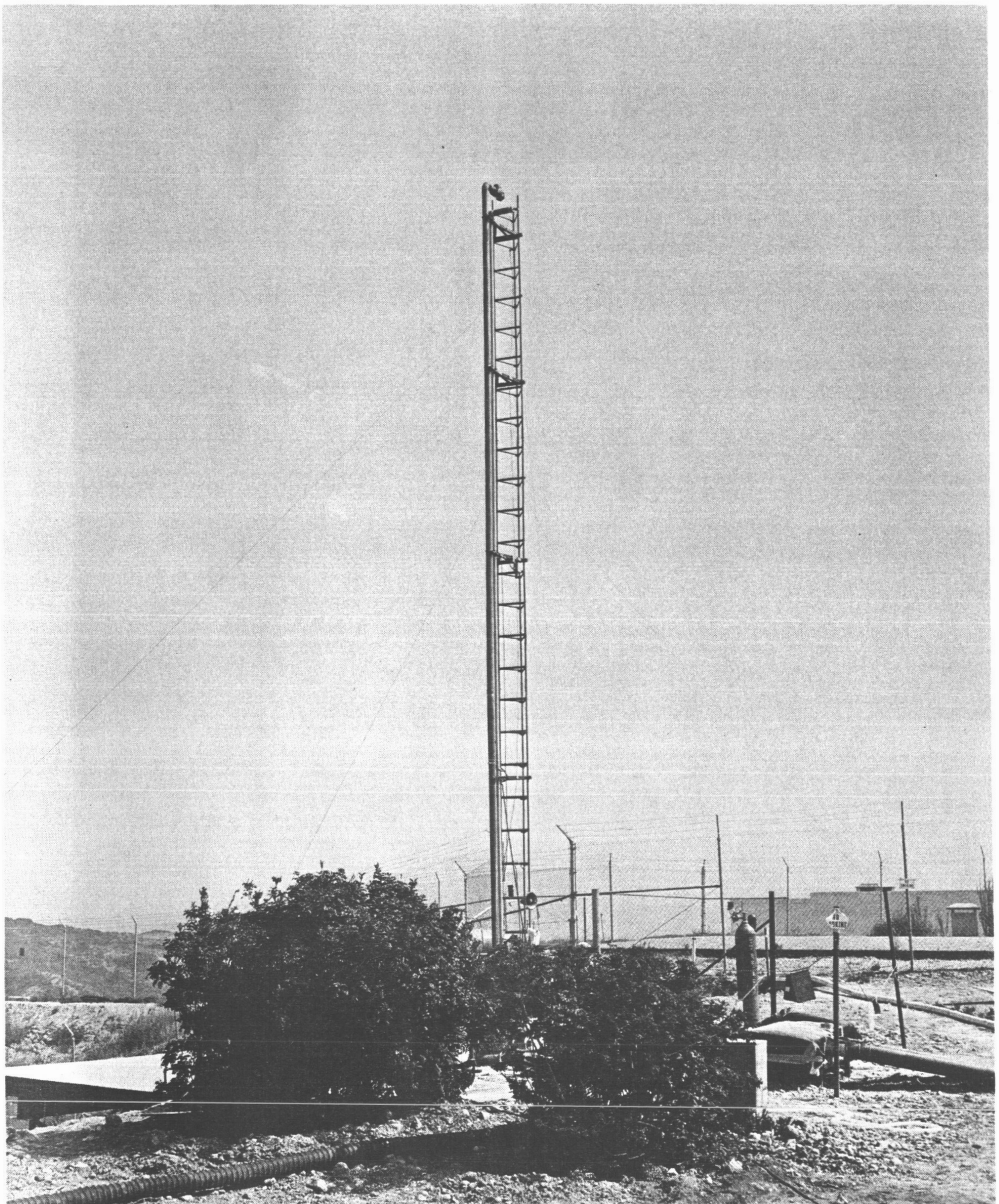


Fig. 2.8--LH_2 vent/dump stack support tower area

did not preclude the possibility that some foreign material may have entered the system during the LH_2 experiments in August 1964 or that corrosion of the 3-in. diameter copper vent line had not taken place.

The procedure used for cleaning the valve package and associated gas and transfer lines is outlined below:

1. The valve seats of the cold valves were vacuumed through external connections where possible.

2. The three solenoid-operated warm gas valves on the valve package were disassembled and the valve stem seals and seats of these valves were carefully inspected and cleaned where necessary. During the previous contract we had difficulty with gas flow through one of the solenoid-operated warm gas valves. The diaphragm on these valves contain two holes diametrically opposite with one slightly larger than the other. One is for gas flow and the other for alignment with an aligning pin. During disassembly it was found that the diaphragm had been installed so that these holes had been interchanged; when this was corrected the problem was eliminated.

3. Every line in the valve package and all lines connected to the valve package were flushed with dry nitrogen gas and the gas lines sealed.

4. To break loose attached particles the valve package was "cold-shocked" and flushed with LN_2. LN_2 was allowed to flow out of the 3-in. diameter copper vent and the 3/4-in. diameter vacuum jacketed dump lines.

5. At LN_2 temperature the valves were checked for proper seating and operation by allowing LN_2 on one side of the valve and using a forepump on the other side. Under this condition a vacuum of about 7×10^{-2} mm of Hg was obtained, which is as good as was originally obtained under the previous contract NAS 3-4214.
6. The valve seats of the cold valves were again cleaned to remove any foreign material flushed into them by LN_2.
7. The valve package was then evacuated to remove any water and filled with gaseous nitrogen at a positive pressure of about 15 psig.

A photograph of the valve package is shown in Fig. 2.9.

2.2.6 Transfer Lines from Valve Package to LH_2 Supply Dewar

The vacuum in the vacuum-jacketed transfer lines were checked prior to use and the same vacuum existed as on the previous contract NAS3-4214. These include the dump/fill transfer line from the LH_2 cryostat to the valve package, the dump line from the valve package which rises vertically through the roof of the experimental room and thirty feet above ground level, and a section of the transfer line about 40 ft. in length extending from the valve package to the outer edge of the experimental room through an unused flight tube.

Early in the contract period problems arose with a 3/4-in. O.D. by 0.035-in. wall thickness vacuum jacketed transfer line which mated with the 40 ft. transfer line mentioned above and was used to locate the LH_2 supply dewar at a safe distance. This transfer line was about 50 ft long and was originally borrowed from Convair Division, General Dynamics.

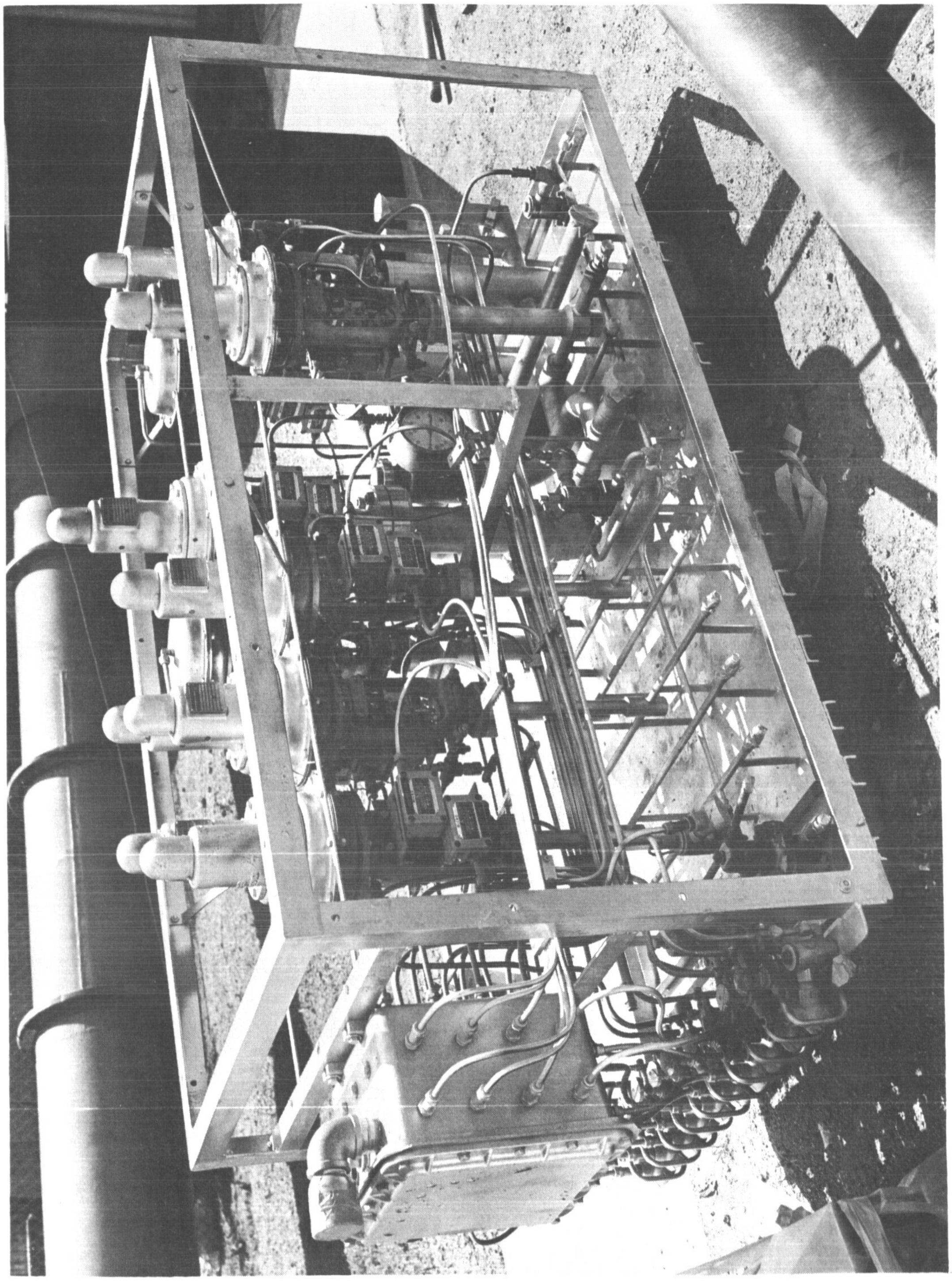


Fig. 2.9--Valve Package

At the completion of the previous program we had requested that the lines be retained for our use on the new program. However, in the period between the liquid hydrogen contracts, Convair Division moved from a temporary site to a permanent installation and these lines apparently were inadvertently scrapped. As a result of the above a thorough search was undertaken to locate 50 ft of acceptable transfer line from other Divisions of General Dynamics as well as NASA-Lewis Research Center and the Plumbrook installation. Since no suitable transfer line could be borrowed 50 ft of transfer line was purchased from the Cryogenic Engineering Company (Cryenco). The purchased transfer line was composed of two 25-ft sections.

2.2.7 "Bottle Farm"

The "bottle farm" is an array of nitrogen bottles and a helium tube trailer which are used for purging and for supplying the valve drivers. Since two types of purging are required two separate systems must be used. A third system is also used for supplying the valve drivers and a constant purge for various pieces of electrical equipment. One system acts as an emergency supply for quick dumping of the LH_2, heavy purging of the vent and dump lines, and transfer of the LN_2 or LH_2 within the cryostat. The other system supplies a small constant purge on the dump and vent lines and when necessary on the cryostat. Gaseous nitrogen is used for the LN_2 runs and gaseous helium for the LH_2 runs. The third system, which is used for the valve drivers and purging electrical equipment, always uses gaseous nitrogen. The "bottle farm" area is shown in Fig. 2.10.

The gas piping system and its controls were redesigned for the present series of experiments to provide a simpler, more easily read control panel to lessen operator indecision or possibility of mistakes during an emergency condition. Since the gaseous helium supply system was changed from cylinders to a tube trailer, the helium piping system was revised to accommodate the new trailer. New gaseous nitrogen lines were run to the uranium source cooling-water pump and to the three TV cameras, all of which were enclosed in conducting plastic shrouds to provide a constant nitrogen atmosphere at a slight positive pressure around these possible ignition sources. The Linac bending, steering, and focusing magnets were also purged in the same manner. A schematic of the revised piping system is shown in Fig. 2.11.

2.2.8 Remote Control Liquid Hydrogen Console

The liquid hydrogen console, which is remotely located in the data lab area, is the control center for all valves. A photograph of the console is shown in Fig. 2.12.

The LH_2 console also performs a number of other functions, many of which are associated with safety devices. The functions of the LH_2 console are discussed below.

One panel on the console contains a schematic of the flow of gaseous or liquid hydrogen and lights indicate the position of the valves (open or closed) which control this flow.

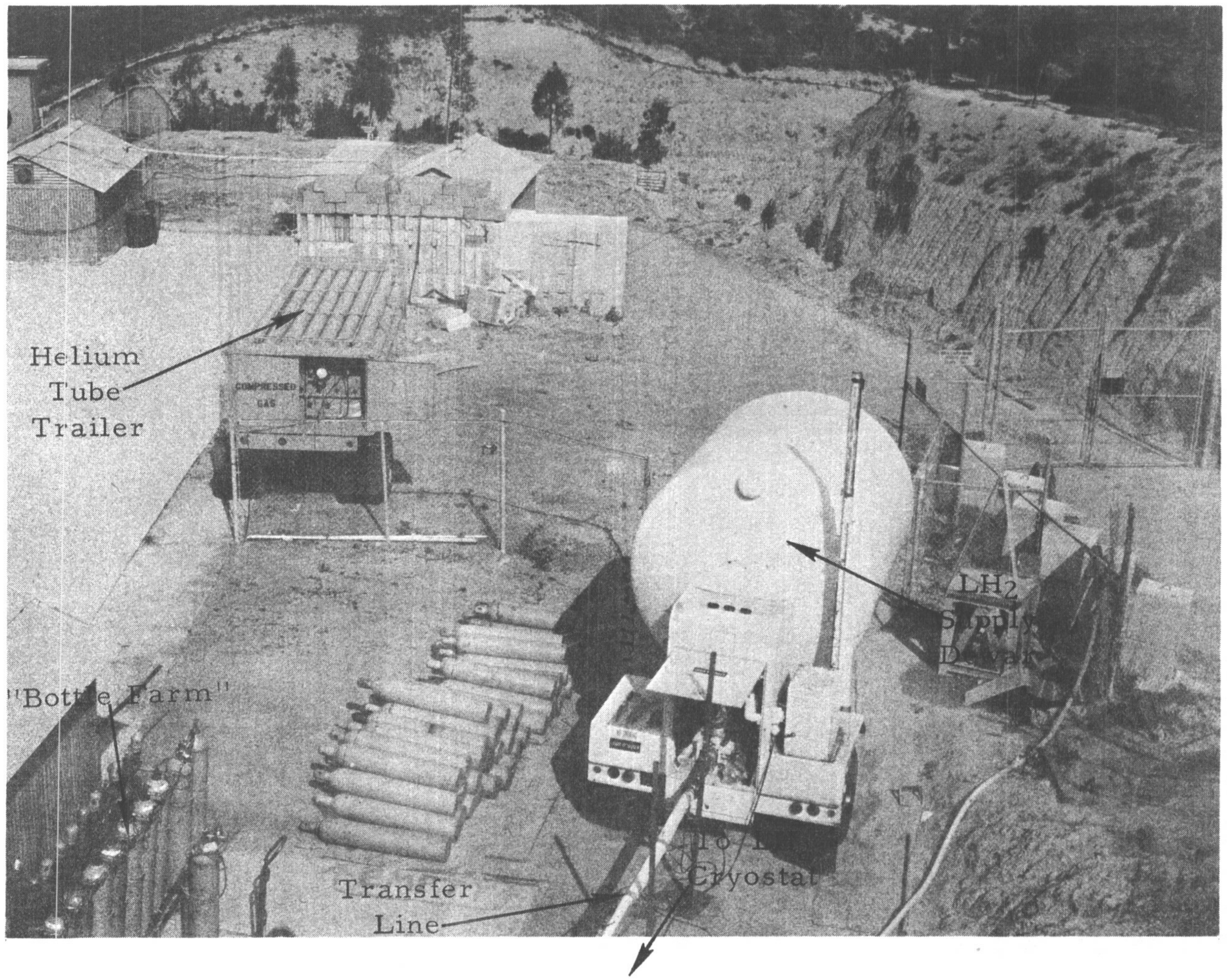


Fig. 2.10--"Bottle farm" area showing the LH_2 supply dewar and helium tube trailer

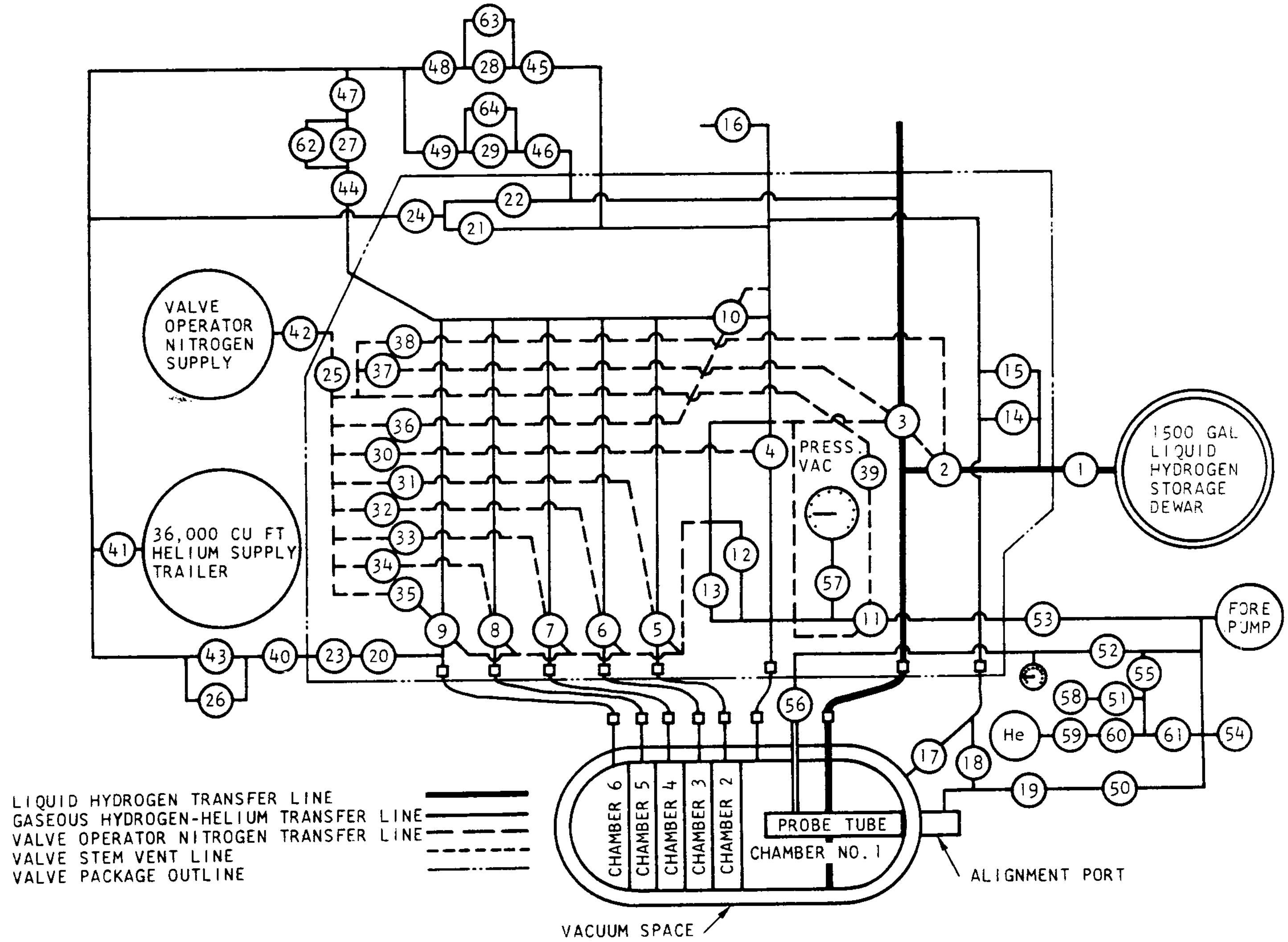


Fig. 2.11--Revised valve and piping system schematic

LEGEND FOR FIG. 2.11

Number	Normal Position	Valve
1		Storage dewar hand valve
2	NC*	Dewar fill valve - BS&B vacuum jacketed 3/4" pneumatic valve
3	NO**	Dewar dump valve - BS&B vacuum jacketed 3/4" pneumatic valve
4	NC	Chamber No. 1 vent valve - BS&B extended stem 2" pneumatic valve
5	NC	Chamber No. 2 vent valve - BS&B extended stem 3/8' pneumatic valve
6	NC	Chamber No. 3 vent valve - BS&B extended stem 3/8' pneumatic valve
7	NC	Chamber No. 4 vent valve - BS&B extended stem 3/8' pneumatic valve
8	NC	Chamber No. 5 vent valve - BS&B extended stem 3/8' pneumatic valve
9	NC	Chamber No. 6 vent valve - BS&B extended stem 3/8' pneumatic valve
10	NO	Chamber No. 2 - No. 6 isolation valve - BS&B extended stem 3/4" pneumatic valve
11	NC	Vacuum purge valve - BS&B extended stem 3/4" pneumatic valve
12		Rupture disk - BS&B 2" - set at 60 psig
13		Blowoff valve - Farris 2" - set at 40 psig
14		Blowoff valve - Farris 1/2" - set at 100 psig
15		Rupture disk - BS&B 1/2" - set at 150 psig
16		Vent line flapper valve
17		Cryenco dewar vacuum space relief valve
18		Cryenco alignment port vacuum space relief valve

*NC - normally closed
**NO - normally open

Number	Normal Position	Valve
19		Alignment port evacuation hand valve
20	NO	Dewar purge valve - 1/2" Skinner solenoid valve
21	NO	Vent line purge valve - 1/2" Skinner solenoid valve
22	NO	Dump line purge valve - 1/2" Skinner solenoid valve
23		Dewar purge line regulator - Fisher 1/2" valve set at 35 psig
24		Vent-dump purge line regulator - Fisher 1/2" valve set at 35 psig
25		Valve operator line relief valve - Kunkle 1/2" valve set at 55 psig
26	NO	Transfer bypass solenoid valve
27	NC	Dewar micropurge solenoid valve
28	NC	Vent line micropurge solenoid valve
29	NC	Dump line micropurge solenoid valve
30	NC	No. 1 vent operator solenoid valve
31	NC	No. 2 vent operator solenoid valve
32	NC	No. 3 vent operator solenoid valve
33	NC	No. 4 vent operator solenoid valve
34	NC	No. 5 vent operator solenoid valve
35	NC	No. 6 vent operator solenoid valve
36	NC	No. 2 - No. 6 isolation operator solenoid valve
37	NC	Dump operator solenoid valve
38	NC	Fill operator solenoid valve
39	NC	Vacuum purge operator solenoid valve
40		Dewar purge hand valve
41		Helium purge regulator valve - set at 35 psig
42		Valve operator regulator valve - set at 50 psig
43		Liquid transfer regulator valve - set at 5-8 psig
44		Dewar micropurge hand flow rate valve

Number	Normal Position	Valve
45		Vent line micropurge hand flow rate valve
46		Dump line micropurge hand flow rate valve
47		Dewar micropurge flowmeter
48		Vent line micropurge flowmeter
49		Dump line micropurge flowmeter
50		Alignment port hand vacuum pump shutoff valve
51		Probe tube relief valve shutoff hand valve
52		Probe tube vacuum hand valve
53		Dewar vacuum hand valve
54		Thermocouple vacuum gage readout
55		Helium probe tube hand valve
56		Probe tube hand shutoff valve
57		Vacuum-pressure gauge hand shutoff valve
58		Probe tube pressure relief valve - popoff at 20 psig
59		Helium pressure regulator valve - set at 5 psig
60		Helium shutoff hand valve
61		Helium vacuum line hand valve
62		Dewar micropurge hand bypass valve
63		Vent line micropurge hand bypass valve
64		Dump line micropurge hand bypass valve

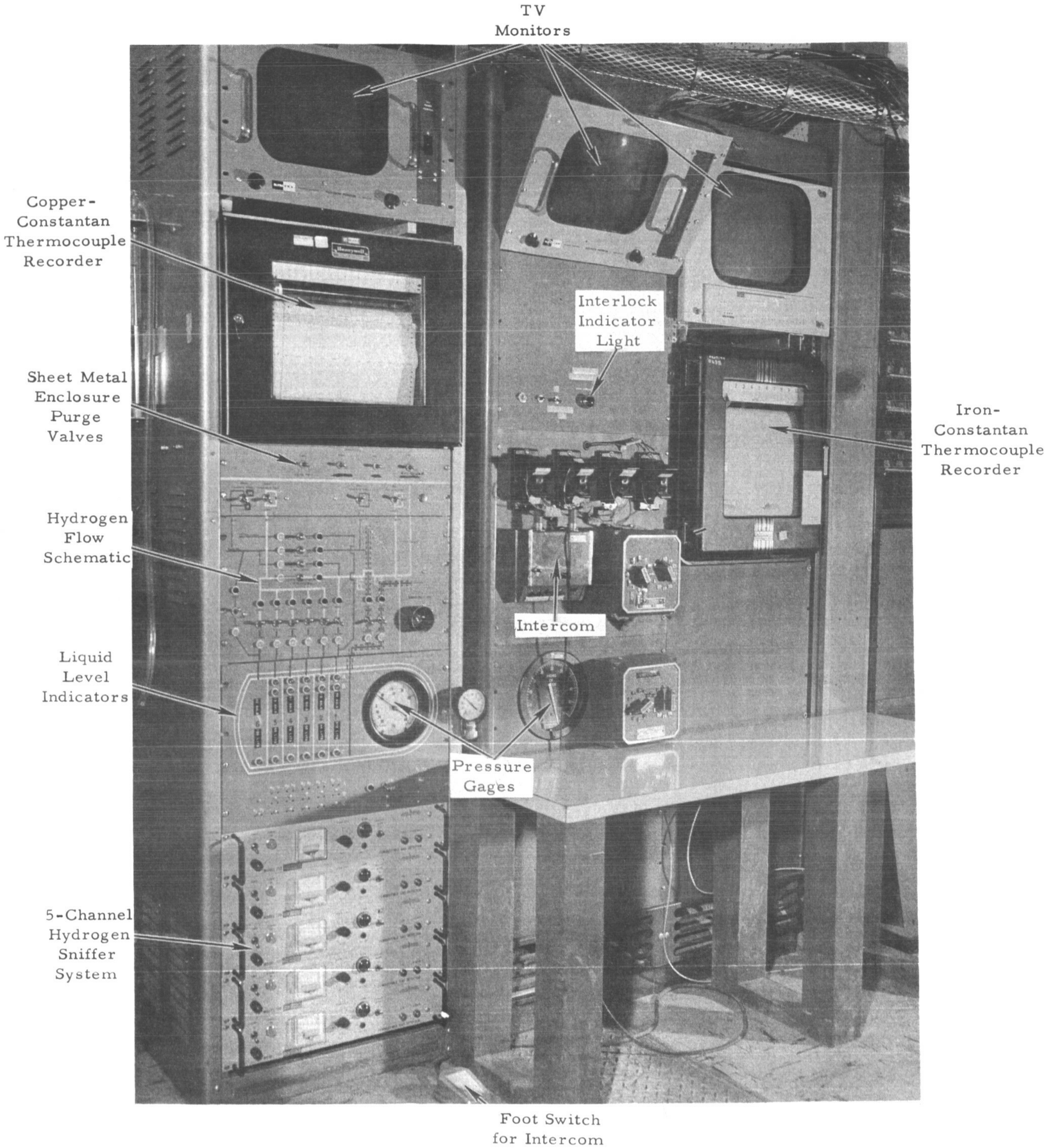


Fig. 2.12--Liquid hydrogen console

Another panel contains the controls for remotely-operated valves for purging the sheet metal enclosure around the LH_2 cryostat. In case of fire this enclosure can be purged with an inert gas to preclude the entry of oxygen. On the previous contract (NAS 3-4214) carbon dioxide supplied from a dewar was chosen for this gas. However, at the flame temperature of hydrogen, carbon dioxide can break down into carbon monoxide and oxygen. Since this was considered unsafe, a 160-gallon, 100-psi maximum pressure liquid nitrogen dewar was rented from Linde and the existing CO_2 piping system to the valve package and cryostat areas was modified to fit the new dewar. This system performed satisfactorily; it required only about 35 seconds at 60 psi dewar pressure to flood the sheet metal enclosure with cold gaseous nitrogen. Carbon dioxide had also been used for a fire fighting system to control possible fires in the LH_2 supply dewar area. Since this area is open the use of carbon dioxide is permissible; CO_2 gas cylinders equipped with nozzles were placed in this area. A fire in the LH_2 supply dewar area could also have been controlled by water hoses located about 100 ft from the supply dewar.

The LH_2 console also contains 16 liquid level indicators for either LN_2 or LH_2. The liquid level indicators utilize 1/4-watt, 1000-ohm, carbon composition resistors as liquid level sensors. The resistance of these resistors at liquid nitrogen (LN_2) temperature is about 1450 ohms and at LH_2 temperature is 2800 ohms. The unbalance of a bridge circuit is used to indicate the level of the liquid. Each carbon resistor is backed by two duplicate resistors. One set of these resistors was monitored with a Wheatstone bridge and was extremely useful during filling, dumping, and transferring of the liquid from one chamber to another.

An intercom system connects all of the remote areas with the console. A voice-operated relay was originally planned to free the operator of the LH_2 console from manual operation of the intercom during critical operations. However, this system was not satisfactory because of background noise and a foot switch was used instead.

Three TV monitors located at the LH_2 console were used. One monitor was used to view the electron beam spot position in the hole of the uranium source and to determine positive seating of the aluminum monitor slug holder. The second monitor viewed the vent line connections and fill/dump line connection at the top of the dewar. This monitor would have determined if a break had occurred at these connections. The third TV monitor was used to verify the position of the B^{10} background plug. Since the LH_2 cryostat has a very small ullage space, LH_2 can easily be entrained in the nonvacuum jacketed vent lines and cause liquid oxygen to form on these lines. This condition can also be caused by the flow of cold hydrogen gas through the vent lines. Therefore, the third monitor was also used to observe the vent lines to determine if liquid oxygen was being formed on the vent lines.

The uranium source is water-cooled and is interlocked with the electron linear accelerator interlock system by means of a flow switch in the water system. In case of a water leak or rupture the Linac is automatically shut off and a light on the LH_2 console indicates the interlock has been interrupted.

Two sets of thermocouples are used to monitor temperature. Copper-Constantan thermocouples were used to determine the temperature of the liquid hydrogen in three positions of chamber one of the LH_2 cryostat as shown in Fig. 2.3. This type of thermocouple was also used to determine the temperature of the six vent line connections at the dewar and the temperature of the vent lines at the lowest points of vent lines number one and two.

Iron-Constantan thermocouples were used to determine the presence of fire at the dewar, valve package, LH_2 supply dewar, dump, and vent lines. The Iron-Constantan thermocouples were also used to monitor the temperature of the uranium source. The recorder for measuring the Iron-Constantan thermocouples was interlocked with the Linac so that if the temperature should exceed 500°F the Linac would automatically be shut off. The same visual indicator as for the water supply for the uranium source would note this condition and steps would then be taken in accordance with our "Emergency Procedures" given in Appendix A.

Following Dr. John Liwosz's (NASA Project Manager) approval hydrogen sniffers were ordered from General Monitors, Inc. This hydrogen sniffer system consisted of five channels; three of the channels not located in a radiation field used thermistors as the sensing heads, while the two channels located in the radiation field used bifilar platinum wire sensing elements as were used on the previous contract (NAS 3-4214). The monitor for these hydrogen sniffers is located at the LH_2 console shown in Fig. 2.12. One bifilar platinum wire sensing element was placed above and between the LH_2 cryostat and valve package inside the sheet metal enclosure and the other near the ceiling just outside the enclosure. The thermistor sensing elements were placed about 4 ft up the 18-in. diameter ceiling exhaust duct for the sheet metal enclosure, at the dump and vent line exit above the top of the Linac experimental building, and at the LH_2 supply dewar position. During the first series of neutron spectrum measurements, the LH_2 supply dewar developed a hydrogen leak at the packing around the manually-controlled fill-drain valve and it was quickly detected by the hydrogen sniffer at that location averting a possible hazardous situation.

2.2.9 Checkout of the Liquid Hydrogen Facility Using Liquid Nitrogen

As noted above each component of the liquid hydrogen facility was given a thorough checkout. To obtain an integral check on the LH_2 facility, LN_2, which is the most logical cryogenic fluid nearest to LH_2 temperature, was used. Three LN_2 checkouts of the LH_2 facility were made. These served to determine that the entire system was functioning properly and also to gain familiarization with the operation of the facility. The last LN_2 checkout was used as a "dress rehearsal" for the liquid hydrogen runs since it was conducted less than a week prior to the first series of LH_2 experiments.

2.2.10 Checkoff list, Operational and Emergency Procedures

Prior to each set of measurements involving LH_2, very detailed checkoff lists were used. These served to preclude the possibility of forgetting some minor task which might interfere with the experiment or create a hazardous condition. For the same reason operational procedures were used as guidelines for filling the cryostat with LH_2, changing the LH_2 from one chamber to another, emptying the cryostat and purging it between each series of measurements. Emergency procedures were written covering a number of typical emergency situations which could occur. These checkoff lists and operational and emergency procedures are included in Appendix A.

III. EXPERIMENTAL TECHNIQUES

3.1 EXPERIMENTAL PROCEDURES

The following procedure was used in making neutron spectrum measurements using the LH_2 facility. The proper precollimator was installed in the flight path and the flight system setup, the probe tube was aligned with the flight path, and the angle of the cryostat adjusted to the desired angle. The proper detector was placed at the end of the flight path. The checkoff lists were completed. The electron beam tube was positioned by use of the variable angle beam bending system described in Ref. 1 so that the electron beam will strike the base of the cylindrical opening in the spherical uranium source. The electron beam is positioned in the cylindrical hole of the source by the various focusing, steering, and bending magnets. The cryostat is then filled to the largest thickness with LH_2. The aluminum slug monitor is inserted in its holder and the neutron spectrum is measured by the time-of-flight technique. Various aspects of these experimental techniques are discussed in the following sections.

3.2 GEOMETRY FOR THE NEUTRON SPECTRUM MEASUREMENTS

Details of the geometry for the differential angular neutron spectrum measurements are shown in Figs. 2.3 and 3.1. The 0.0625 in. 304 stainless steel baffles divide the cryostat into five chambers having

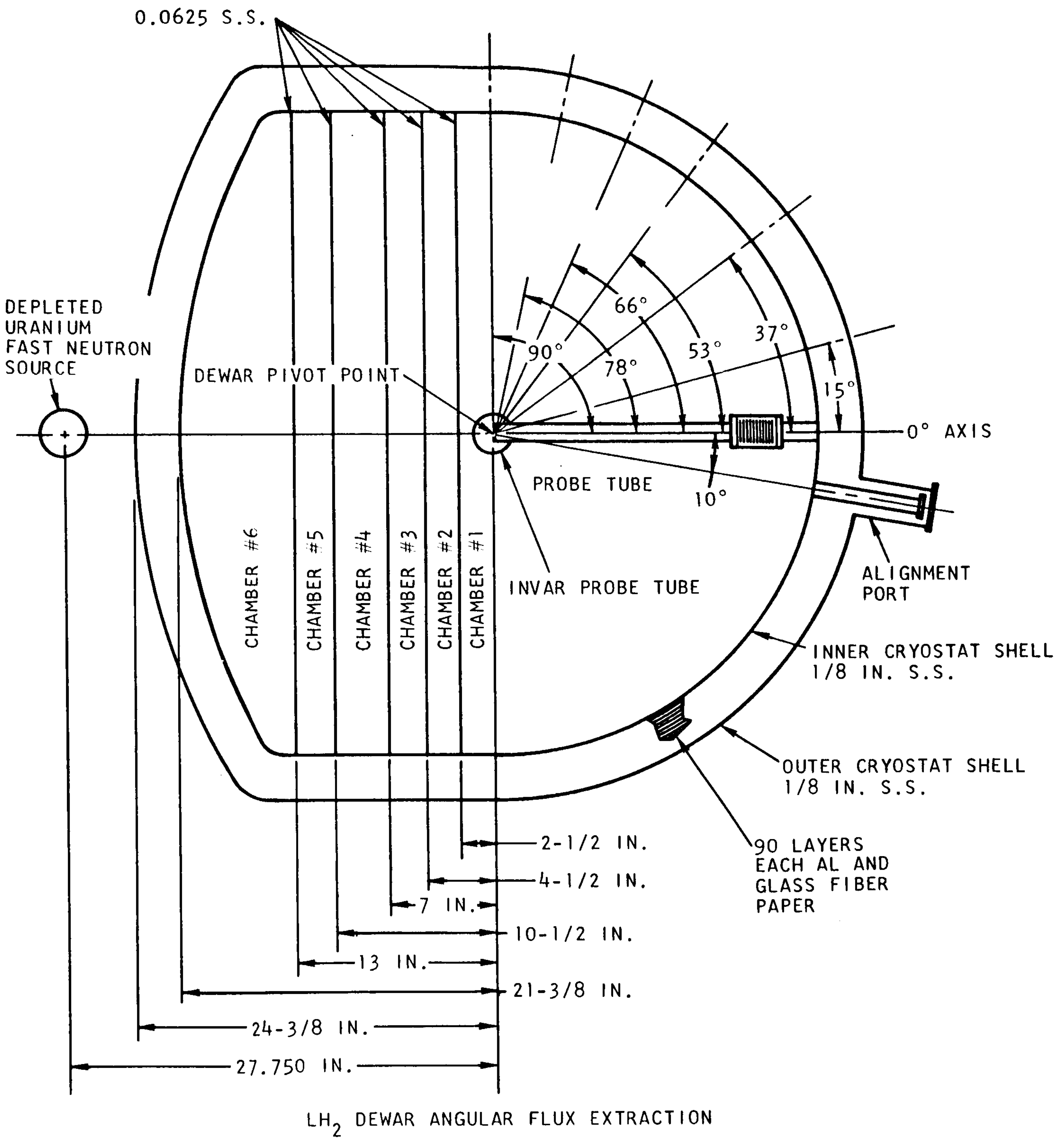


Fig. 3.1--Geometry for the neutron spectrum measurements

discrete thicknesses of LH_2 of 2.5, 4.5, 7.0, 10.5, and 13.0 in. measured between the probe tube inner window and the last filled chamber. Chamber number six does not normally contain LH_2, however during the filling procedure this chamber is filled so that the entire inner dewar shell is at LH_2 temperature. Then chamber number six is emptied.

The neutron spectrum measurements are first taken at the largest thickness (chamber number 5) then proceed through chamber numbers 4, 3, and 2 until the smallest thickness (chamber number one) of LH_2 is reached. The neutron spectrum is measured at the center of the hemispherical section of the cryostat at the inner probe tube window. The neutrons start their flight at the outer thickness of the inner probe tube window, .03125 in. down the probe tube, which is filled with 5 psig of helium at 20.4^{o}K, through the outer probe tube window (0.035 in. thick 304 stainless steel), through the inner cryostat shell window (0.0726 in. of stainless steel) and through the outer cryostat shell window (0.0789 in. of stainless steel) then down the flight path. No multilayer insulation is present between the inner and outer cryostat windows.

The depleted uranium fast neutron source remained in the same fixed geometry for every measurement.

The various angles are obtained by leaving the probe tube fixed and aligned and rotating the cryostat. The angle of the spectrum measurement is then the angle between the axis of the probe tube and the axis of the cylindrical portion of the cryostat (0^{o} direction).

3.3 PROBE TUBE ALIGNMENT MECHANISM

Accurate positive alignment of the experimental dewar probe tube with the flight path was essential to the acquisition of good experimental data. Due to the nature of the experiment, it was necessary to have an alignment and support system which allowed us to initially align with a transit the dewar with the flight path. For this purpose an alignment port had been provided. However, during operation this port must be closed and the dewar rotated to any desired angle without affecting the probe tube alignment. As the new dewar support system, described in Section II. 2.2 proved to be extremely rigid and stable, it was felt that the external shaft of the probe tube could be rigidly attached to the alignment roof plate after alignment, to insure no relative motion with respect to the flight path. A somewhat modified version of the alignment system used on the previous program (Fig. 3.2) was designed and built. In the new system the two alignment arms are at 90° with respect to each other, while the large diameter tubes extending downward from the roof plate are a loose slip fit in the alignment arm holes (see Fig. 3.3). Observation of the cross hairs on the probe tube with a transit while a moderate load was applied to the dewar and to the alignment arms showed no discernable movement, indicating that alignment would be maintained even if the alignment arms were bumped. The alignment plate at the top of the dewar was machined by Cryenco so that its flat upper surface would be exactly perpendicular to the centerline of the probe pivot tube. A close tolerance bore in the

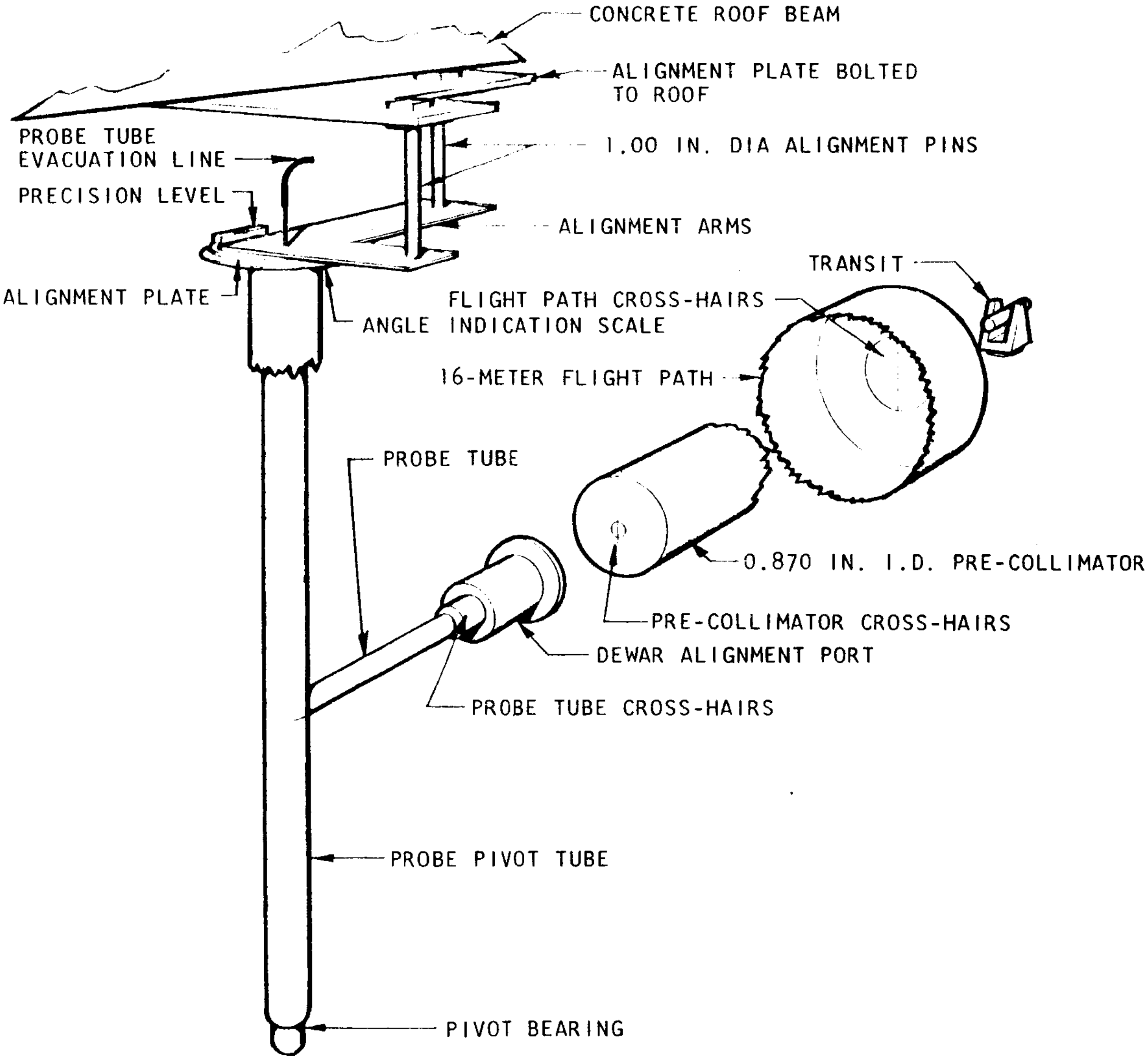


Fig. 3.2--Cutaway view of the probe tube alignment system

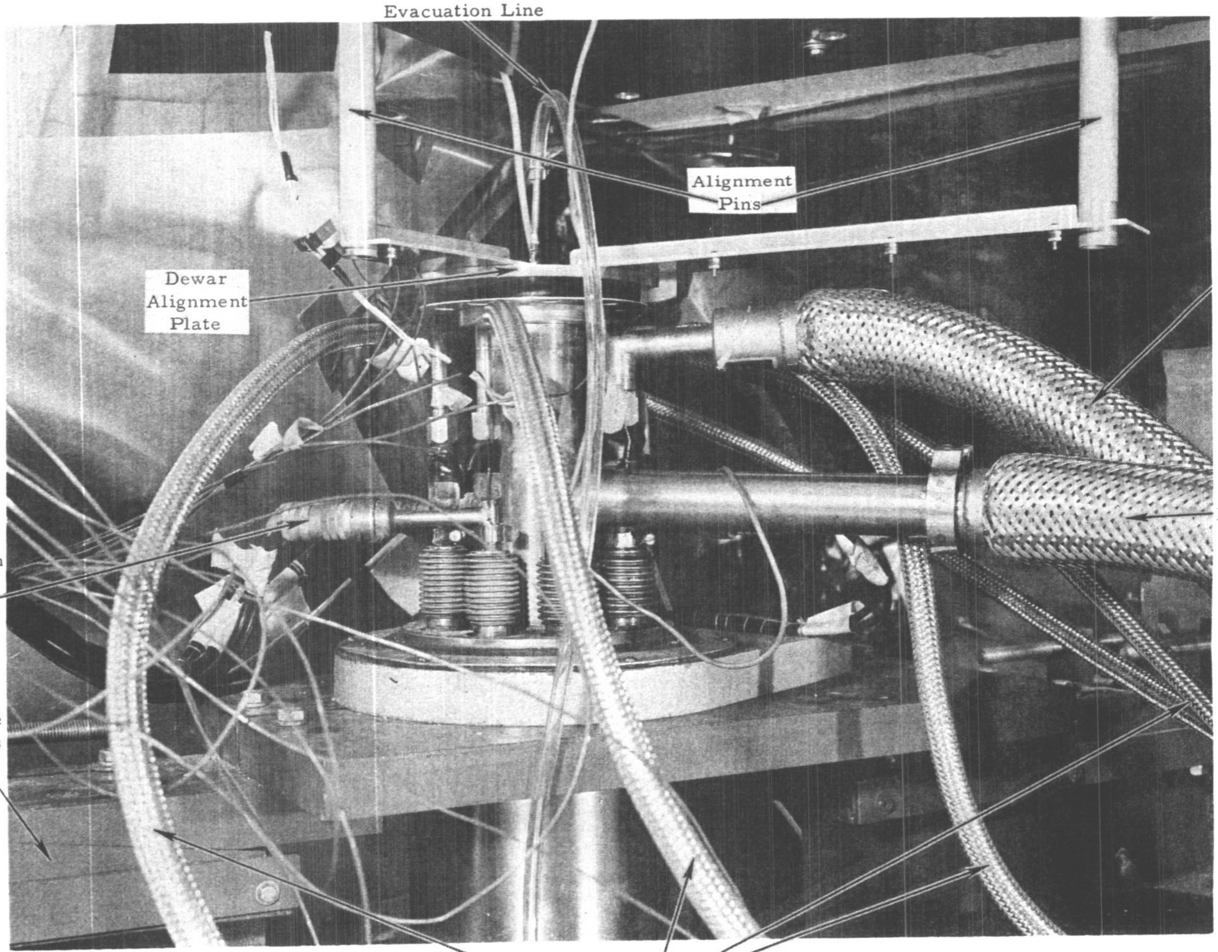


Fig. 3.3--Photograph of the alignment plate

center of the plate fits very tightly over a bearing surface concentrically machined at the top of the probe pivot tube. The alignment plate bearing surface is external to the dewar. During manufacture the probe tube was carefully welded to the invar pivot tube. The centerline of the probe tube is perpendicular to the pivot tube's centerline within 0.005 in. over the entire length of the probe tube. Therefore, this provided a positive method of knowing the attitude of the probe tube centerline in relation to the horizontal. During the alignment procedure, the dewar attitude was adjusted by using the leveling mechanism on the dewar support so that a precision level placed on the flat surface of the dewar alignment plate indicated dead horizontal at two positions 90° apart. The inner cross hairs on the probe pivot tube were then aligned with the flight path while the probe tube was pivoted to a position 90° from the flight path centerline; the probe tube was then pivoted back to the flight path centerline, the alignment tubes lined up in the alignment arms and roof plate holes, and the whole alignment assembly was then securely tightened.

3.4 WATER-COOLED ISOTROPIC FAST NEUTRON SOURCE

A portion of the research performed under the previous contract NAS 3-4214 included the development of an air-cooled isotropic neutron source; details of this development are described in Ref. 1. The neutron source for these measurements was a water-cooled, depleted uranium sphere 3.0 in. diameter with a 1.0 in. diameter reentrant hole for the admission of the electron beam to 0.33 in. from the center of the sphere. The depth of the hole was controlled so that the effective center of neutron production is at the center of the uranium sphere (the radius of the production region is estimated at 0.33 in.). The neutrons then make, on the average, the same number of collisions in any direction (except at the reentrant hole) and source emission is almost independent of angle with respect to the electron beam.

In order to operate at higher beam power and hence obtain a higher neutron output from the source it was necessary to increase the heat removal capabilities of the isotropic uranium source. Therefore, a thin water cooling jacket was added to the same copper-nickel clad 3.0-in. diameter depleted uranium sphere which had produced an isotropic fast neutron source preserving isotropy as much as possible. A 0.030-in. thick stainless steel spherical water jacket directs cooling water over the entire outer surface of the uranium sphere in a stream 0.090-in. thick; the jacketing also directs a high flow-rate stream of water between the uranium and the copper window which the electron beam strikes, thus applying the maximum cooling effect to the major point of heat input. Design calculations indicated that with a water flow of six gallons per minute at a pressure of 30 psi, 1.7 kilowatts of Linac power could be removed from the source without the temperature of the uranium exceeding 250°F. Experimentally, the source more than lived up to power removal expectations. Details of the water-cooled source are shown in Fig. 3.4.

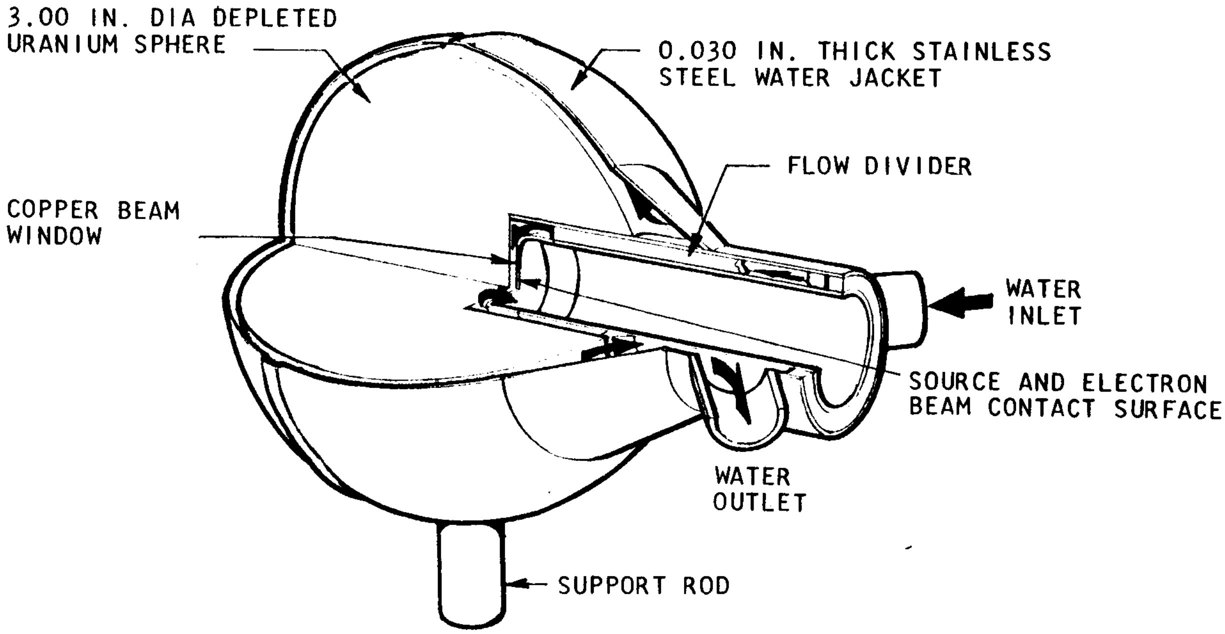


Fig. 3.4--Details of the water-cooled 3-in. diameter spherical uranium fast neutron source

The position and size of the electron beam spot must be controlled for the electron beam to be steered and focused within the 1-in. diameter reentrant hole in the source. A 0.001-in. thick aluminum mirror was placed at approximately a 45° angle within the electron beam as shown in Fig. 3.5. A thin stainless steel insert was placed at the base of the reentrant hole and the reflection from the mirror of the fluorescence of the beam spot on the stainless steel was observed with the aid of closed-circuit television. Essentially no degradation of the electron beam energy occurred in the mirror.

The distribution of neutron emission relative to the direction of the electron beam axis was measured with a circular array of threshold activation foils placed around the water-cooled source and compared with the results for the air-cooled source under the same geometry. Data taken with sulfur foils, for the S^{32} (n, p) P^{32} activity (3 MeV threshold) are shown in Fig. 3.6, normalized to 1.0 at 0°. Distributions as measured by Al^{27} (n,α) Na^{24} activation (7 MeV threshold) are shown in Fig. 3.7, again normalized to 1.0 at 0°. The deviations are 6-10% except in the backward direction, where uranium has been removed for admission of the electron beam.[2]

Time-of-flight measurements of the neutron energy spectrum of the source hemisphere-integrated flux have been made at angles of 46°, 95°, and 134° to the electron beam and are reported in Ref. 2. These results confirm the good uniformity of emission of the 3-in. diameter

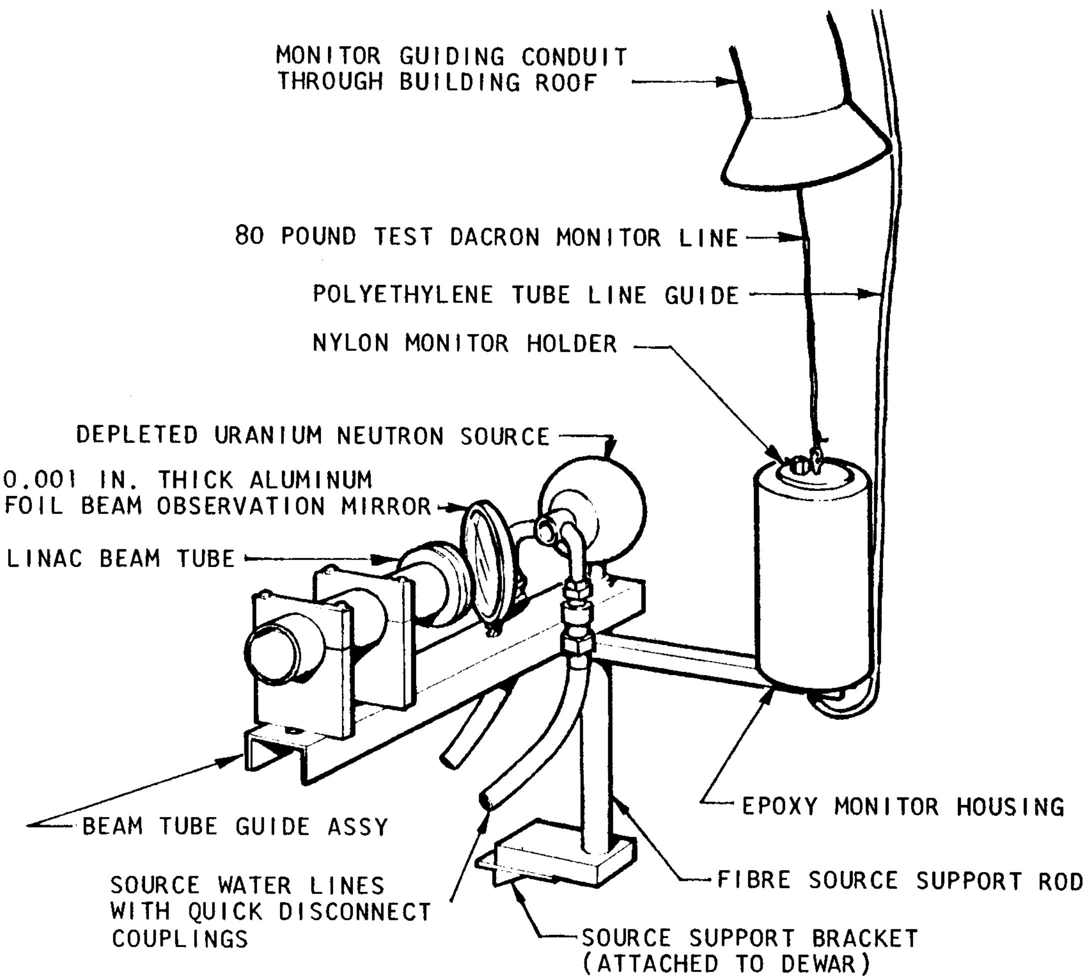


Fig. 3.5--Uranium source and support, beam tube guide, aluminum slug monitor and holder, and mirror used for monitoring electron beam

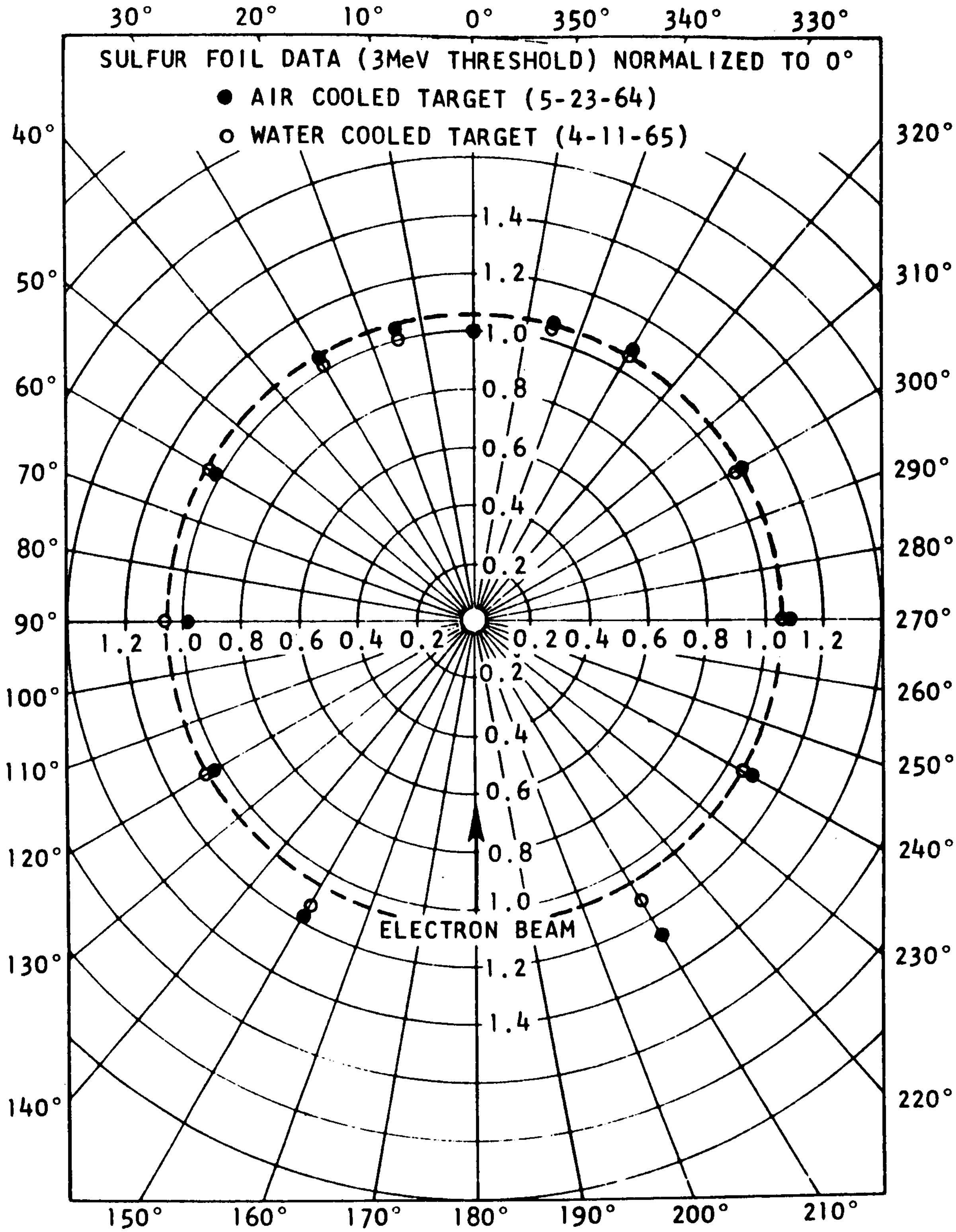


Fig. 3.6--Sulfur activation, air and water cooled
3 in. uranium source

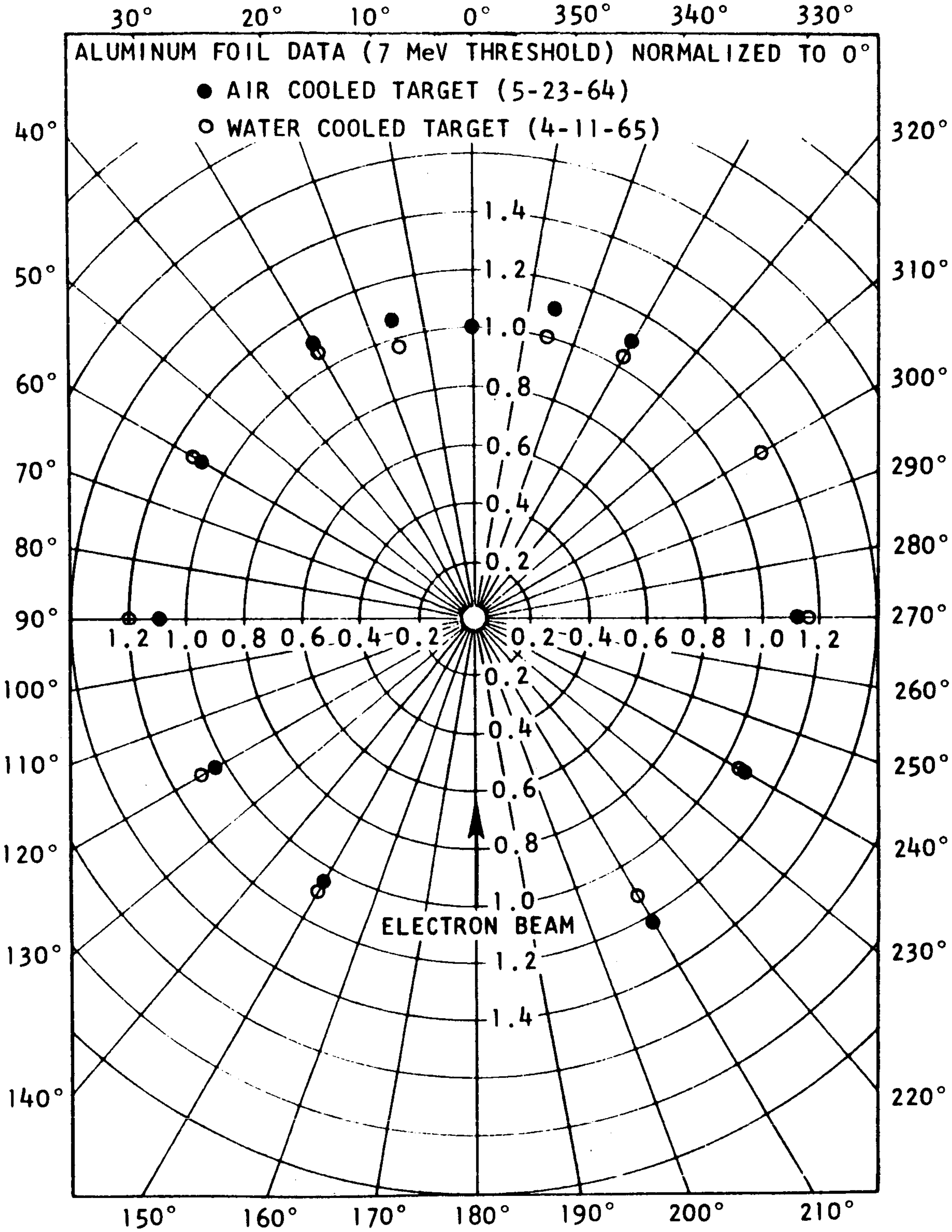


Fig. 3.7--Aluminum activation, air and water cooled 3 in. uranium source

target. Figure 3.8 shows the comparison of the source hemisphere-integrated flux in the fast neutron energy region made at an angle of 95° to the electron beam for the air-cooled and water-cooled uranium source. These spectra show good agreement. Two different water-cooled uranium sources were used for the present program since the first source failed and had to be replaced. The first source failed as a result of a pinhole leak which reduced the effectiveness of the water cooling. This loss of water resulted in the electron beam drilling another hole in the copper beam window which is the most crucial heat removal area. The initial pinhole leak developed as a result of fatigue in the solder joint between the hemispherical shells of the stainless steel water jacket. These two sources are compared in Fig. 3.9 and tabulated in Appendix B at an angle of 95° for the intermediate and fast neutron energy region. For the 1-30-66 measurements a 2-in. lead gamma filter was used and for the 4-9-66 measurements a 1.238 in. uranium gamma filter was used. Again there is good agreement for the two sources. The importance of this result is that the source spectrum for all the present measurements was the same and that the fast neutron source spectrum for the present measurements and those measurements taken during Contract NAS 3-4214 were the same.

3.5 SOURCE MONITORS

The main requirement of a source monitor is accuracy (the ability to follow from run to run the changes of source strength and to indicate these changes in direct proportion to the actual source strength variation). It must correctly indicate flux variations over a wide range and must be insensitive to changes made in the experimental area, seeing only actual primary

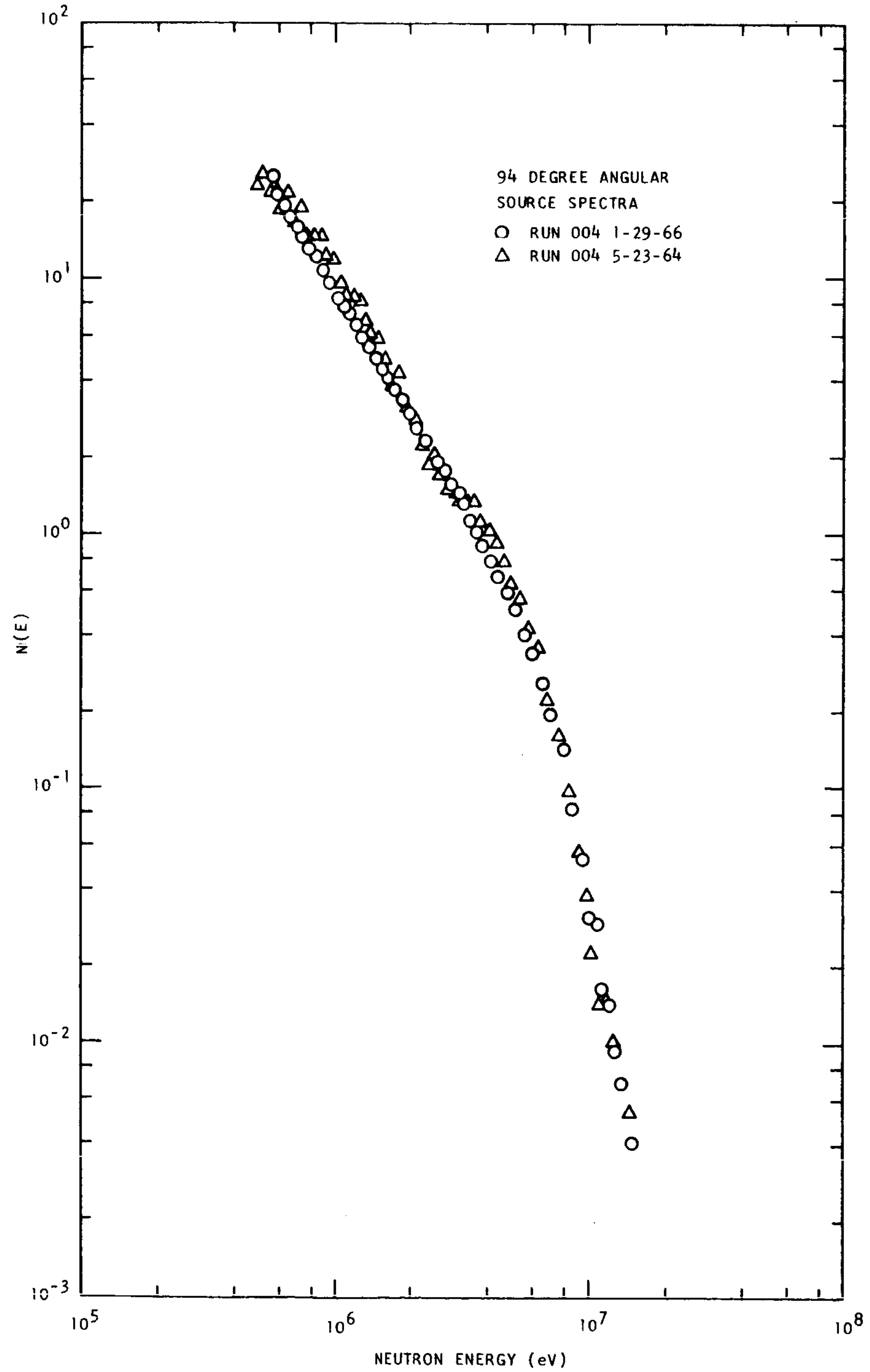


Fig. 3.8--Comparison of the air-cooled and water-cooled uranium source hemisphere-integrated flux.

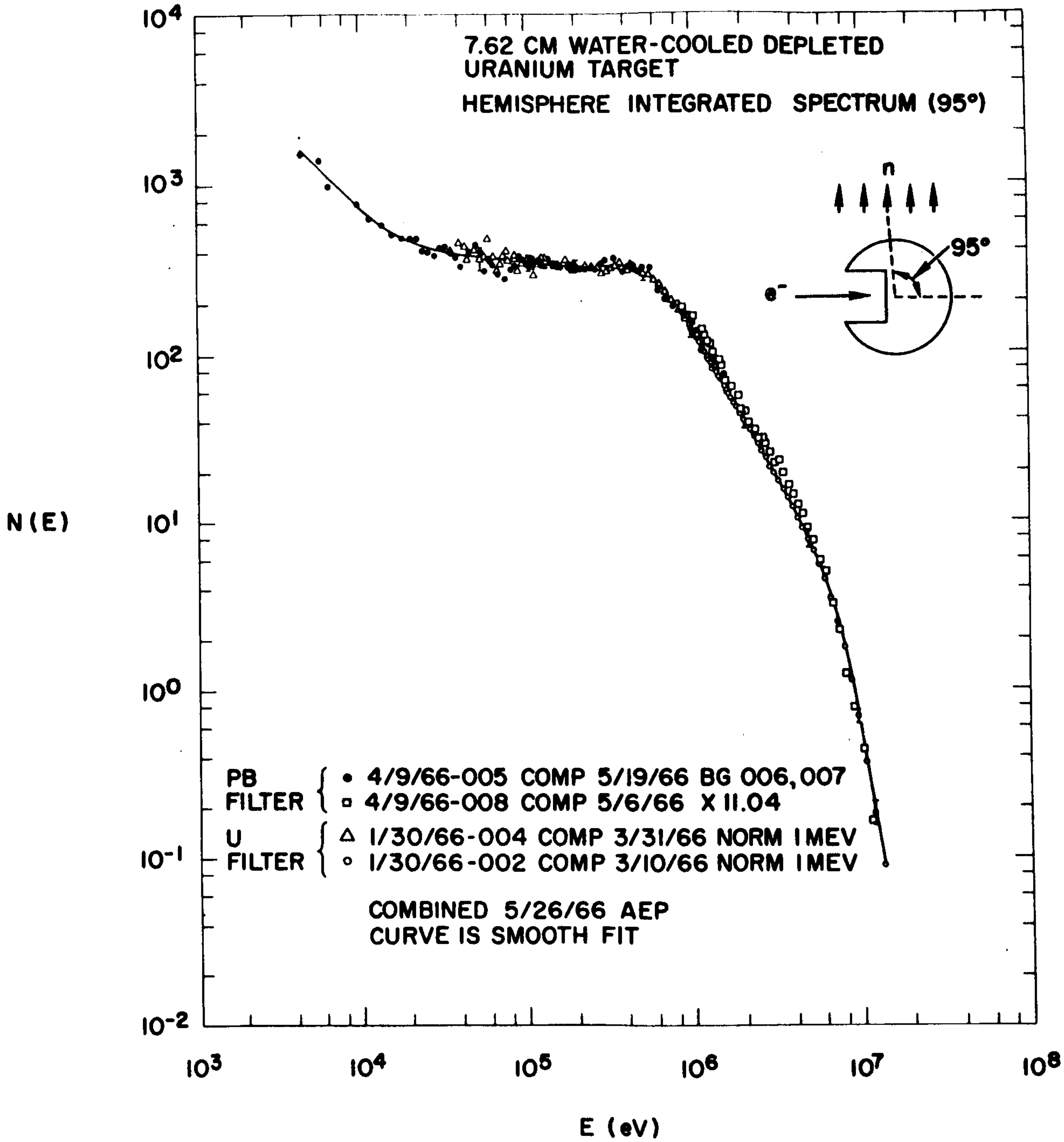


Fig. 3.9--Comparison of neutron spectra for the two water-cooled isotropic fast neutron sources

flux intensity changes. The monitor must be reliable, reasonably inexpensive, and fairly simple to set up or locate. Its results should be comparable on a day-to-day basis; therefore the setup, biasing, or locating procedures must be easily standardized and repeated. For the 1964 series of LH_2 experiments, two types of monitors were used, an aluminum activation monitor and a U-235 fission counter. These monitors were retained for the present LH_2 experiments since they had shown excellent performance characteristics during the earlier experiments.

The activation source monitors used with the present LH_2 experiments were 1100 series aluminum slugs 5/8-in. diameter by 1-3/4 in. long, positioned in a new epoxy-nylon housing as shown in Fig. 3.10 and oriented with respect to the uranium source as shown in Fig. 3.11. Aluminum has a 7 MeV threshold for the $Al^{27}(n,\alpha)Na^{24}$ reaction.

Because of the high activation threshold an aluminum activation monitor is relatively insensitive to albedo from the dewar material, liquid hydrogen surface, and environmental surroundings. The epoxy-nylon housing also provided some albedo shielding and guaranteed positive identical location of the aluminum slug for each run. The entire housing and monitor slug holder assembly were redesigned for the present series of LH_2 experiments for easier and more positive operation. The safety requirement of no entrances to the experimental area during the presence of LH_2 in the dewar forced the adoption of a remote positioning and seating device for the source monitor; the 1964 system was redesigned for more reliable operation since some difficulty had been experienced in getting

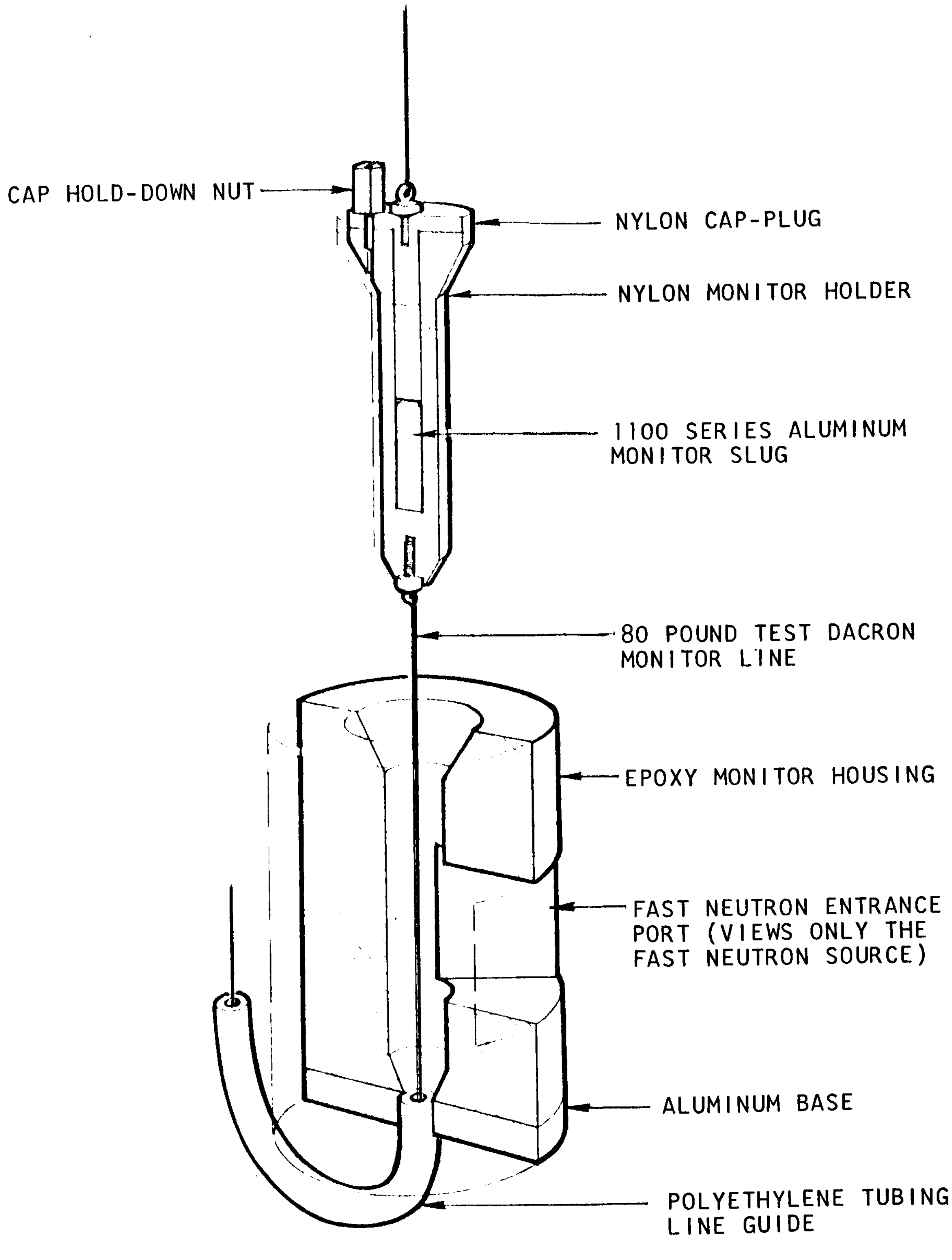


Fig. 3.10--Aluminum monitor system

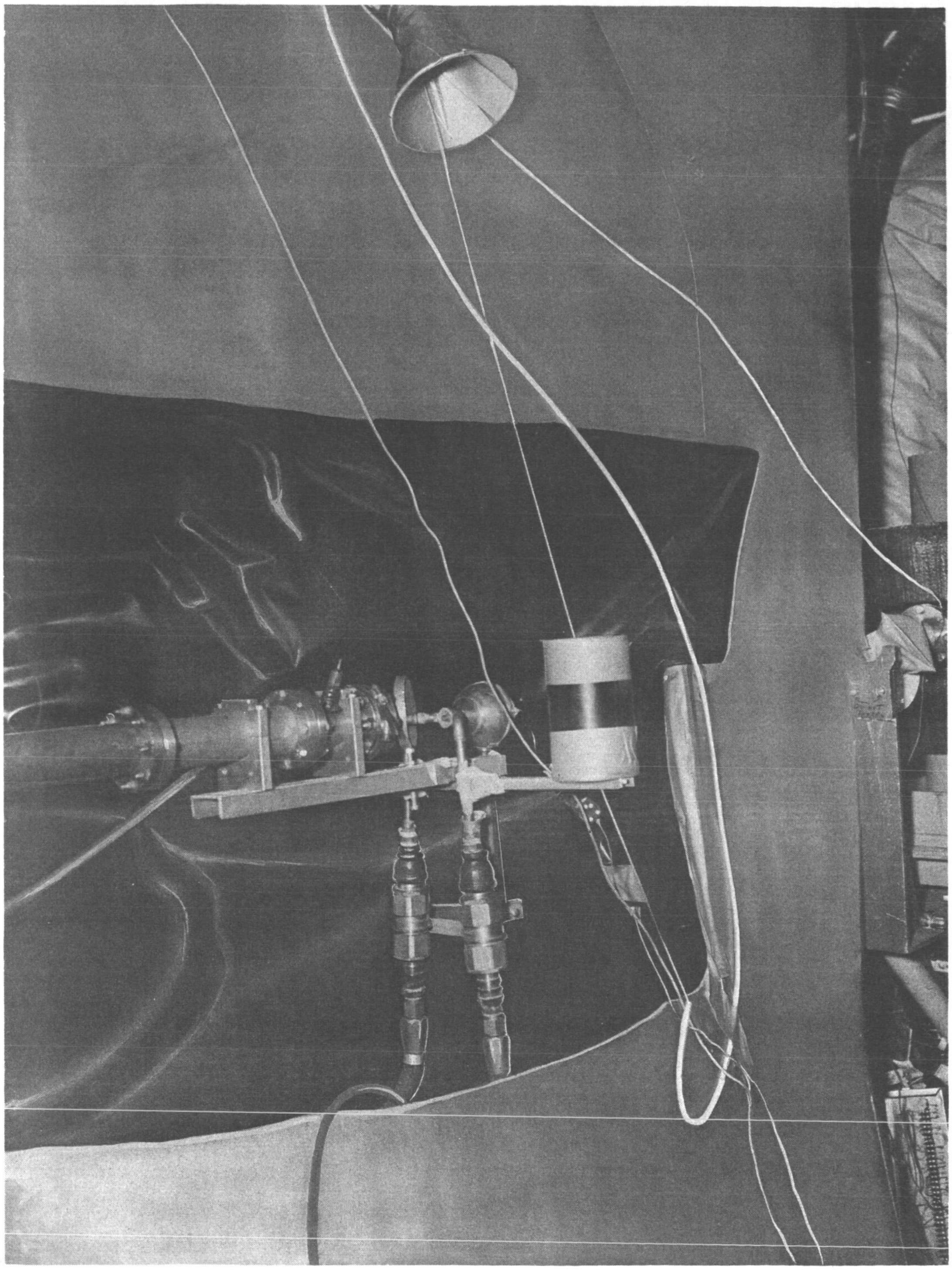


Fig. 3.11--Photograph of uranium source and epoxy monitoring housing

the source monitor slug holder through the small roof passage. Handling difficulties during the changing of the slug also dictated a redesign of the slug holder. A pipe was placed in the passage to allow the monitor holder a free run without interference from the liquid level cables, thermocouple wires, and other control cables running through the roof passage. The return run of the monitor slug holder cable was through a polyethylene tubing line guide which entered the bottom of the monitor holder. A different aluminum monitor slug was used for each run.

The Na^{24} activity from the Al(n, α) reaction was counted by using a well-type NaI (Tl) scintillator and conventional electronics. Great care was taken to maintain the same bias for each day. This was accomplished by taking pulse height distributions for the signal in coincidence with the discriminator output and adjusting the discriminator bias to 1 MeV. Each aluminum monitor was counted several times with at least 1% statistical accuracy to insure that the bias was adjusted for only the Na^{24} 15-hour half-life activity. Some discrepancy in the dieaway of the radiation from the activated aluminum monitors was observed when the slugs were counted soon after activation. This activity had a 2-1/2-hour half-life and was probably due to Mn^{56} which occurs in trace quantities in aluminum. Since the half-life of the extraneous activity was 2-1/2 hours, the aluminum monitors were reliably counted sixteen or more hours after irradiation.

The alternate monitor used on the LH_2 experiments consisted of a small U-235 fission chamber and associated amplification electronics. This monitor was used only as an instantaneous trouble-indicating monitor and as a backup for the activation monitor.

3.6 TIME-OF-FLIGHT TECHNIQUE

The angular neutron energy spectrum is measured by extracting a collimated beam from the experimental assembly and measuring the time-of-flight over a fixed distance. Time-zero is defined by pulsing the neutron source. Electrons from the linear accelerator impinge on the uranium source and generate bremsstrahlung, which in turn release a broad spectrum of fast neutrons through the (γ, n) and (γ, fission) reactions. Neutron emission is coincident with and proportional to the electron current pulse. The time delay between emission and detection is measured by a Technical Measurements Corporation (TMC) 1024-channel analyzer with a time-of-flight logic unit. The analyzer sweep is started by an electrical pulse from the Linac injector trigger, which has a fixed time relationship (within a few nanoseconds) with the electron current pulse. A detector pulse above a certain discrimination threshold (bias) stops the analyzer sweep, and stores a count in the proper time channel.

A variety of flight paths and detectors were used and these are discussed below.

3.7 FAST NEUTRON SPECTRUM MEASUREMENTS

Fast neutron spectrum measurements were performed at thicknesses of 13.0, 7.0, and 2.5 in. of LH_2 and the empty dewar for 0^o, and thicknesses of 10.5, 4.5, and 2.5 in. of LH_2 and the empty dewar for 37^o.

The purpose of these measurements was to recheck some of the fast neutron spectrum measurements performed under the previous program, establish whether experimental conditions were the same for the present measurements, and insure that all possible corrections to the previous data had been accomplished.

The fast neutron spectra were measured by extracting a collimated beam from the LH_2 cryostat and measuring the time of flight over 50 meters. The Model 201 time-of-flight logic unit was used with the TMC 1024-channel analyzer. A channel width of 0.03125 μsec was used in these experiments.

The windows of the flight path system were mylar, while on the previous program they were aluminum. This allowed transit alignment of the probe tube of the LH_2 cryostat and the fast neutron detectors without the necessity of breaking the vacuum in the flight path. Details of the 50-meter flight path collimation system are shown in Fig. 3.12. The large diameter steel drift tubes are evacuated to rough vacuum by mechanical forepumps. The collimation system is designed so that the edge of the precollimator nearest the experimental assembly and the 3.0 in. i.d. steel collimator at the 16-meter position define the viewed spot size at the assembly and the beam spot size at the detector. With a given dewar probe tube inner diameter of 1.125 in. at 28 in. from the precollimator, an 0.870 in. i.d. precollimator gave a viewed spot diameter on the probe tube inner window of about 0.954 in.; this allowed a misalignment tolerance of 0.171 in., which was well within our alignment capability. The maximum beam spot size at the 50-meter detector position produced by

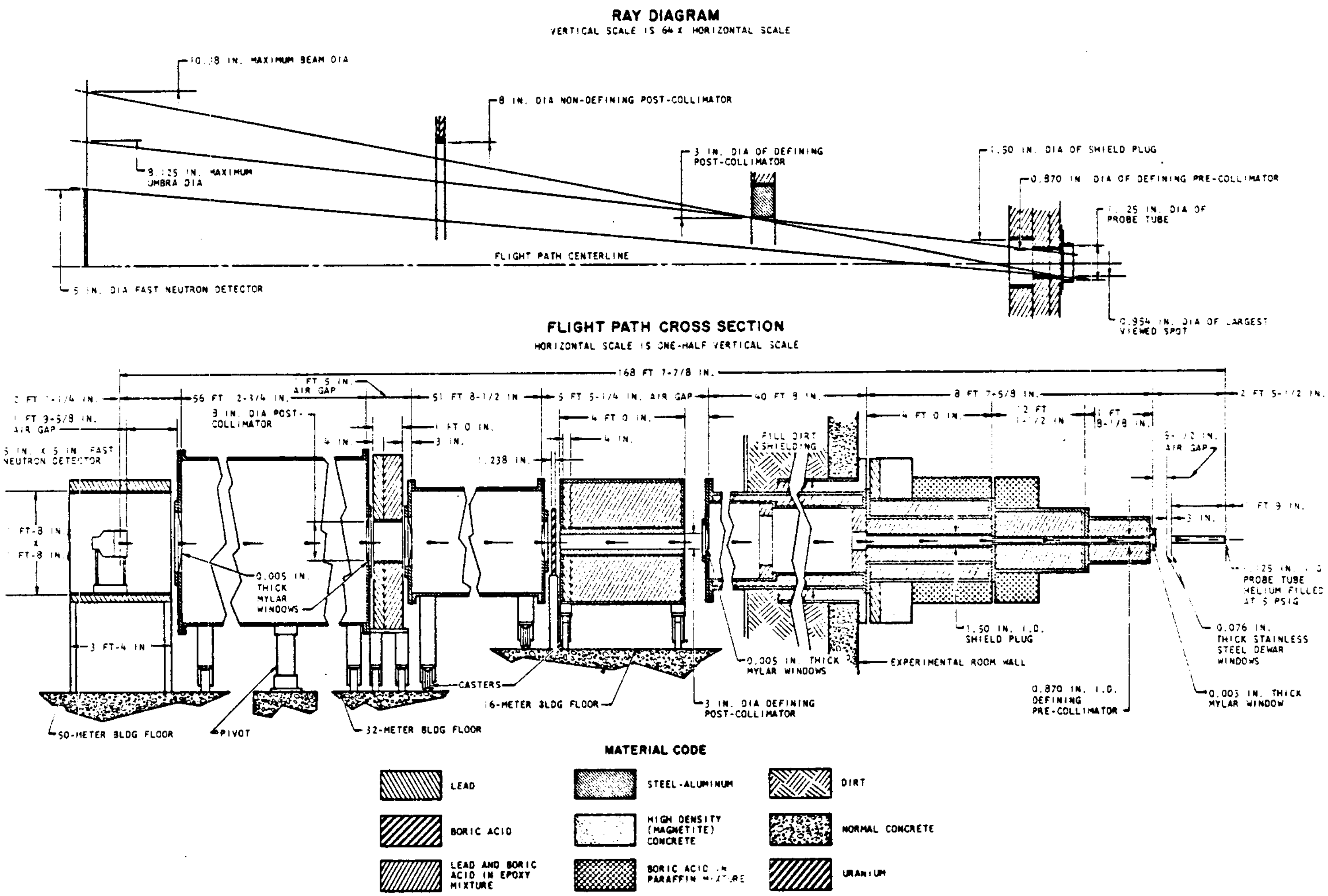


Fig. 3.12--Flight path configuration for fast neutron experiments

this collimation system was 10.38 in. One additional post-collimator was added at the 32-meter position to eliminate stray background-producing gamma rays and high energy neutrons from reaching the detector. A depleted uranium plate 30.5 by 30.5 by 3.144 cm thick at the 16-meter position suppresses any bremsstrahlung flash and delayed gamma rays from the fast neutron source or the LH_2 cryostat.

The ambient background composed primarily of the natural radioactivity of the liquid scintillator and environment and cosmic radiation was reduced by shielding the detectors in a dolly-mounted lead "housing" around the entire detector system, open at both ends to allow the highly collimated neutron beam to pass through without striking the walls of the "housing." The walls were 2-in. thick lead and the "housing" was 40 in. long.

Two detectors were used for the measurement of the fast neutron spectra with the main difference being the volume of the scintillating fluid. A 2-in. diameter by 2.5-in. long cylinder of NE 211 liquid scintillator, mounted with the neutrons incident perpendicular to the symmetry axis, was used for the 0° measurements. The high voltage was 2130 volts. This detector and time-of-flight electronics have been described in detail in Ref. 3. Its intrinsic efficiency is less than the larger volume scintillator which is described below but its response to the bremsstrahlung flash is also much less. The bremsstrahlung would ordinarily cause a large overload pulse leaving the detector inoperative for several microseconds.

However, the photomultiplier tube is on-gated a few-tenths of a microsecond after the flash. Even so the scintillation caused by the gamma flash can be very intense so that when the photomultiplier tube is on-gated there is still light emitted in the scintillator that can produce an afterglow which can interfere with the measurement of the fast neutron spectrum up to about 8 MeV. The smaller scintillator and hence smaller afterglow eliminates this interference.

The 5-in. diameter by 5-in. high liquid scintillation detector, mounted with the neutrons incident on the plane end and parallel to the symmetry axis was used for the 37^{o} measurements since at this angle the fast neutron source is not viewed directly through the LH_2 and because the higher intrinsic efficiency is needed. The detector and time-of-flight electronics are nearly the same as described in detail in Ref. 2. HV was typically 2400 volts. This detector is shown in Fig. 3.13.

The difference is in the time-of-flight electronics. Instead of using the Ortec units for remote biasing a potentiometer mounted on the photomultiplier chassis was adjusted manually to obtain the proper bias.

The intrinsic efficiencies for the 2-in. and 5-in. detectors are sensitive functions of the bias for neutron energies up to two or three times the bias energy.

The measurements and calculations of Verbinski, et al.,[4] provide accurate pulse height spectra and efficiencies vs bias, in terms of a standard light unit. Verbinski, et al., used Monte Carlo (O5R)

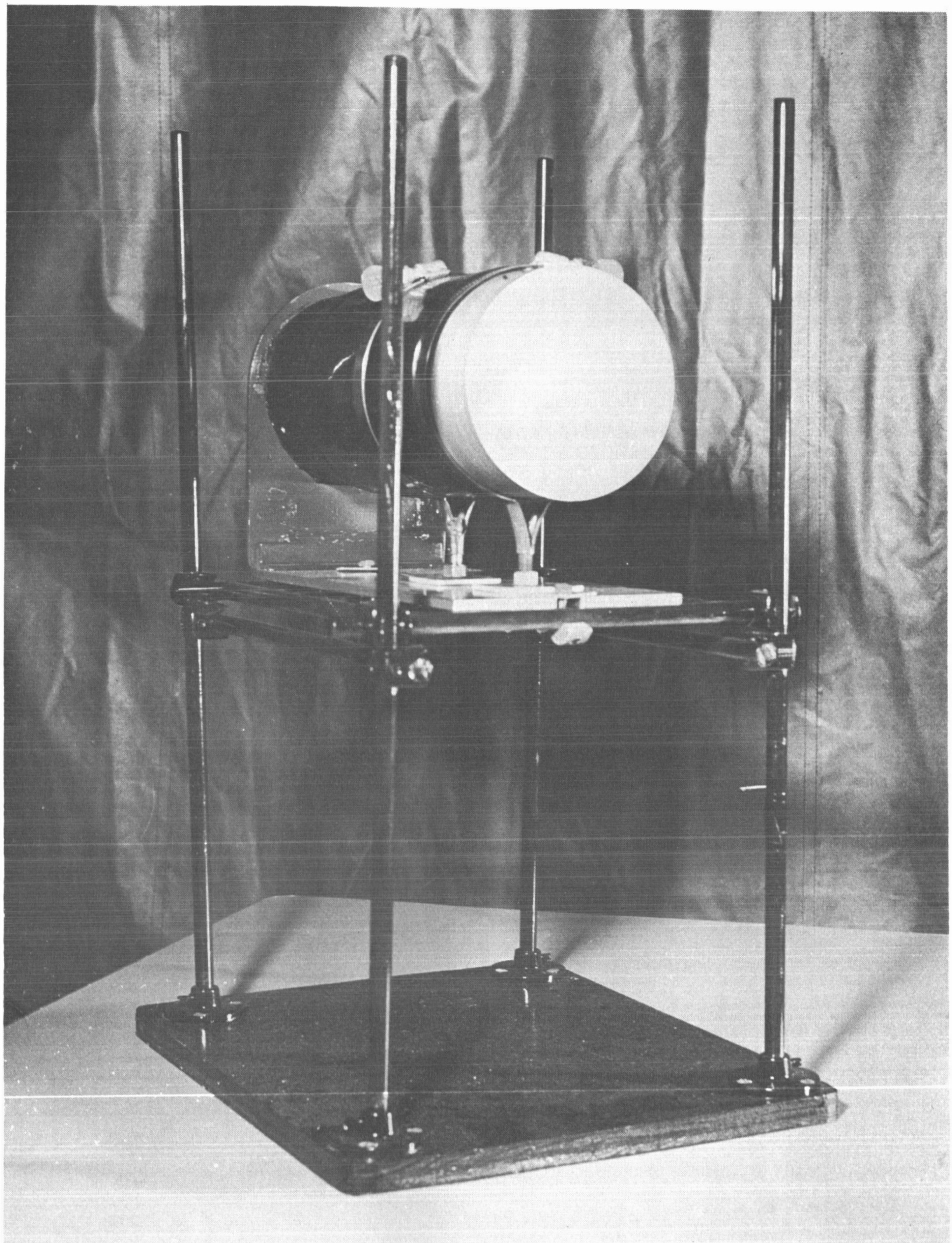


Fig. 3.13--NE-211 liquid scintillation detector
(5-in. diameter by 5-in. long)

calculations to obtain pulse height distributions, including efficiencies, for monoenergetic neutrons. These were smeared and adjusted to fit the measured responses in shape and maximum light pulse size. The integral under the pulse height distribution, for a neutron of energy E, normalized to one incident neutron, when integrated from the maximum pulse height, L_{max} down to a pulse height L_b, the bias setting, yields the efficiency of the detector for neutron energy, E, and bias setting L_b. To avoid confusion relating to light units Verbinski normalized the pulse heights to the pulse-height distribution from a Co^{60} source and defined a "cobalt" unit which was used as the standard of reference for the scintillator light scale. The "cobalt" unit was defined as the pulse height at one-half of the maximum intensity on the falling portion of the spectrum from the 1.17 and 1.33 MeV gamma rays of Co^{60}. This also corresponds to the Compton edge and is equivalent to 1038 keV. To use Verbinski's tabulated values, it is necessary to determine the bias cobalt unit. Efficiencies between tabulated results are determined from plots of the efficiency versus the bias in "cobalt" units and values are extrapolated from the smoothly varying curves.

The bias is determined in "cobalt" units and adjusted until the proper value is obtained, usually .046. The bias procedure is to take a pulse height spectrum of Co^{60} in coincidence with the fast discriminator. The bias channel for the pulse height is taken as the half-height on the rising edge of the distribution. The channel for E_c for Co^{60} is determined as described above, from the same pulse height. The fractional cobalt unit is then $\frac{N_B}{N_C}$ = bias "cobalt" unit, where N_B = bias channel and N_C = E_C for Co^{60}. Prior to taking the pulse height distribution the linearity of the system is established and zero channel of the analyzer determined. The above procedure is used to determine the bias "cobalt" unit for the 2 by 2.5 in. liquid scintillator. A better procedure would be to bias at a known energy as it is done for the 5 in. by 5 in. liquid scintillator. The total absorption peak for Am^{241} (60 keV) is used but is not used for the 2 by 2.5 in. liquid scintillator since this peak cannot be resolved. Horrock's[5,6] and Flynn[7] have shown that relative pulse height (RPH) as a function of energy can be fit by two piecewise linear segments,

$$\mathrm{RPH} = \frac{(E-2)\ \mathrm{keV}}{0.437} \qquad (E < 80\ \mathrm{keV})$$

and

$$\mathrm{RPH} = \frac{(E-18)\ \mathrm{keV}}{0.34} \qquad (E > 80\ \mathrm{keV})$$

From these relations the RPH for Am^{241} is 134 and for the E_C of Co^{60} it is 3000. The ratio of their RPH is 0.0446, and is the value of the "cobalt" unit when the bias is adjusted to split the Am^{241} peak.

The absolute neutron detection efficiency of the 5-in. liquid scintillator biased at the Am^{241} peak was calibrated by E. A. Profio and J. C. Young using monoenergetic neutrons from the Texas Nuclear Corporation 3.5 MeV Van de Graaff accelerator.[8] In Fig. 3.14 results of this calibration are compared with the results of Verbinski for a bias

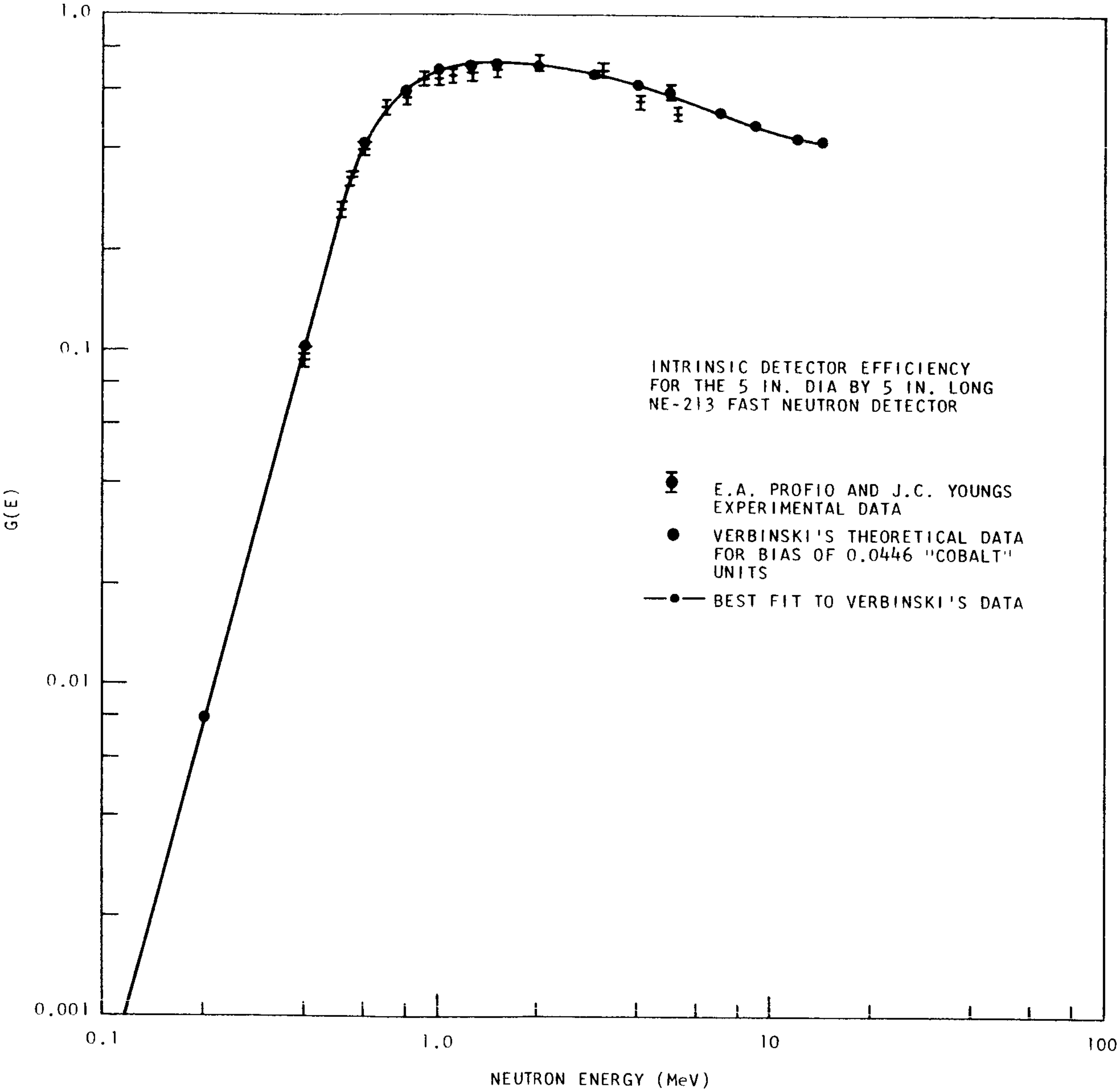


Fig. 3.14--Comparison of experimental data biased at peak of Am^{241} Verbinski's data for a bias of 0.0446 cobalt units.

of .0446 cobalt units. The agreement is excellent especially in the neutron region near the bias; .0446 cobalt units were used to reduce the data measured with this detector. A value of 0.05 was used for the 2-in. liquid scintillator.

3.8 INTERMEDIATE NEUTRON SPECTRUM MEASUREMENTS

A total of twenty-nine angular neutron spectra were measured in the intermediate neutron region for angles of 5, 15, 37, 53, and 78°.

The intermediate neutron spectra were measured by extracting a collimated beam from the LH_2 cryostat and measuring the time of flight over 16 meters. The Model 201 time-of-flight logic unit was used with the TMC 1024-channel analyzer. A channel width of 0.125 μsec was used in these experiments.

The flight path is shown in Fig. 3.15. The intermediate neutron precollimator (carbon steel 0.630 in. I.D. and 20 in. long) was fitted into the 0.870 I.D. precollimator of the fast neutron flight path system. As shown in the ray diagram in Fig. 3.15 this collimation system gave a maximum viewed spot of 1.00 in. The maximum beam spot size at the 16-meter detector position produced by this collimation was 1 ft and smaller than the 20 in. opening in the lead housing (2-in. thick, 40 in. long) used to reduce the ambient background. A 0.175-in. thick boron filter located just prior to the precollimator was used to eliminate thermal neutrons. The intermediate neutron detector is sensitive to thermal

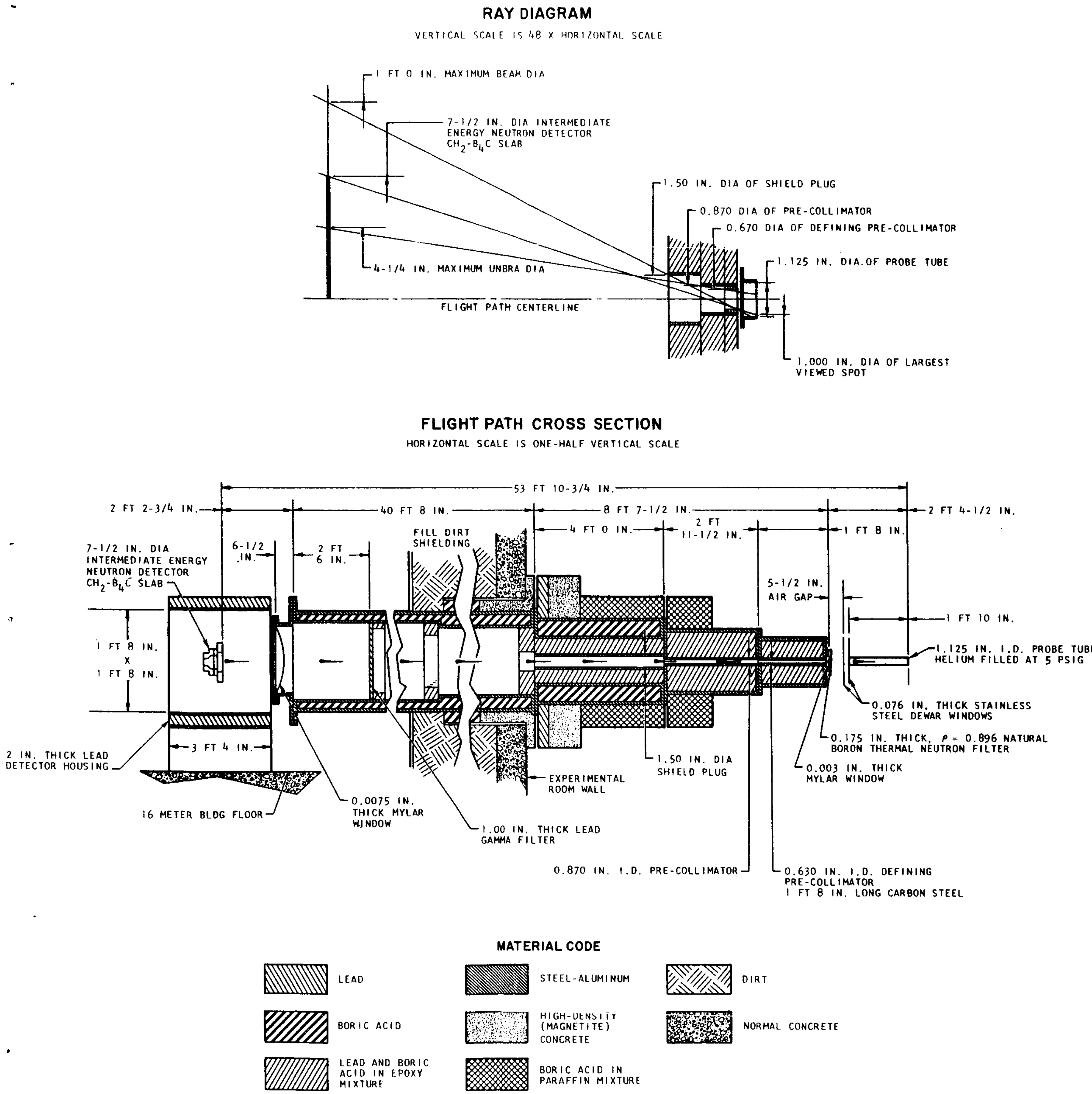


Fig. 3.15--Flight path configuration for intermediate neutron experiments

neutron captures in the boron carbide-paraffin wax disk and with a pulse repetition rate of 360 pps used in this experiment, pulse overlap would occur making a thermal neutron appear in the analyzer to be a fast neutron. A one in. thickness of lead placed 30.5 in. from the detector was used to suppress the gamma flash and to minimize the effect of capture gammas. The flight path windows were 0.003 and 0.0075 in. mylar. Both mylar and lead were chosen for use in the flight path since they contain a minimum of resonances in the intermediate neutron region.

The intermediate neutron detector shown in Fig. 3.16 consisted of a boron carbide-paraffin wax disk to moderate and capture the neutrons, backed by an NE 226 (hexofluorobenzene) scintillation counter to detect the 480 keV boron capture gamma rays. The time-of-flight electronics is the same as for the 5-in. diameter by 5-in. long fast neutron detector described in Section 3.7. The detector is mounted horizontally with the neutrons incident on the plane end of the boron carbide-paraffin wax disk. The disk is 7.5 in. in diameter and 4 in. thick, and is composed of 74.5 wt % normal boron carbide and 25.5% paraffin wax, melted, mixed, cooled, and machined to size.

The bias was determined as a fraction of the Compton energy for Co^{60} and Cs^{137} and was 150 keV. The bias procedure is similar to that for the fast neutron detectors.

The absolute detection efficiency for the capture gamma rays was determined by using a similar boron carbide-paraffin disk and

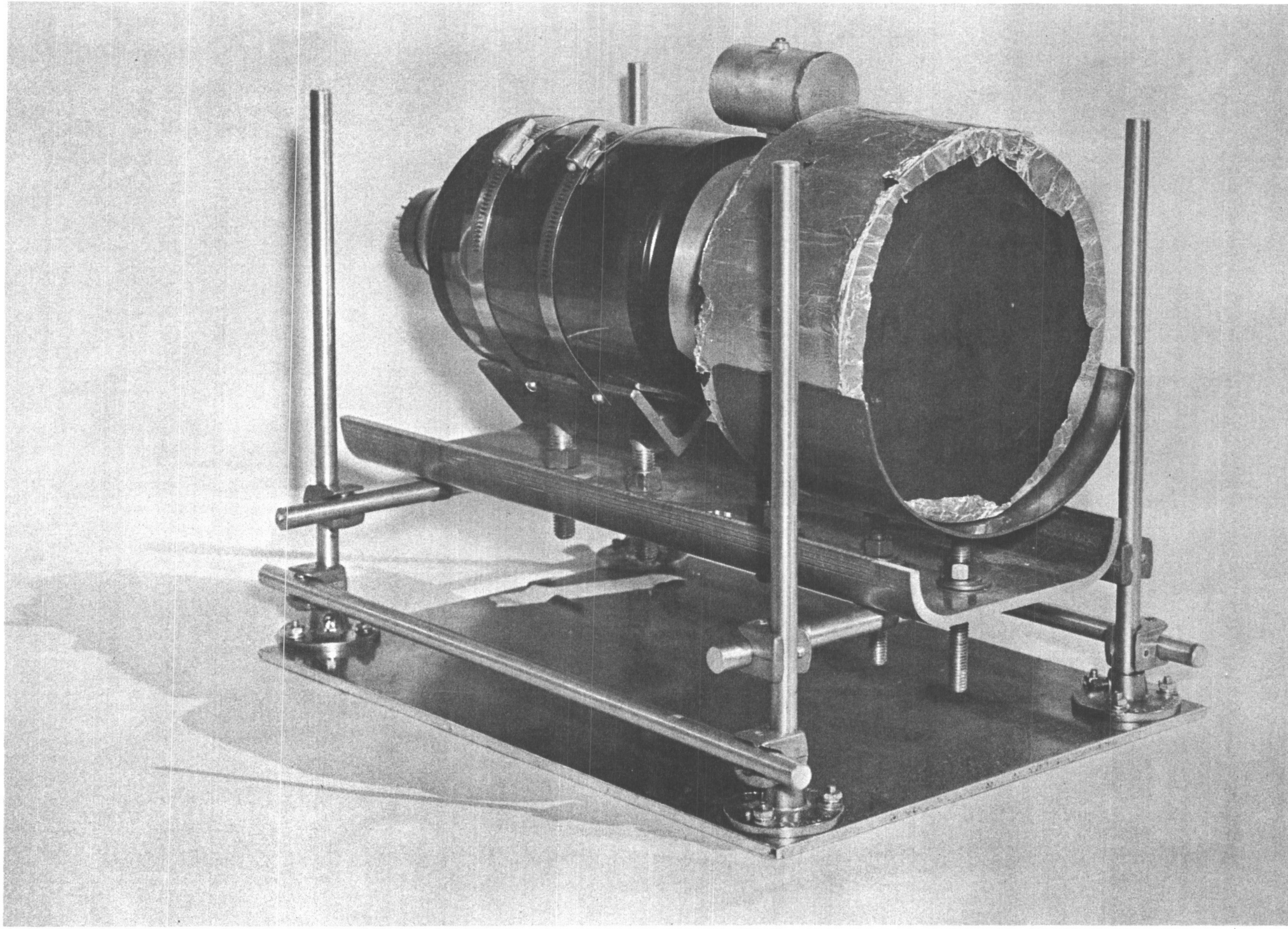


Fig. 3.16--Intermediate neutron detector showing boron-carbide paraffin wax disk, 5-in. diameter by 5-in. long NE-226 scintillator photomultiplier tube, and support.

drilling four 3/8-in. diameter holes, at different radii, through the disk and parallel to the axis. The holes were plugged with aluminum tubing filled with the B_4C-CH_2 mixture. The hole containing the Be^7 source was filled with short plugs so that the center of the source could be moved from one side to the other in steps of approximately 3/8 in. The Be^7 source was 3/8 in. in diameter and 3/8-in. long and was chosen since it emits a 480 keV gamma ray and is therefore the same energy as the boron capture gamma ray. The detector was biased at 150 keV for these measurements.

The probability of producing a capture gamma as a function of position in the disk was calculated by the O5R Monte Carlo code. These capture gamma probabilities were then multiplied by the absolute detection efficiency for the capture gamma rays, and integrated over the volume of the disk, to obtain the absolute intrinsic neutron detection efficiency versus energy.

Since these intermediate spectrum measurements were made over a period of several days the bias was checked daily and remained at 150 ± 5 keV. A change in the bias of 5 keV would not affect the relative efficiency but would change the absolute efficiency by about 7%.

Since the scintillating fluid contains no hydrogen, the neutron detector is relatively insensitive to transmitted neutrons but quite sensitive to transmitted gamma rays through the B_4C-CH_2 disk. Preliminary measurements had indicated that the interference of the gamma flash from the uranium source made it undesirable to perform measurements at exactly 0^{o} angle. However, at slightly off axis to the collimator (5^{o}) this inference was not present. Therefore, angular spectrum measurements were made at an angle of 5^{o} instead of 0^{o}.

3.9 THERMAL NEUTRON SPECTRUM MEASUREMENTS

Thermal neutron spectra were measured at angles of 37 and 78^{o} for thicknesses of 2.5, 4.5, 7.0, 10.5, and 13.0 in. of LH_2.

The thermal neutron angular spectra were measured by extracting a collimated beam from the LH_2 cryostat and measuring the time of flight over 16 meters. Time-zero was defined by turning on the analyzer sweep of the TMC 1024-channel analyzer with a Model 212 time-of-flight logic unit with an electrical pulse from the Linac injector trigger, which has a fixed relationship with the electron current pulse. A channel width of 40 μsec was used in these experiments.

The collimator viewed a spot at the inner end of the 21 in. long probe tube through two thin stainless steel windows. The probe tube was filled with 5 psig of helium and was located at the center of the hemispherical section of the cryostat. The flight path is shown in Fig. 3.17. The thermal neutron precollimator made of boron nitride 0.425 in. in diameter and 8.0 in. long was fitted into the 0.870 in. i.d. precollimator of the fast neutron flight path system. A post-collimator was placed immediately adjacent to the detector bank; this collimation system gave a viewed spot size on the inner probe tube window of 0.965 in. This

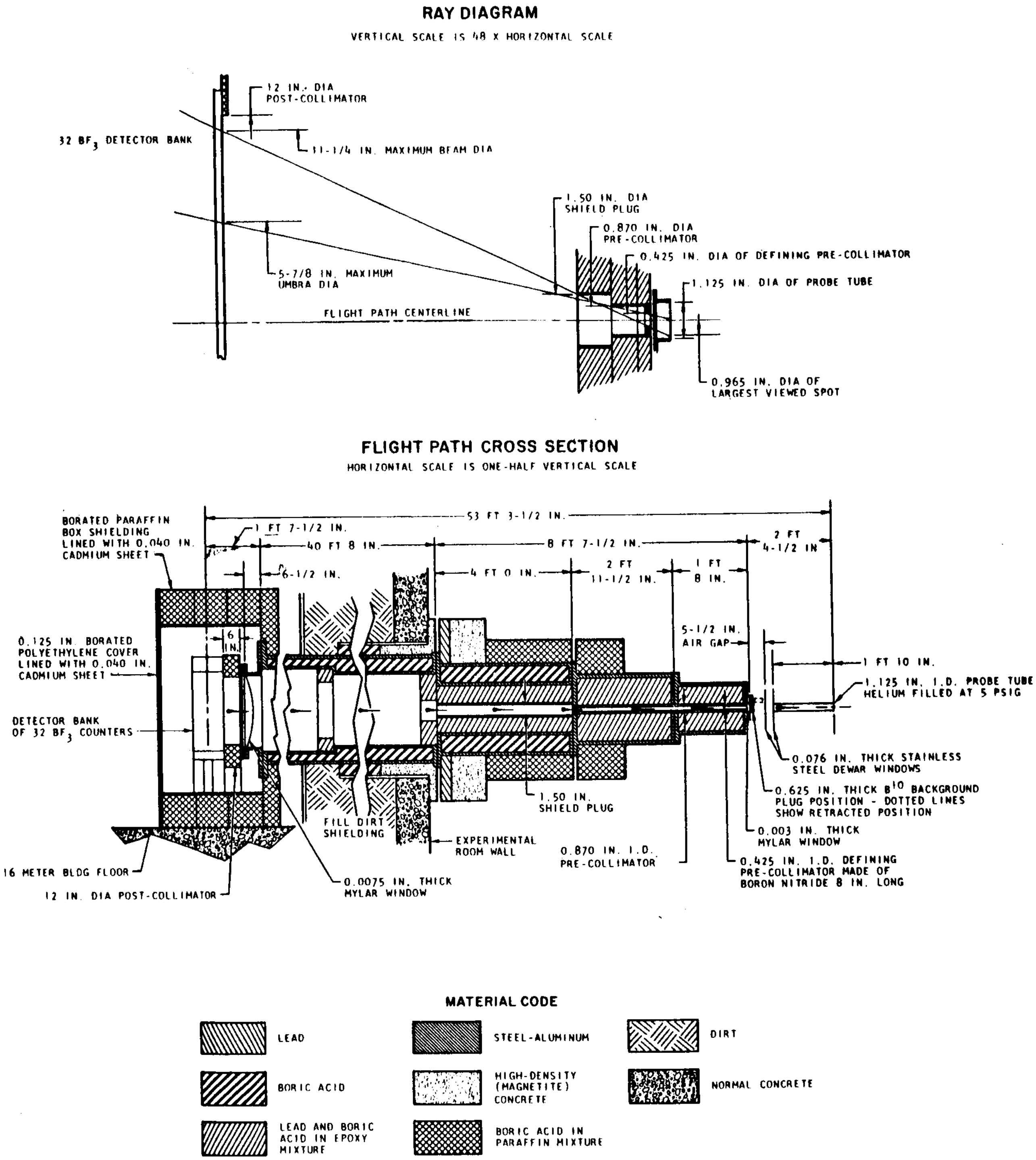


Fig. 3.17--Flight path configuration for thermal neutron experiments

allowed a misalignment tolerance of 0.160 in. which was well within our alignment capability. The probe tube was aligned with the flight path system as explained in Section 3.3. The pressure in the 16-meter flight path was 145 microns.

The thermal neutron detector was an array of 32 BF_3 counters with neutrons incident perpendicular to their axis of symmetry and stacked in a 6, 7, 6, 7, 6 order. The BF_3 detector bank was housed in a small low-background building made from 12 by 12 by 6 in. wooden boxes filled with hydrous boric acid. The inner walls of this housing were lined with 25 wt % borated polyethylene to absorb scattered thermal neutrons.

The LH_2 cryostat was covered with 0.030 in. of cadmium to prevent the influence of thermal neutron room return.

Electrons from the Linear Accelerator impinge on the cylindrical surface of the water-cooled uranium source and generate bremsstrahlung, which in turn produce a spectrum of fast neutrons via the (γ, n) and $(\gamma,$ fission) reactions. The LH_2 cryostat is fixed for a particular angle and filled to the largest thickness with LH_2. The angular neutron spectrum measurements proceed from the largest thickness.

A means of eliminating the thermal neutron signal from the experimental dewar was needed to provide a method of determining the amount of "background" counts observed in the BF_3 detector bank for each signal run. These "background" counts may be due to cosmic events and neutron transmission through the flight path shielding and collimators, and must be subtracted from the signal run to yield the true neutron spectrum originating in the LH_2 dewar. The boron isotope B^{10} was used because of its high thermal neutron cross section; since the B^{10} was in powder form an aluminum container shown in Fig. 3.18 was built to provide a B^{10} cylinder 0.625-in. thick and 1.375 in. in diameter. The 0.625 in. thickness is sufficient to eliminate all neutrons below 300 eV.

Since our safety procedures precluded entry into the experimental area during the LH_2 experiment while hydrogen was in the dewar, a remote control mechanism, also shown in Fig. 3.18, was constructed to introduce and remove the background plug into the flight path. The position of the plug during the experiments was verified with one of the television monitors mounted at the liquid hydrogen console. For each thickness signal and background measurements were made and the fast neutron source intensity monitored for each.

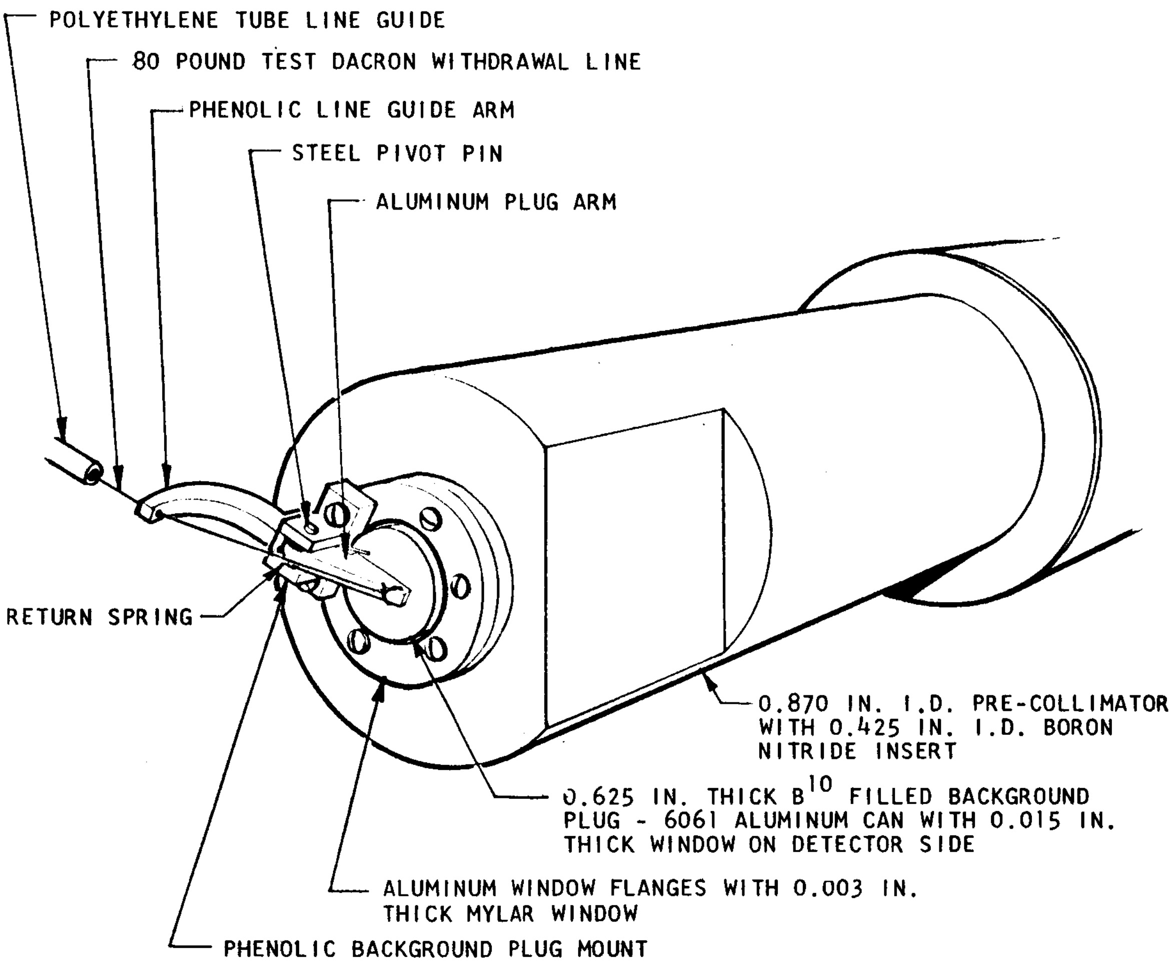


Fig. 3.18--B^{10} background plug

IV. THEORETICAL CALCULATIONS OF NEUTRON SPECTRA IN LIQUID HYDROGEN

4.1 THEORETICAL CALCULATIONS IN THE FAST NEUTRON REGION

Theoretical calculations were made in the fast neutron region which extends from 15 to 0.5 MeV. These calculations were made with a modified form of GAPLSN[9] which is called GGSN; it requires less computer time to run since only downscattering is considered.

The liquid hydrogen cryostat is a two-dimensional geometry. It essentially represents a cylindrical container of LH_2 with an isotropic fission source at one end. The experimental geometry is shown in Figs. 2.3 and 3.1. GGSN is a one-dimensional S_n transport theory code. Within the framework of GGSN, the geometry of the LH_2 cryostat can be represented either as a sphere or slab. Both approaches have been used and the results of these calculations are discussed below.

4.1.1 Spherical Geometry

A volume source was used for the spherical geometry calculations. The uranium in the fast neutron source was not included in the calculations. Instead, the source was approximated by an isotropic emitter with intensity uniformly distributed over the target sphere of radius 3.81 cm. The input source was the measured hemisphere - integrated source spectrum of run 1, 6-28-65, which was measured under another program. The energy-group structure and Q, the group source intensities, are listed in Table 4.1. Since the spectrum was not measured below 0.5 MeV the source was arbitrarily set to zero; group 10 is simply a catch-all for degraded neutrons. The energy groups were chosen to adequately represent the flux spectrum and to allow correct calculation of neutron transport at deep penetrations in liquid hydrogen.

Experience with similar calculations has shown that the off-zero degree flux is relatively insensitive to the angular distribution of the source neutrons whereas the flux at 0^o does depend on the details of the source description.

Group cross sections for hydrogen and stainless steel were obtained from the GAM-II code.[10] Only P_0 cross sections were available or needed for the small amount of stainless steel involved, but P_3 cross sections were calculated for hydrogen. Experience with neutron transport calculations in CH_2[3] have shown that a P_1 approximation of the hydrogen elastic scattering distribution is inadequate. The spectrum for group averaging was obtained from a B_3 calculation ($B = 10^{-10}$ cm^{-1}) in GAM-II, with a U^{235} fission source spectrum assumed as this is sufficiently accurate for the purpose. The hydrogen macroscopic cross section ($n_H = 0.04264 \times 10^{24}$ cm^{-3}) was obtained as well as the stainless steel microscopic cross sections averaged over the flux in pure hydrogen. In the transport calculation, an atom density of 0.0843×10^{24} cm^{-3} was used for the stainless steel.

TABLE 4.1

GROUP SOURCE INTENSITY

Group	E (MeV)	Q (n/cm^{3}sec)
1	14.92-10.00	1.5446
2	10.00- 7.41	6.6871
3	7.41- 5.49	17.3894
4	5.49- 4.07	28,0207
5	4.07- 3.01	38.3966
6	3.01- 2.02	65.0463
7	2.02- 1.00	148.6630
8	1.00- 0.743	66.8939
9	0.743-0.550	58.8153
10	0.550-0.41 eV	0.0000

A preliminary calculation in spherical geometry was carried out with an S_8 angular mesh and 124 spatial intervals with a liquid hydrogen thickness of 13 inches. It was felt, however, that an S_{16} angular mesh should be used to correspond more exactly with the angles in the experiment, and to represent the forward-peak nature of the angular flux more exactly. Since the fineness of the spatial mesh has to be consistent with the angular mesh and the mean free path, and since many intervals also have to be included between the source and the liquid hydrogen, the storage capacity of the computer was severely taxed.

The S_{16} calculation of 11-5-65 was performed for the geometry shown in Fig. 4.1. This approximates the geometry for the measurement of the spectrum at a liquid hydrogen thickness of 4.5-in., but there is no material past the 4.5-in. depth. The source region and region between the source and first stainless steel baffle was taken as gaseous hydrogen (density 1.57% of the liquid hydrogen density). The calculated angular flux spectra are plotted in Fig. 4.2.

A similar calculation was made for a liquid hydrogen thickness of 7 inches. The geometry is shown in Fig. 4.3 and the calculated spectra in Fig. 4.4.

Previous experience had indicated that the angular flux from 0^o-60^o would be quite insensitive to whether or not additional material was present beyond the 70.485-cm radius, which corresponds to the position of the probe tube or the sampling point of the neutron spectrum in the experiment. To check this, the calculation was repeated on

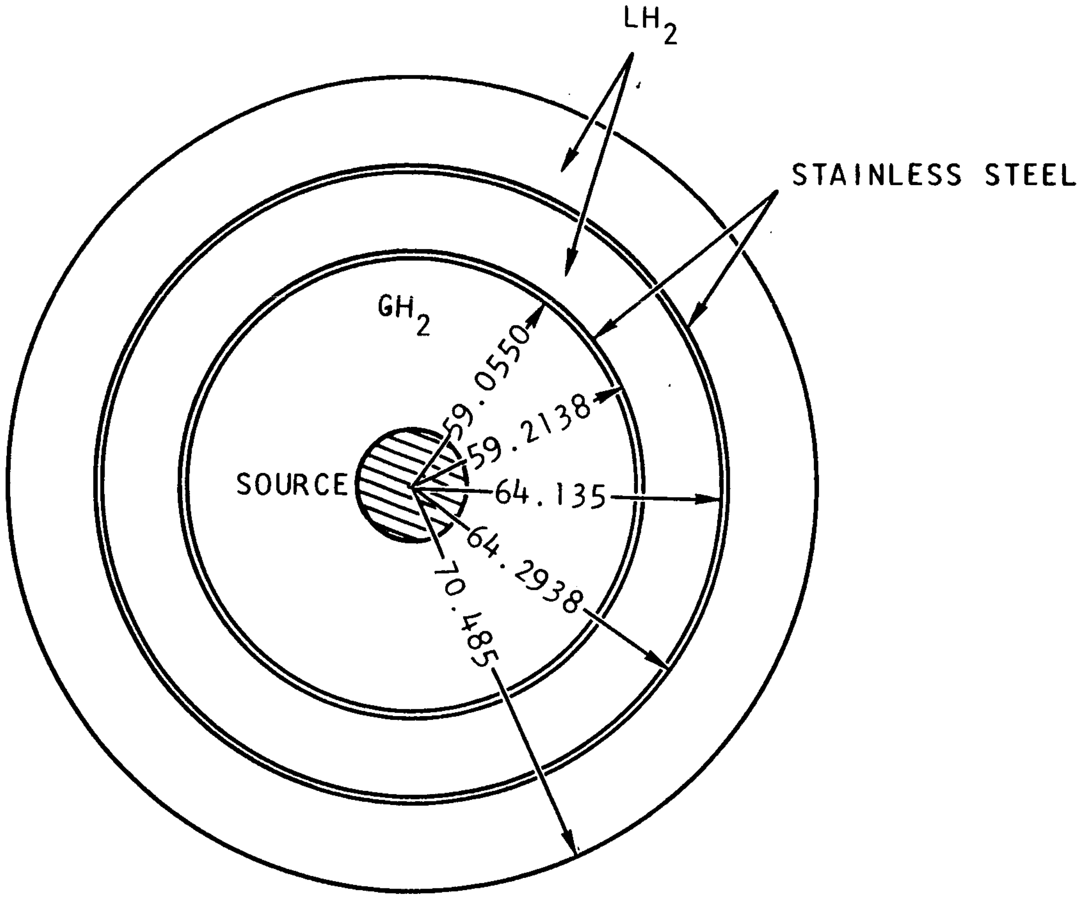


Fig. 4.1--Geometry for 4.5-in. GGSN 11-5-65

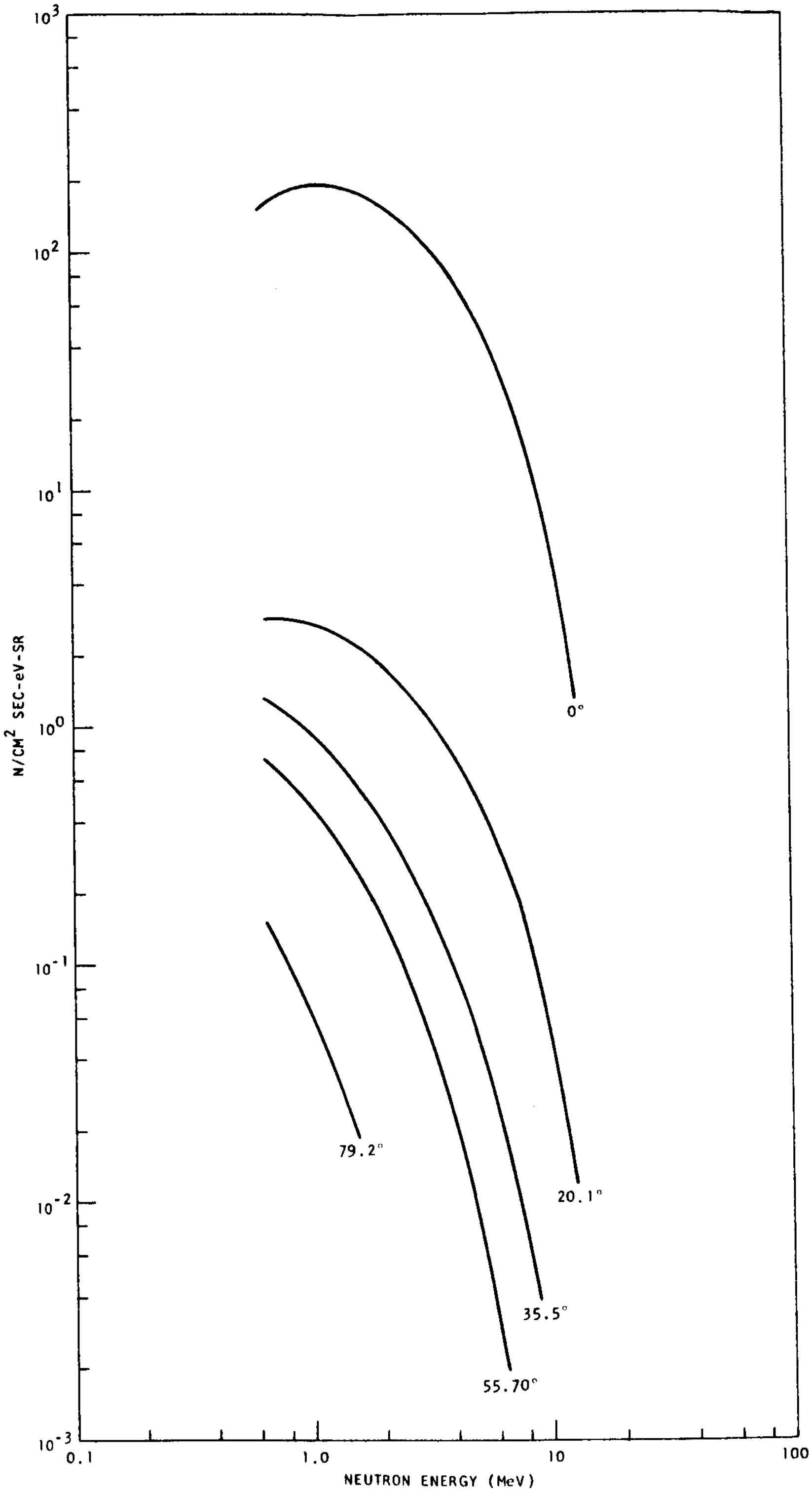


Fig. 4.2--LH_2 spherical GGSN, 4.5-in. 11-5-65, P_3S_{16}

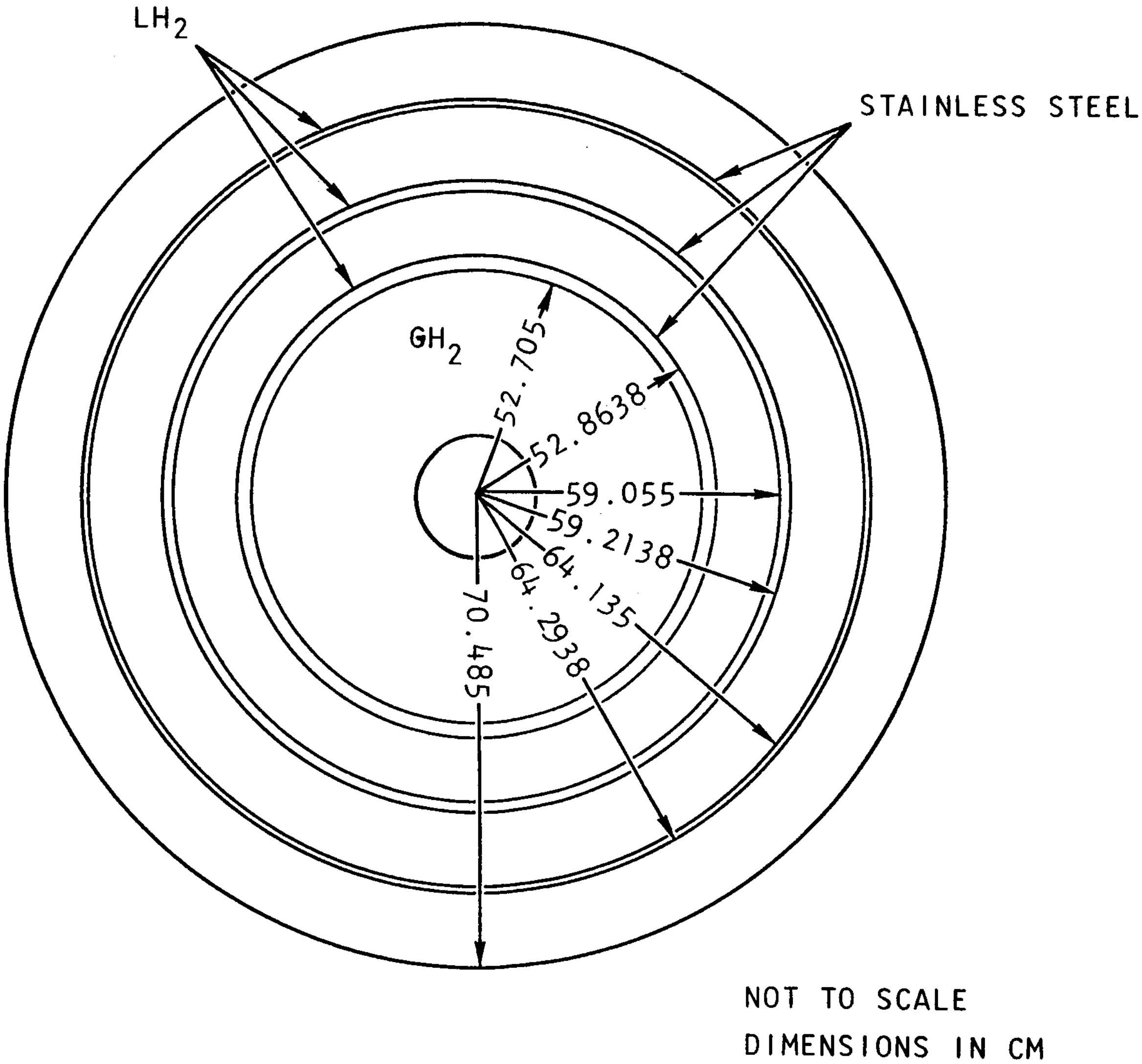


Fig. 4.3--Geometry for 7-in. GGSN 11-5-65

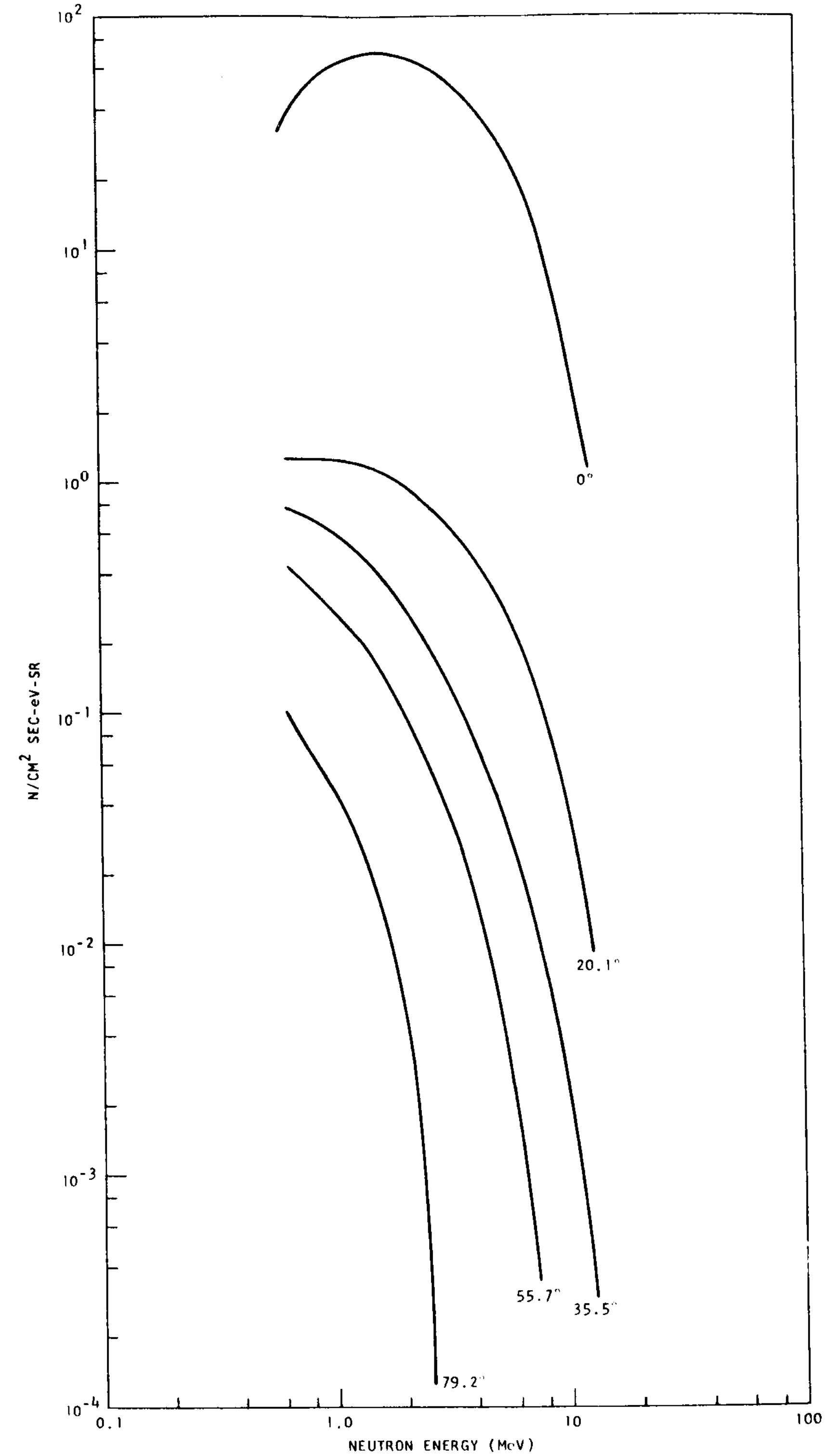


Fig. 4.4--LH_2 spherical GGSN, 7-in., 11-5-65, P_3S_{16}

11-9-65 with the geometry corresponding to the 4.5-in. thickness (Fig. 4.1) except that additional liquid hydrogen was included, to an outside radius of 88.265 cm. Also, since we suspected the stainless steel baffles had little influence on the spectrum, they were omitted. In Fig. 4.5 the 4.5-in. calculation of 11-9-65 is compared with the 4.5-in. calculation with baffles but no hydrogen back-scattering also plotted in Fig. 4.2. Differences are small and are probably due to the different amount of hydrogen behind the measurement point. Agreement between the 11-5-65 and 11-9-65 calculations (not shown here) is also very good at a penetration depth of 7 inches.

4.1.2 Slab Geometry

In one-dimensional slab geometry, the lateral extent is assumed infinite, a very good approximation of the experimental situation. An advantage of the slab is that a surface source can be specified, avoiding the need for space points in the region between source and shield (in the spherical GGSN a surface source can be specified only on the outer radius). However, the true angular distribution of the neutrons incident in the experiment cannot be reproduced exactly in the one-dimensional calculation (no radial dependence of angle or intensity). We do have a special version of GGSN for slab calculations which allows us to specify the angular mesh in the input, rather than being limited to equal intervals as in the spherical geometry. Furthermore, the angular distribution of the surface

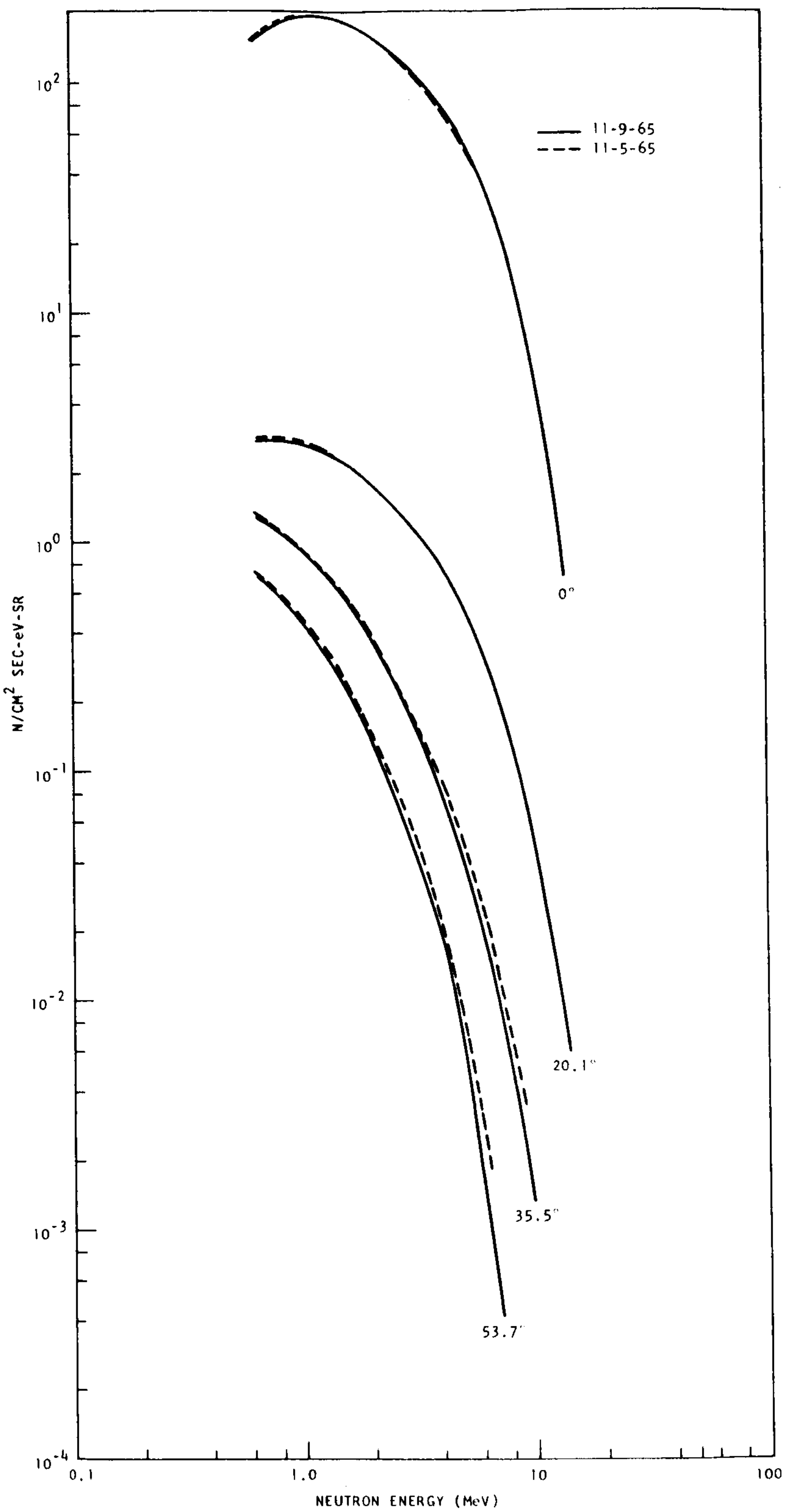


Fig. 4.5--LH_2 spherical GGSN, 4.5-in., 11-9-65, P_3S_{16}

source can be limited to the first interval near zero, thus allowing us to specify normal incidence, plus or minus a range of angles about normal incidence corresponding to the width of the first angular interval. The same source spectrum shape was used as in the spherical calculations.

The angular mesh boundaries (in $\mu = \cos\theta$) for the GGSN slab calculation of 11-13-65, and the group surface source intensity, Q_s, are given in Table 4.2. The source is assumed to be on the right hand side of the slab, so the angles of interest are for negative μ. The stainless steel baffles were omitted. The angular flux spectra calculated at nominal 4.5-in. penetration (less two baffles of 0.625 in. each or 4.375-in. of liquid hydrogen) are plotted in Fig. 4.6. The curves are seen to lie much closer together than in the spherical case. The source angular interval is $\mu = 1.000$ to 0.9999, or $0^\circ \pm 51'$. The spectra at the nominal 7-in. penetration (less three baffles of .0625 in. each or a liquid hydrogen thickness of 6.8125 in.) are given in Fig. 4.7. The total slab thickness was 33.0 cm.

The angular intervals specified in Table 4.2 are considerably larger than the angular resolution of the experiment at other than zero-degrees. The flux calculated by the S_n method is the average over the angular interval. To see if this had any effect on the results, the calculation was repeated on 12-13-65 with the angular interval boundaries of Table 4.3, which include intervals at the experimental resolution (the first angular interval is smaller than for the 11-13-65 calculation but this was inadvertent).

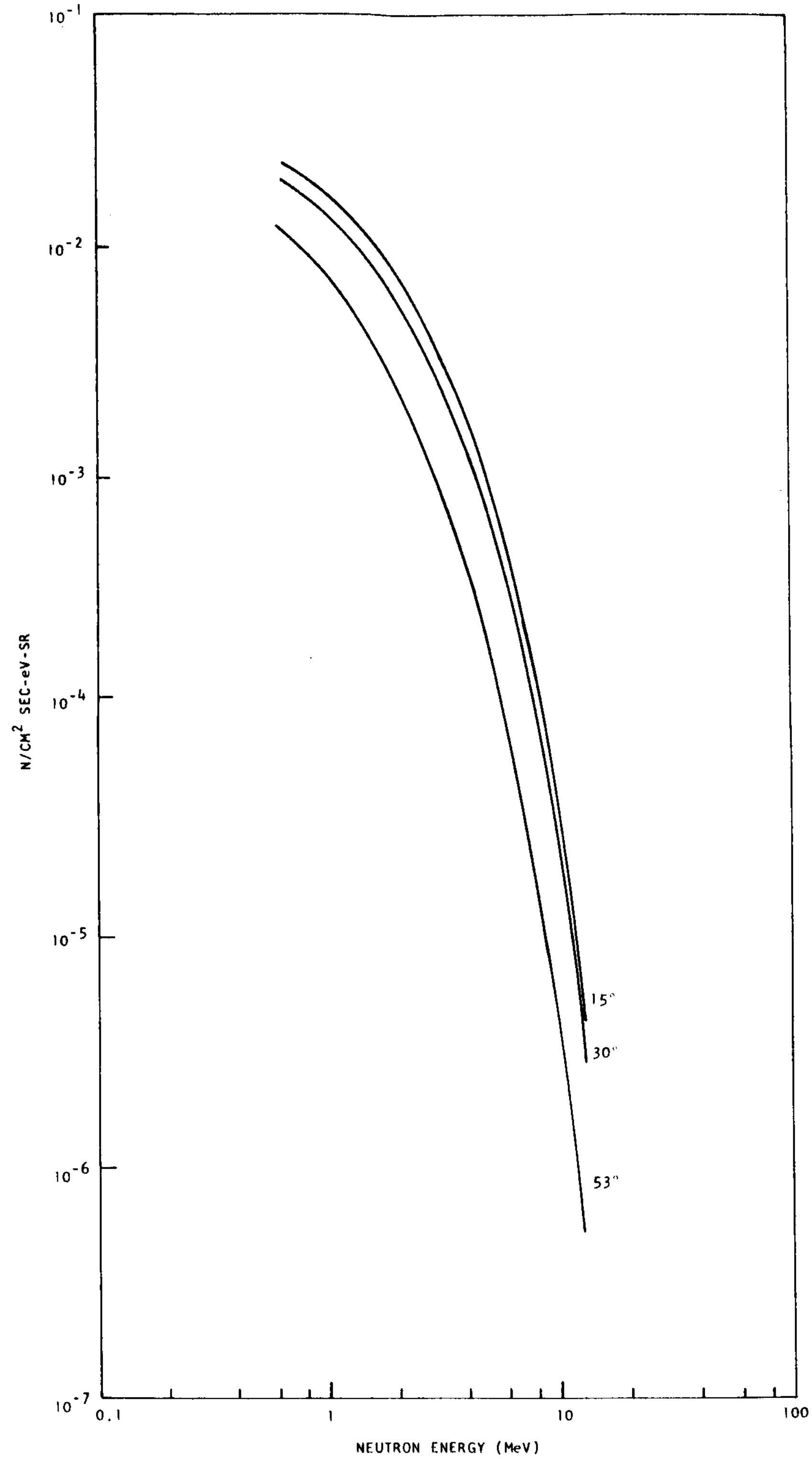


Fig. 4.6--LH_2 slab, GGSN, 4.5-in., 11-13-65

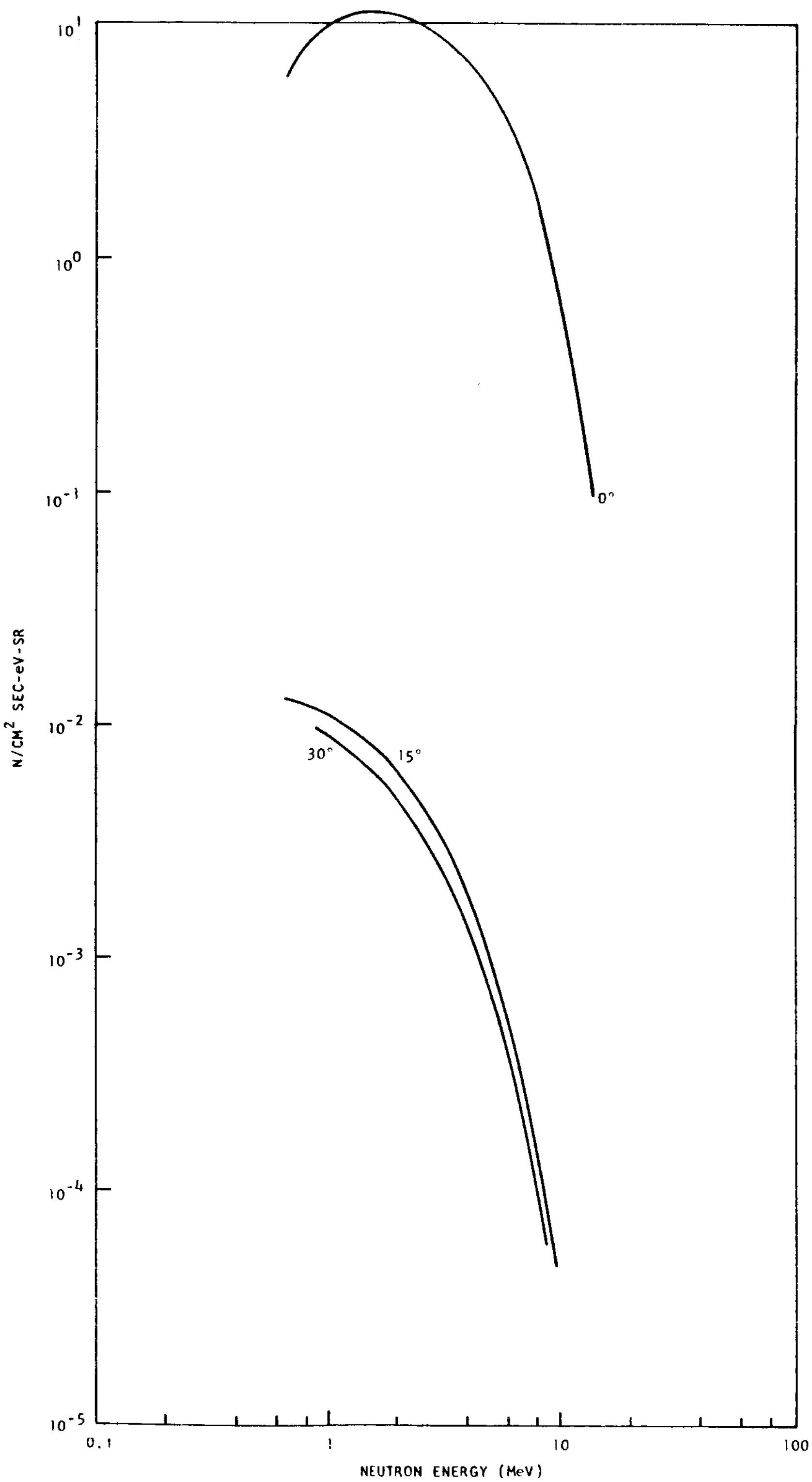


Fig. 4.7--LH_2 slab, GGSN, 7-in., 11-13-65

TABLE 4.2

SLAB GGSN. 11-13-65

μ bounds

-1.00000 to -0.9999	0.000 to 0.125
-0.9999 to -0.9788	0.125 to 0.250
-0.9788 to -0.9530	0.250 to 0.375
-0.9530 to -0.7782	0.375 to 0.500
-0.7782 to -0.4254	0.500 to 0.625
-0.4254 to -0.3880	0.625 to 0.750
-0.3880 to 0.0000	0.750 to 0.875
	0.875 to 1.000

Group	Q_s
1	1.5446
2	6.6871
3	17.3894
4	28,0207
5	38.5966
6	64.0463
7	148.6630
8	66.8939
9	58.8153
10	0.0000

TABLE 4. 3

SLAB GGSN, 12-13-65, NARROW SOURCE

μ bounds	
-1. 00000 to -0. 99999	0. 000 to 0. 125
-0. 99999 to -0. 97437	0. 125 to 0. 250
-0. 97437 to -0. 95630	0. 250 to 0. 375
-0. 95630 to -0. 81915	0. 375 to 0. 500
-0. 81915 to -0. 77715	0. 500 to 0. 625
-0. 77715 to -0. 62932	0. 625 to 0. 750
-0. 62932 to -0. 57358	0. 750 to 0. 875
-0. 57358 to 0. 00000	0. 875 to 1. 000

Calculated spectra for these intervals are quite close to those in Figs. 4.6 and 4.7 indicating the angular mesh to be sufficiently good and the results not very sensitive to the angular resolution.

Finally, the influence of the angle of incidence of the neutrons was investigated by increasing the width of the first angular interval to $\mu = -0.97437$ ($0^{\circ} \pm 13^{\circ}$). The results at nominal 4.5-in. penetration are plotted in Fig. 4.8 and compared with the results for the narrow source angular range of Table 4.3. Since the intensity of the source was not changed to compensate for the different width, the narrow-angle-source spectra are normalized in magnitude at 15° to the wide-angle-source spectra, to compare shapes and angular distributions. Evidently the spectra at 4.5 in. are not very sensitive to the angle of incidence.

4.2 THEORETICAL CALCULATIONS IN THE INTERMEDIATE NEUTRON ENERGY REGION

4.2.1 Energy Levels

Energy levels were submitted to, and approved by, the Project Manager for calculations in the intermediate neutron energy region (0.5 MeV to 1 eV). These energy levels are presented in Table 4.4. Energy levels are shown for energies higher than 0.5 MeV since the problem must be calculated from the highest energy of the input source. On the basis of this approval calculations were then made in the intermediate neutron energy region, details of which are presented in the next section.

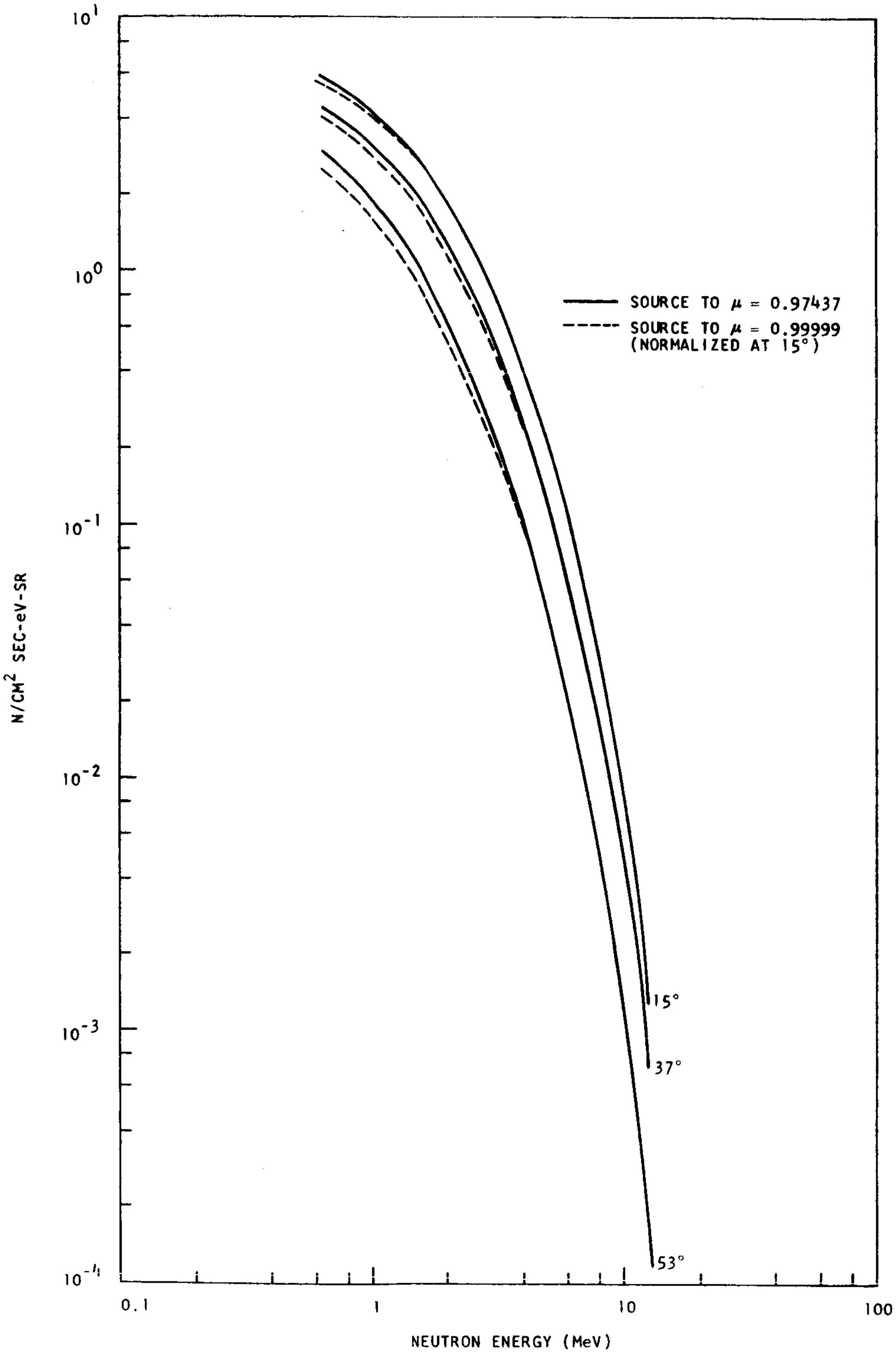


Fig. 4.8--LH_2 slab variable angle, 4.5-in., 12-13-65

TABLE 4.4

ENERGY LEVELS USED FOR INTERMEDIATE NEUTRON ENERGY CALCULATIONS

Group	Energy Level (eV)
1	1.492×10^7
2	1.000×10^7
3	7.408×10^7
4	5.488×10^6
5	4.065×10^6
6	3.012×10^6
7	2.019×10^6
8	1.003×10^6
9	7.427×10^5
10	5.502×10^5
11	3.337×10^5
12	2.024×10^5
13	1.111×10^5
14	6.738×10^4
15	4.087×10^4
16	2.479×10^4
17	1.503×10^4
18	9.119×10^3
19	5.531×10^3
20	3.354×10^3
21	2.035×10^3
22	1.234×10^3
23	7.485×10^2
24	4.540×10^2
25	2.754×10^2
26	1.670×10^2
27	1.013×10^2
28	6.144×10^1
29	2.260×10^1
30	1.370×10^1
31	8.315
32	5.043

4.2.2 Details of the Calculations

The GAM-II code and the GAM-II library cross sections were used to obtain the 32 energy "broad-group" cross sections for the intermediate neutron spectrum calculations. The GAM-II library cross sections are tabulated for 99 fine-groups from 14.9 MeV to 0.41 eV and cross section matrices are included for P_0 through P_3 scattering in the laboratory system. The fine-group cross sections are derived from the basic pointwise data under the assumption that the intragroup flux is constant in lethargy (1/E in energy).[2] The spectrum for group averaging was obtained from a B_3 calculation ($B = 10^{-5}$ cm^{-1}) in GAM-II, with a U-235 fission source spectrum assumed since this is sufficiently accurate for the purpose. The stainless steel of the baffles was homogenized with the liquid hydrogen. The reduced atom density for the liquid hydrogen was 4.122×10^{-2} atoms/barn-cm. The reduced atom density for the stainless steel was 2.09×10^{-3} atoms/barn-cm and is listed in the GAM-II library as tape nuclide number 202.

The source input to GAPLSN was calculated using the LAZYP code[2] which uses the measured fast neutron source spectrum as input. Source spectra are interpolated between measured points averaged over a group, and reduced to 1/V neutrons/cm^3 sec (so that when multiplied by the volume V the source intensity is unity) by the LAZYP code.

The source input to GAPLSN was a nearly normal source contained in the first ray or angular interval $\mu = -1$ to $\mu = .99999$. Slab geometry was used for the GAPLSN calculation and the source was treated as an isotropic surface source. Therefore, in LAZYP the volume was taken as unity. The angular mesh boundaries (in $\mu = \cos\theta$) for the GAPLSN slab calculation and the group surface source, Q_4, are given in Table 4.5. The source is assumed to be on the right hand side of the slab, so the angles of interest are negative μ. A zero transverse buckling was used in these calculations. A variable angle, S_{16}, version of GAPLSN was used. To obtain the mean angles of 5, 15, 37, 53, 66, and 78°, two separate calculations were used for the S_{16} calculation since these angular regions of the mean angles overlapped. Mean angles of 5, 37, and 66° were obtained in one calculation and 15, 53, and 78° in the other. The calculations were done for a P_3, variable angle S_{16}, 60 space points with a spatial mesh of 0.65 cm and a 32 energy group. This spatial mesh provided a backscattering thickness of 6 cm and used the memory capacity of the IBM 7044. The data are presented in graphical form for the five thicknesses in Figs. 4.9, 4.10, 4.11, 4.12, and 4.13. The fast neutron energy region is shown since the problem must be calculated from the highest energy of the input source.

4.3 THEORETICAL CALCULATIONS IN THE THERMAL NEUTRON REGION

4.3.1 Energy Levels

Energy levels were submitted to, and approved by, the Project Manager for calculations in the thermal region (0.0004 to 1 eV). These

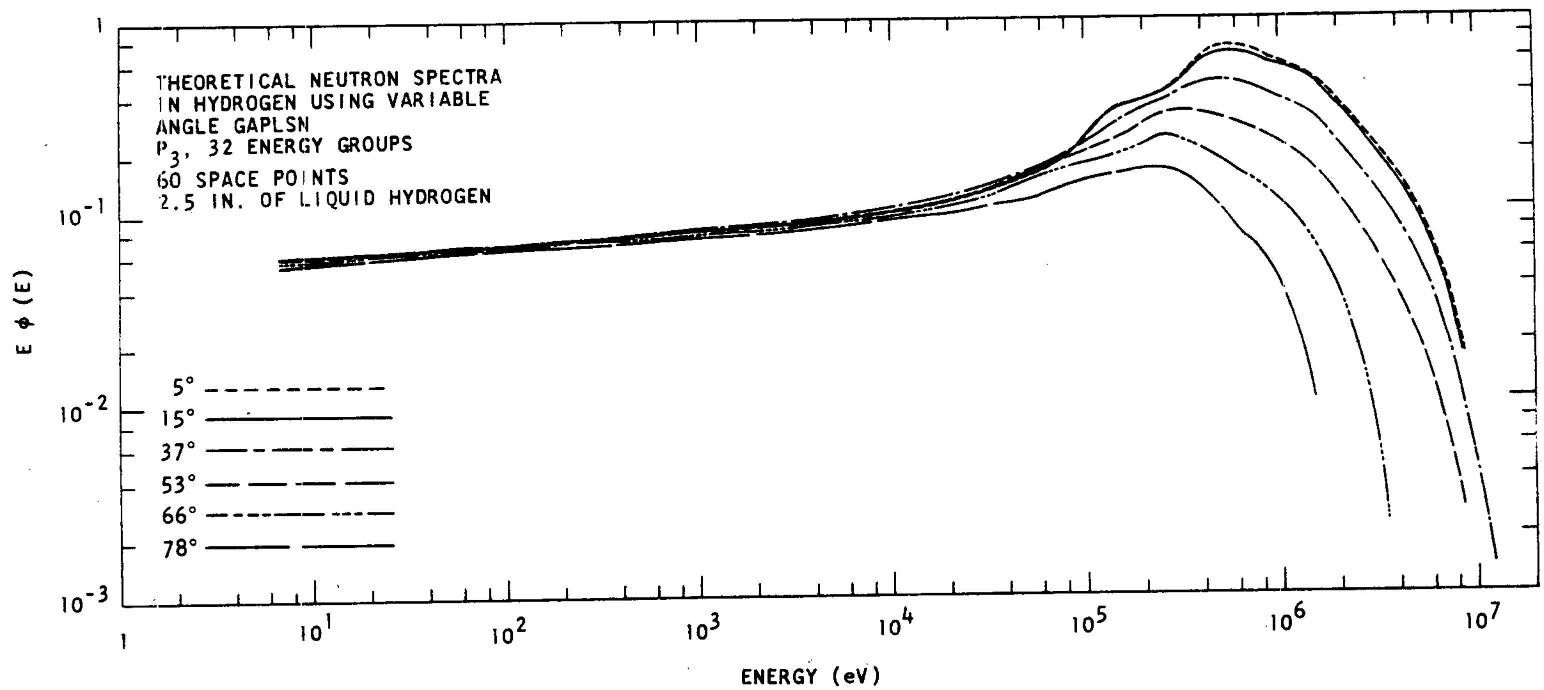


Fig. 4.9--Intermediate neutron spectrum calculations for 2.5 in. of liquid hydrogen

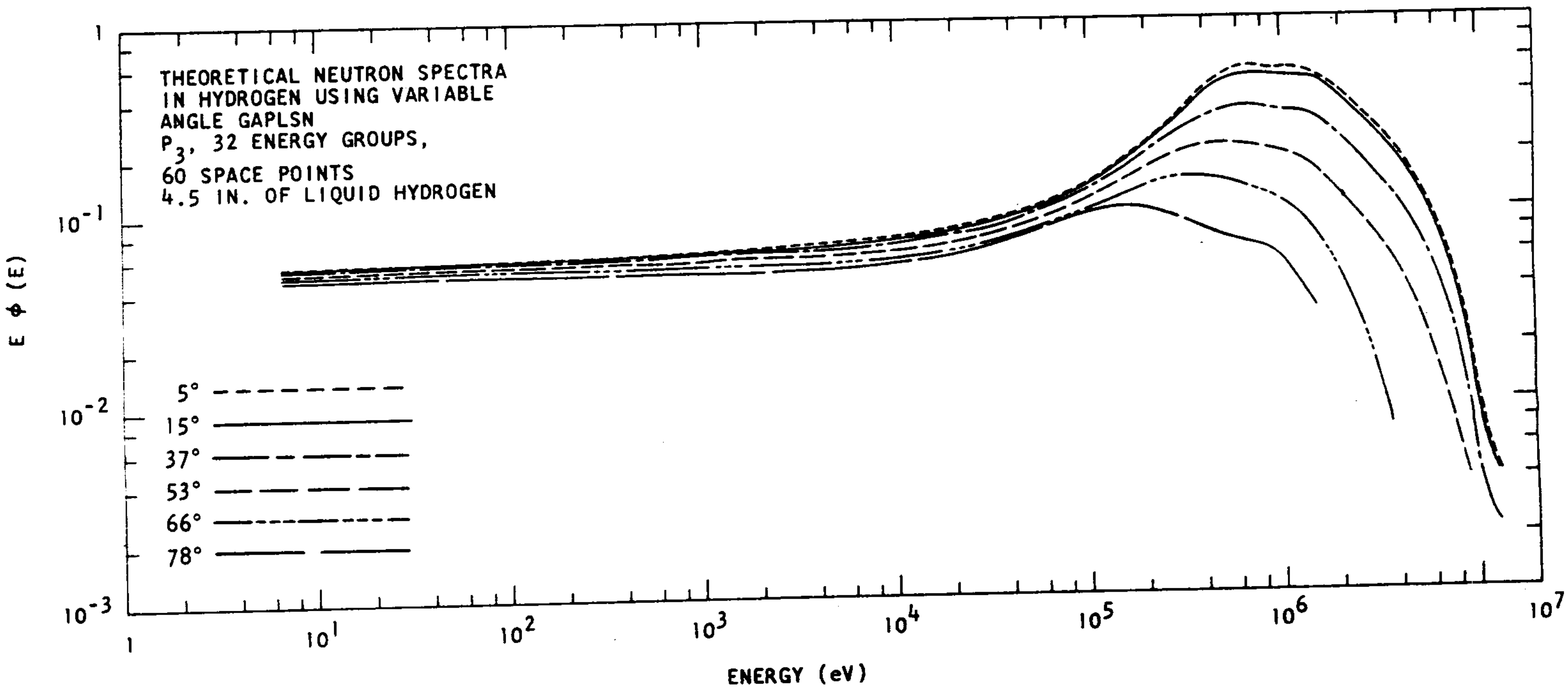


Fig. 4.10--Intermediate neutron spectrum calculations for 4.5 in. of liquid hydrogen

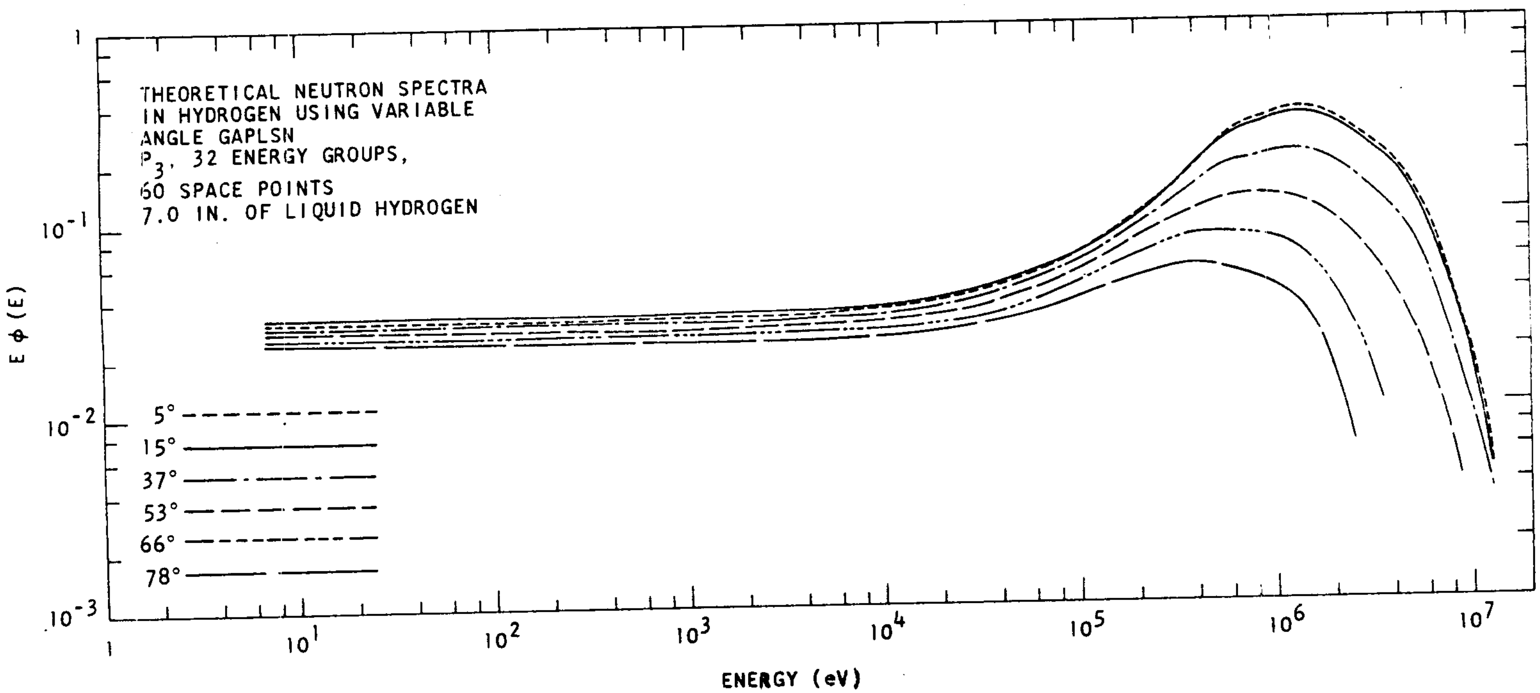


Fig. 4.11-Intermediate neutron spectrum calculations for 7.0 in. of liquid hydrogen

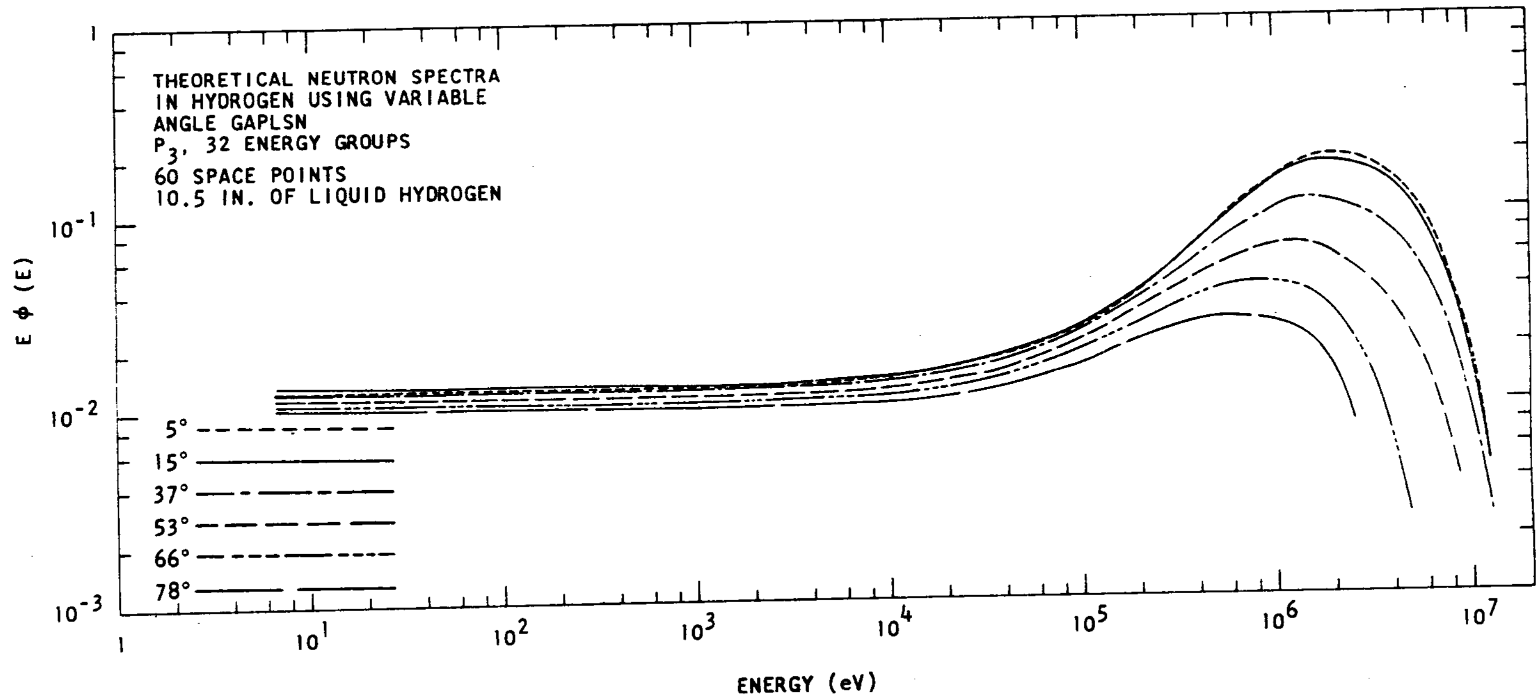


Fig. 4.12--Intermediate neutron spectrum calculations for 10.5 in. of liquid hydrogen

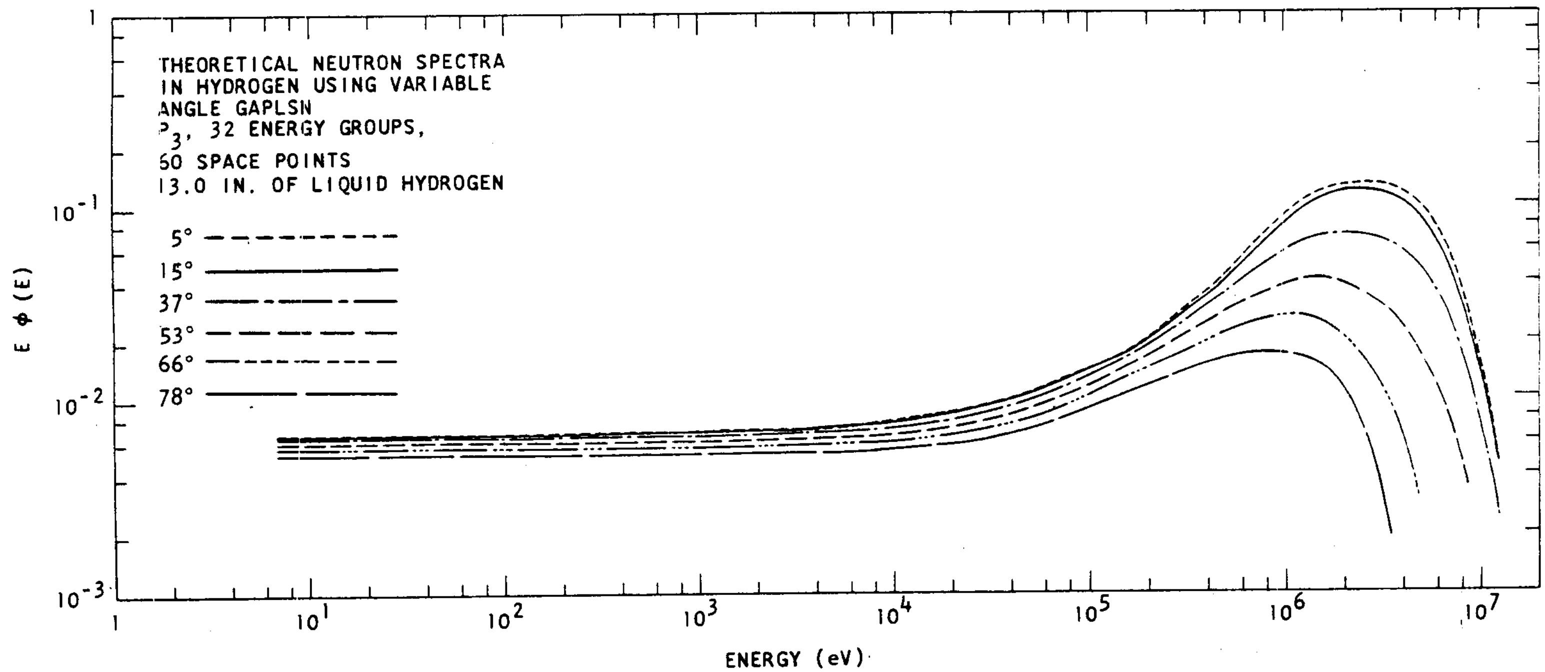


Fig. 4.13--Intermediate neutron spectrum calculations for 13.0 in. of liquid hydrogen

TABLE 4.5

SLAB, VARIABLE ANGLE GAPLSN

μ bounds for 5, 37, and 66^{o} calculation 3-5-66

-1.0000	-0.99999	0.000	0.125
-0.99999	-0.99240	0.125	0.250
-0.99240	-0.89661	0.250	0.375
-0.89661	-0.70066	0.375	0.500
-0.70066	-0.50471	0.500	0.625
-0.50471	-0.30876	0.625	0.750
-0.30876	-0.18043	0.750	0.875
-0.18043	0.00000	0.875	1.000

μ bounds for 15, 53, 78^{o} calculation 3-7-66

-1.0000	-0.99999	0.000	0.125
-0.99999	-0.99239	0.125	0.250
-0.99239	-0.93947	0.250	0.375
-0.93947	-0.70066	0.375	0.500
-0.70066	-0.50297	0.500	0.625
-0.50297	-0.30876	0.625	0.750
-0.30876	-0.10705	0.750	0.875
-0.10705	0.00000	0.875	1.000

Group	Q_4
1	5.4678×10^{2}
2	1.8022×10^{3}
3	4.2419×10^{3}
4	6.6776×10^{3}
5	9.2173×10^{3}
6	1.6162×10^{4}
7	3.9795×10^{4}
8	2.3523×10^{4}
9	2.3028×10^{4}
10	3.0221×10^{4}
11	1.9219×10^{4}
12	1.4249×10^{4}
13	6.9370×10^{3}
14	4.3629×10^{3}

energy levels are presented in Table 4.6. On the basis of this approval, calculations were then made in the thermal neutron energy region, details of which are presented in the next section.

4.3.2 Details of the Calculations

The P_0 and P_1 scattering kernels for para- and ortho-hydrogen were calculated using the code LHK[11] written for the IBM 7044 computer. LHK generates cross sections for 80 energy points, from 0.0002 to 1.0 eV. Although GAPLSN[9] calculations may be performed with this fine-group cross section, the limitations in computer storage required a fewer number of groups; a 32 broad energy group was therefore used. This group collapsing was done by averaging over a calculated flux using the GATHER-II[12] code. The stainless steel of the baffles was homogenized with liquid hydrogen. The stainless steel macroscopic cross section was generated as a 1/v absorber with a value of 0.308 cm^{-1} at 0.0253 eV and a constant macroscopic scattering cross section of 1.016 cm^{-1}. The reduced atom density for liquid para-hydrogen was 0.04131 atoms/barn-cm, and for liquid ortho-hydrogen it was 8.7×10^{-4} atoms/barn-cm since at the boiling point of liquid hydrogen, 20.4^{o}K, the equilibrium para and ortho concentrations are 99.79 and 0.21 percent respectively.[13] Since stainless steel was introduced into GATHER-II as a macroscopic cross section given above, only the volume fraction of 1.909×10^{-2} was used as an input.

TABLE 4.6

ENERGY LEVELS FOR
THERMAL NEUTRON SPECTRUM CALCULATIONS

Group	Energy Level (eV)
1	1.000
2	0.850
3	0.700
4	0.550
5	0.450
6	0.360
7	0.260
8	0.180
9	0.140
10	0.1070
11	0.0830
12	0.0640
13	0.0490
14	0.0380
15	0.0292
16	0.0223
17	0.0196
18	0.0172
19	0.0152
20	0.0133
21	0.0177
22	0.0103
23	0.0090
24	0.0079
25	0.0061
26	0.0047
27	0.0032
28	0.0025
29	0.0019
30	0.0013
31	0.0008
32	0.0004

The code DSZ[14] was used to calculate the P_0 and P_1 components of the volume-distributed first collision thermal neutron source assuming that the spatial dependence of the epithermal flux (above some cut-off energy, E_c, in this case 1 eV) is known. The spatial dependence of the epithermal flux was assumed to be of the form

$$\varphi = \varphi_o e^{-0.122x} \tag{1}$$

DSZ uses the total buckling, B_T^2, where

$$B_T^2 = B_{Transverse}^2 + B_{Axial}^2$$

where B_{Axial}^2 is derived from Eq. (1), and

$$\begin{aligned} B_{Transverse}^2 &= \left(\frac{2.405}{R+d}\right)^2 \\ &= \left(\frac{2.405}{53.34+d}\right)^2 \\ &= 0.0019 \text{ cm}^{-2} \end{aligned}$$

where d is taken as the extrapolation distance for the highest energy group. This gives

$$B_T^2 = -0.013 \text{ cm}^{-2} \ .$$

The LH_2 cryostat in the transverse direction is circular, the buckling being calculated on that basis although slab geometry was used for the calculations.

Since GAPLSN[9] is a one-dimensional transport theory code, the transverse buckling was added as a virtual absorber, $D(E)B^2_{Transverse}$ where

$$D(E) = \frac{1}{3\Sigma_{tr}(E)}$$

and $\Sigma_{tr}(E)$ is the macroscopic transport cross section. Because of the limitation imposed by memory capacity of the computer, the virtual absorber was added to the hydrogen cross sections prior to input to GAPLSN.

Two sets of calculations were done using the one-dimensional transport theory code GAPLSN and slab geometry. The first calculation used an S_4, i.e., four equal angular intervals from $\mu = -1$ to $\mu = +1$; P_1; 75 space points with a 0.5 cm spatial mesh for a total thickness of 37.5 cm (a thickness greater than 13 in. must be used since a back-scattering thickness of several inches is required to make the largest thickness correct); and a 32 energy group. The mean angles for this calculation were 39°14' and 75°31'. This calculation used the memory capacity of the IBM 7044. The results of these calculations are presented in Figs. 4.14, 4.15, 4.16, 4.17, and 4.18 for the two angles 39°41' and 75°31' for thicknesses of 2.5, 4.5, 7.0, 10.5 and 13.0 in. The second set of calculations was made to determine the change of the thermal neutron spectra as a function of angle since the S_4 calculation was limited to two mean angles between 0 and 90°. These calculations were for an S_8, P_1, 50 space points with a 0.5 cm spatial mesh, and a 32 energy group. The memory capacity of the IBM 7044 limited this calculation

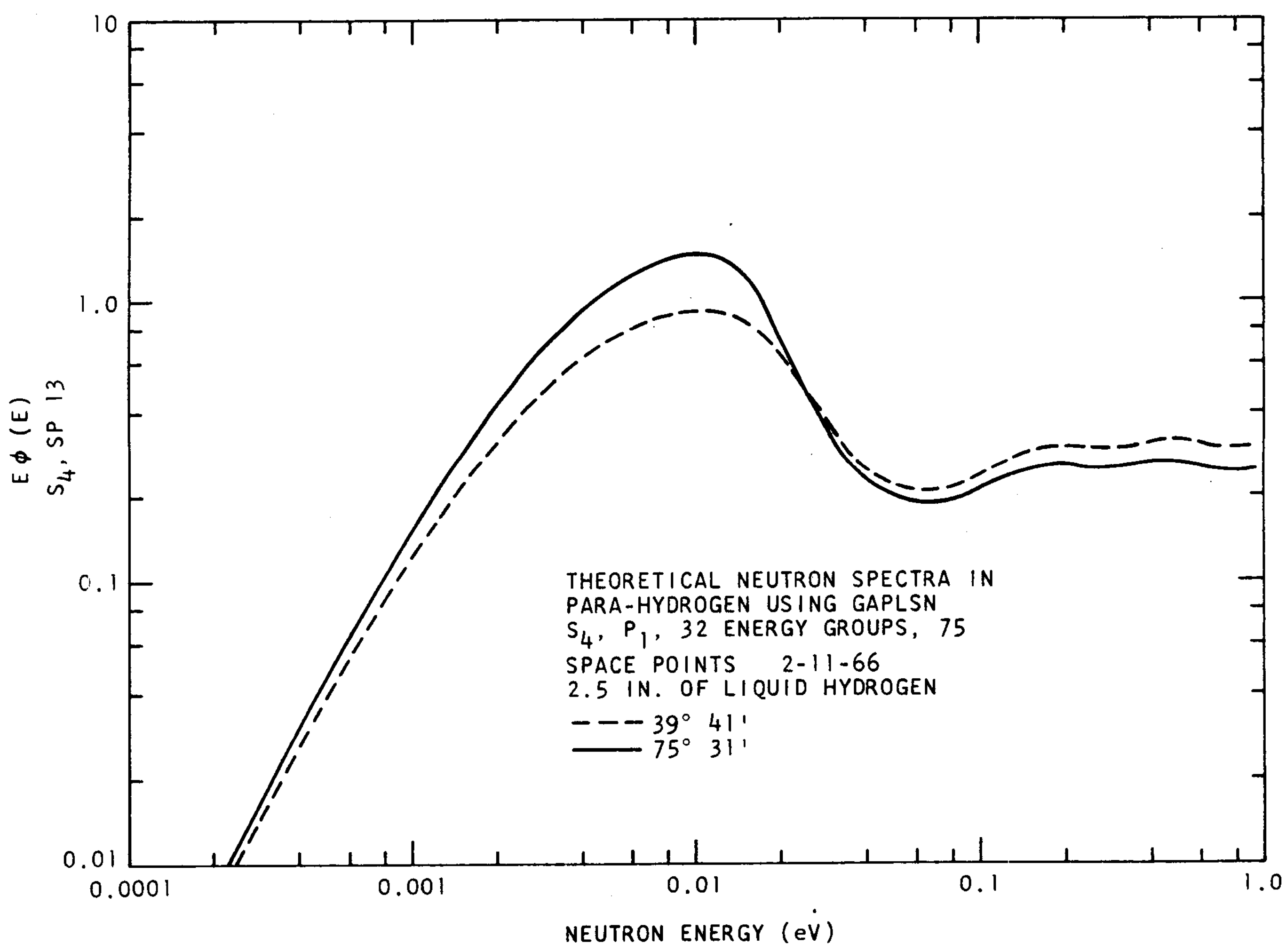


Fig. 4.14--S_4 calculation of the thermal neutron spectra for 2.5 in. of liquid hydrogen

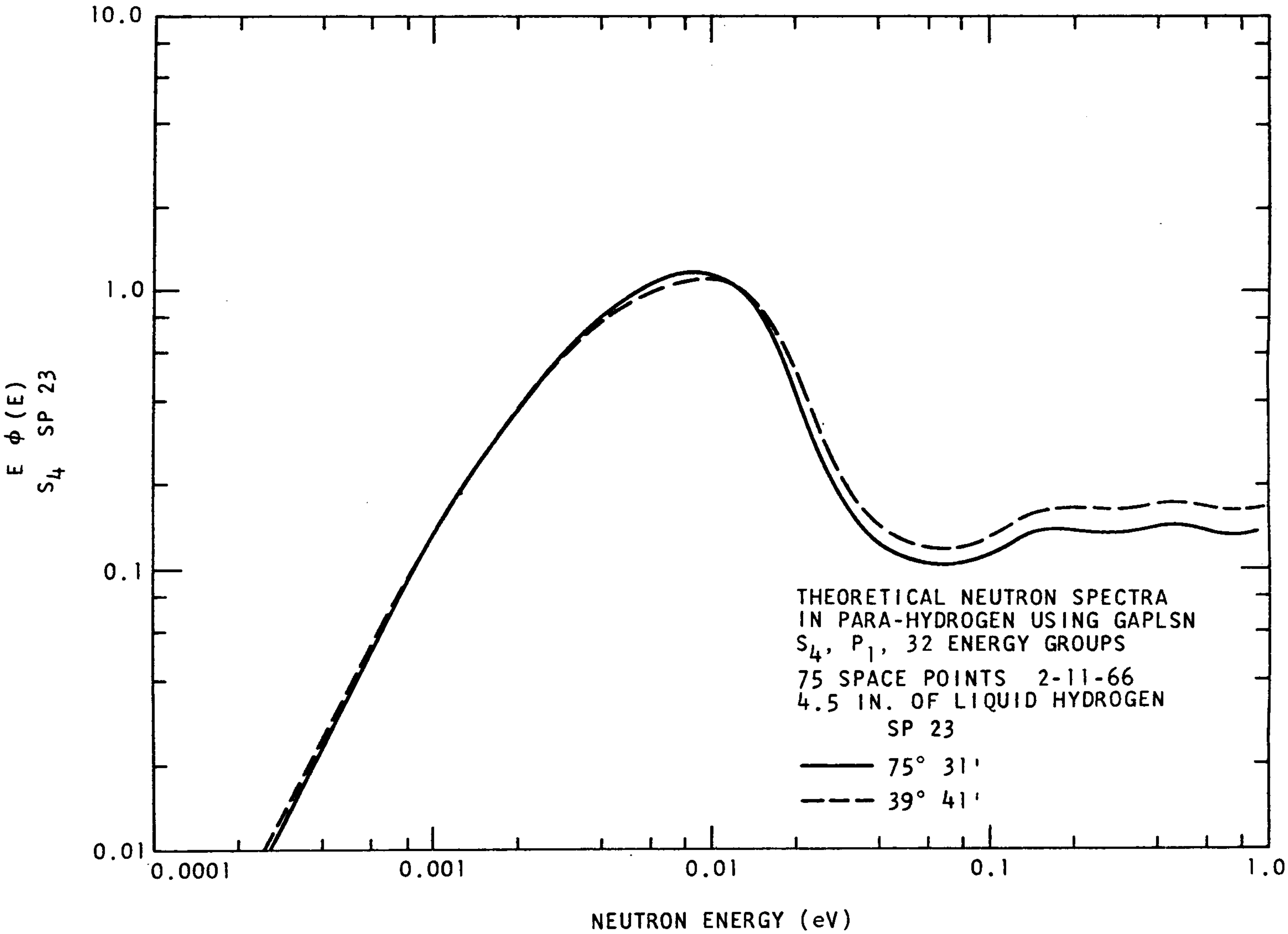


Fig. 4.15--S_4 calculation of the thermal neutron spectra for 4.5 in. of liquid hydrogen

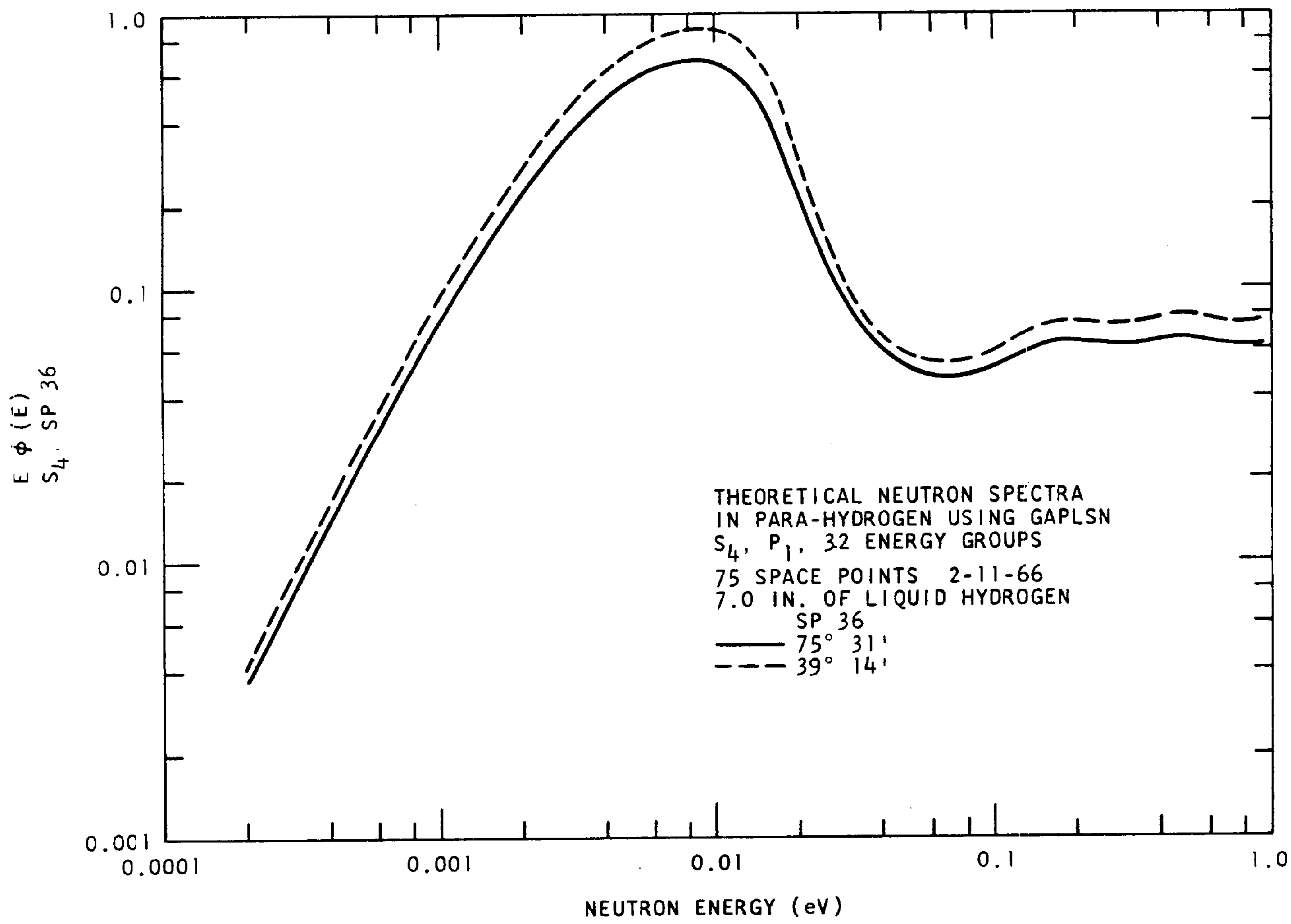


Fig. 4.16--S_4 calculation of the thermal neutron spectra for 7.0 in. of liquid hydrogen

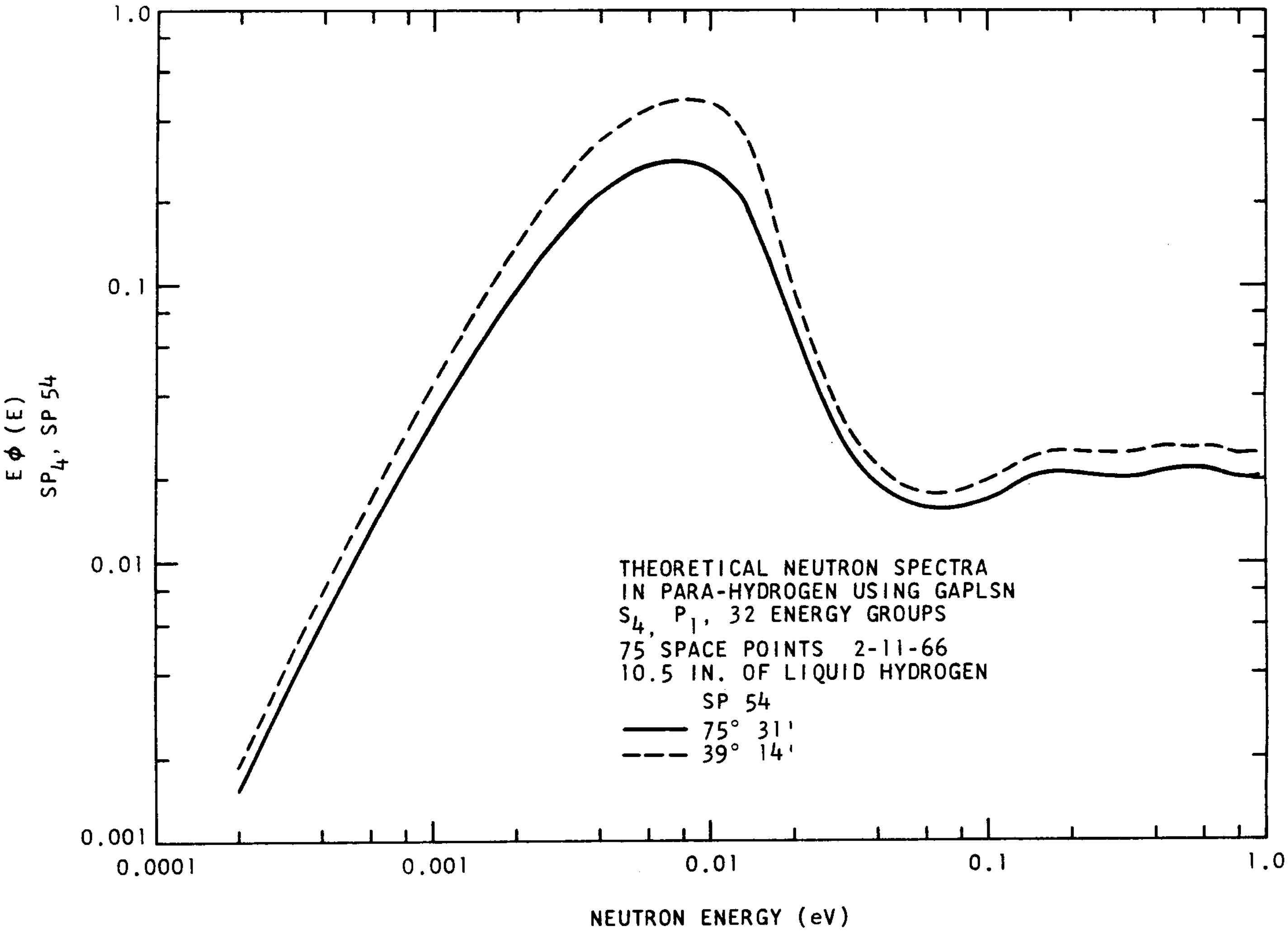


Fig. 4.17--S_4 calculation of the thermal neutron spectra for 10.5 in. of liquid hydrogen

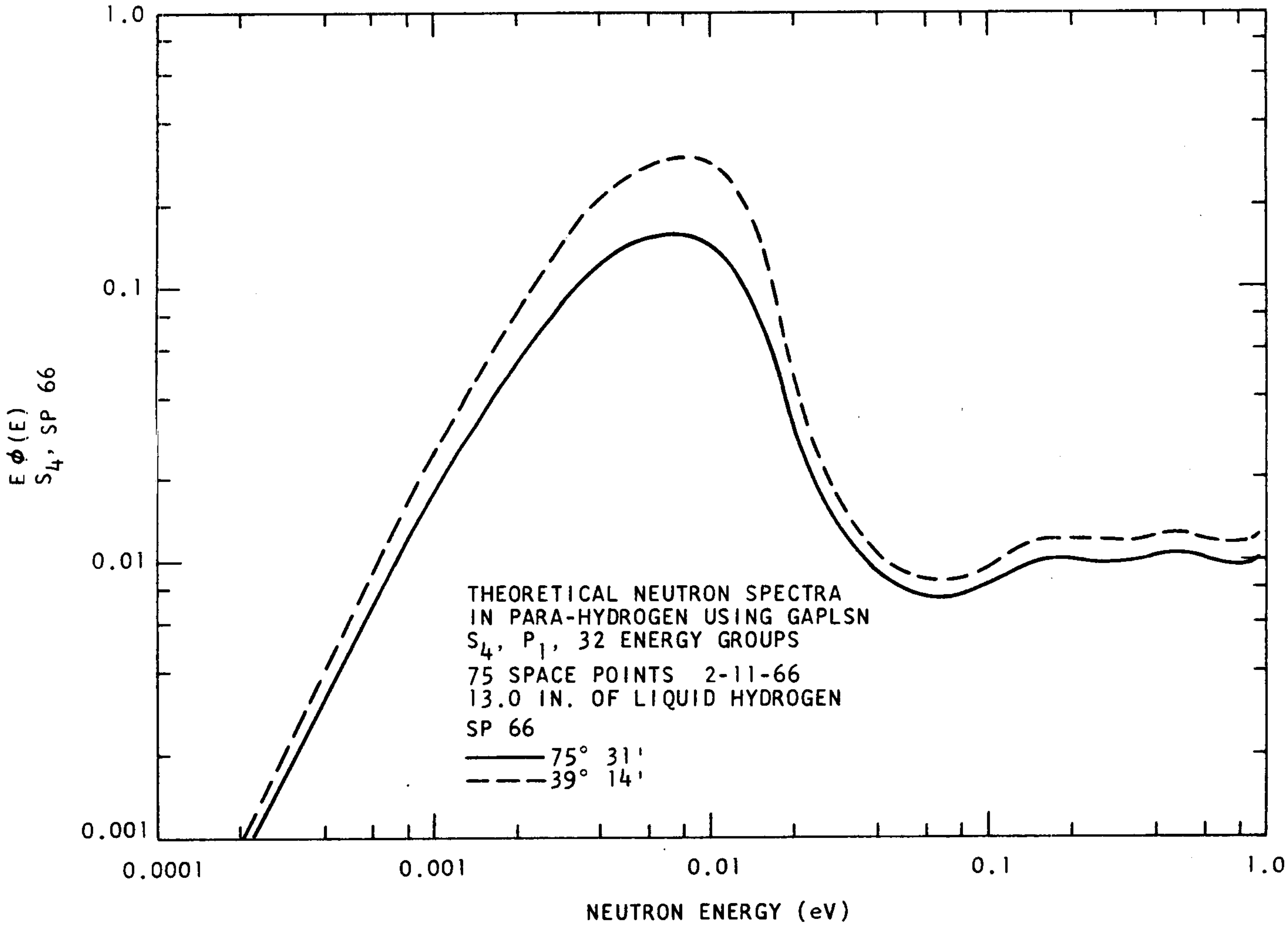


Fig. 4-18--S_4 calculation of the thermal neutron spectra for 13.0 in. of liquid hydrogen to a total thickness of 25 cm which was sufficient to allow a backscattering thickness so that the 7.0-in. data would be correct. The mean angles for this calculations were $28^{\circ}8'$, $50^{\circ}51'$, $67^{\circ}48'$, and $82^{\circ}45'$. The results of these calculations are presented in Figs. 4.19, 4.20, 4.21, 4.22, 4.23 and 4.24. As can be seen from these figures, the intensity and spectral shape are a slowly varying function of angle and thickness.

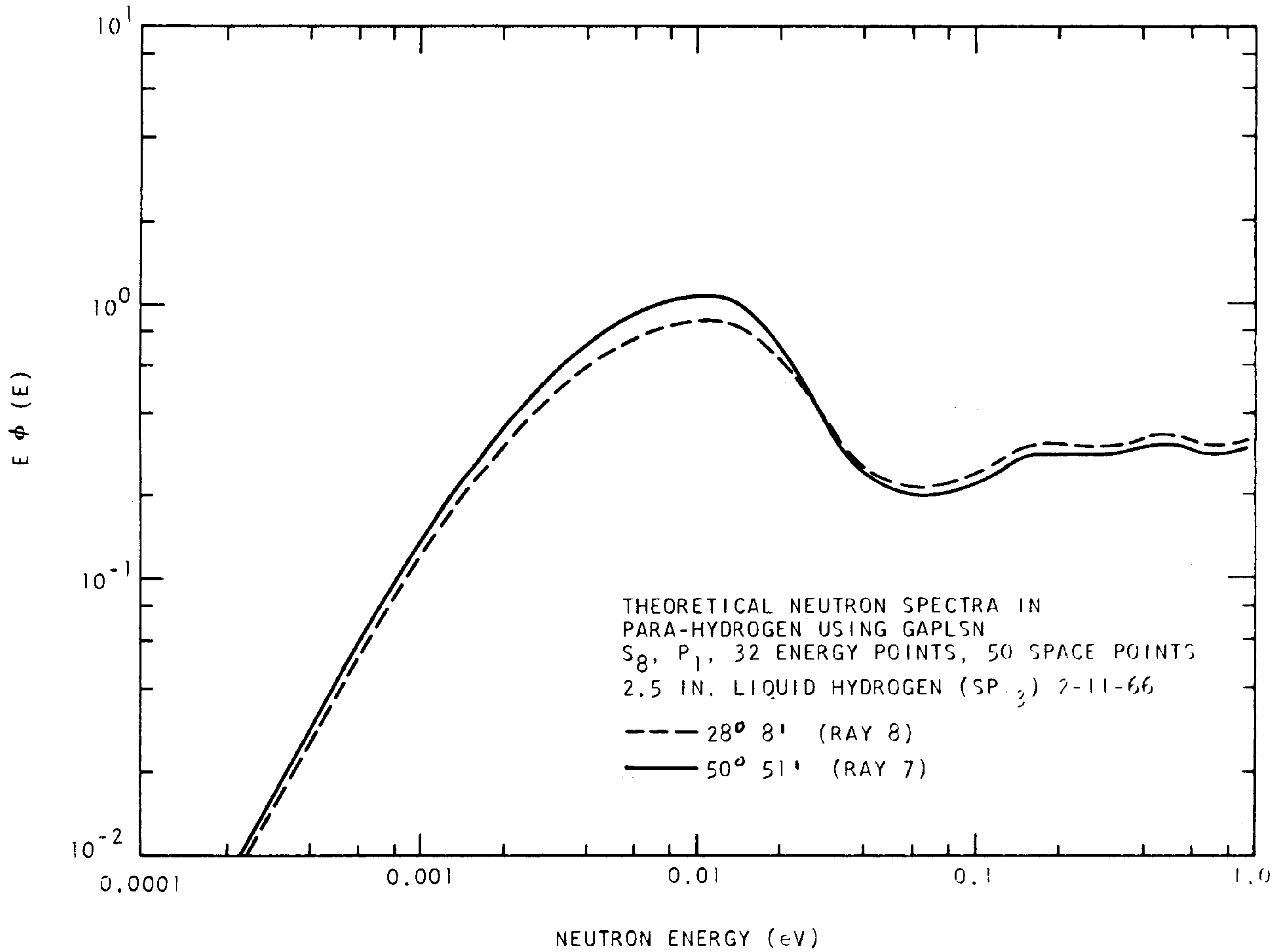


Fig. 4.19--S_8 calculation of the thermal neutron spectra for 2.5 in. of liquid hydrogen at angles of 28°8' and 50°51'

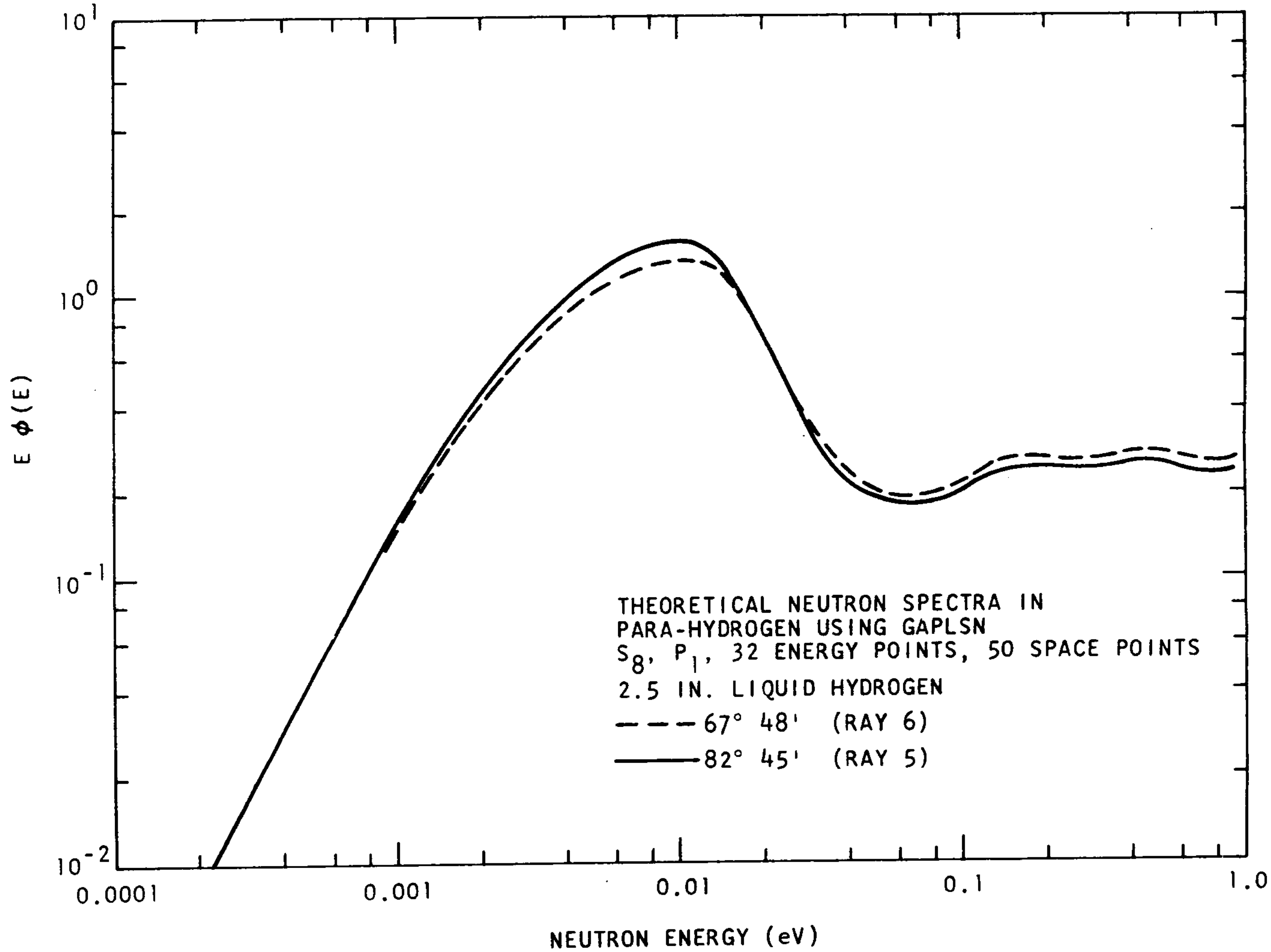


Fig. 4.20--S_8 calculation of the thermal neutron spectra for 2.5 in. of liquid hydrogen at angles of 67°48' and 82°45'

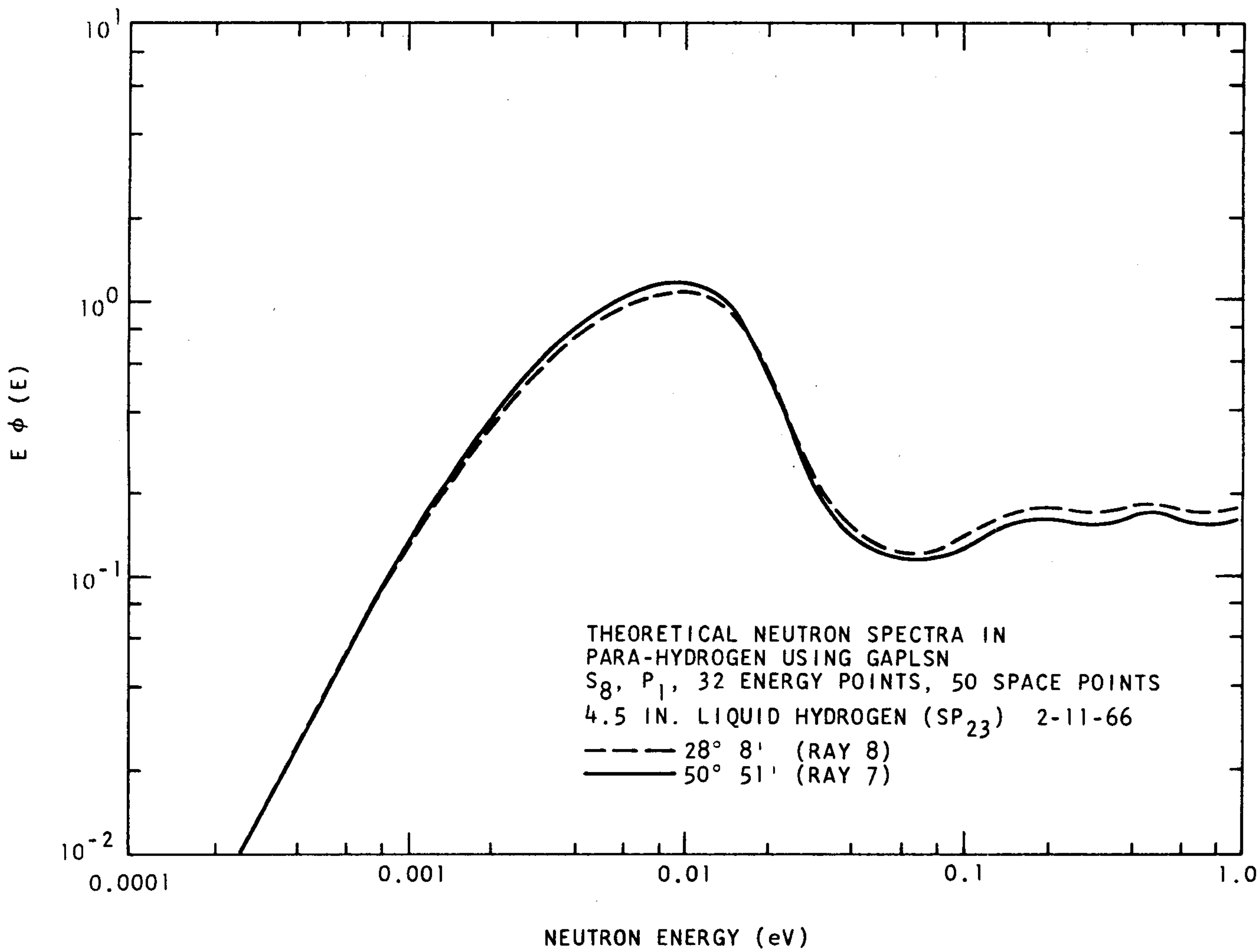


Fig. 4.21--S_8 calculation of the thermal neutron spectra for 4.5 in. of liquid hydrogen at angles of 28°8' and 50°51'

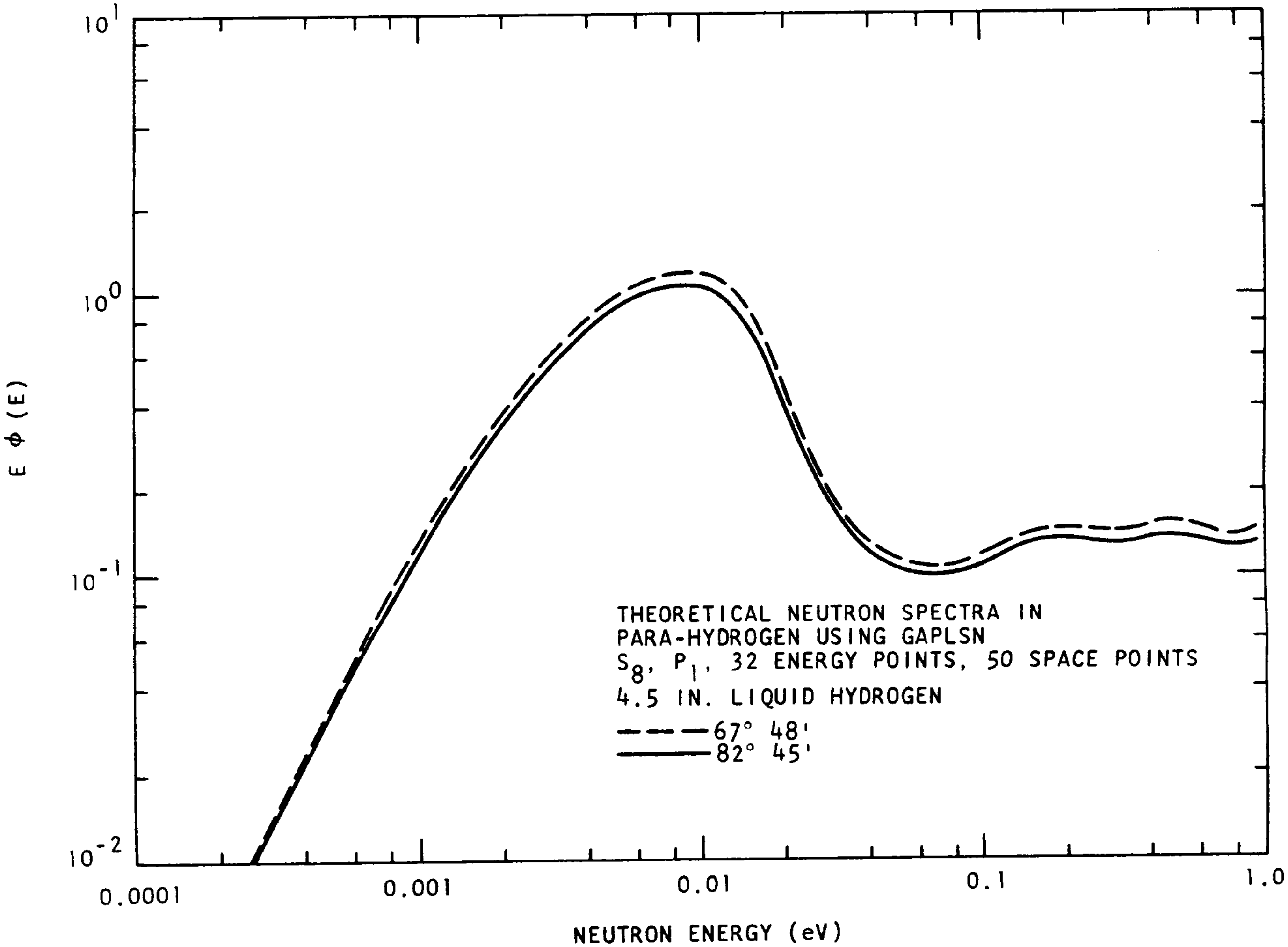


Fig. 4.22--S_8 calculation of the thermal neutron spectra for 4.5 in. of liquid hydrogen at angles of 67°48' and 82°45'

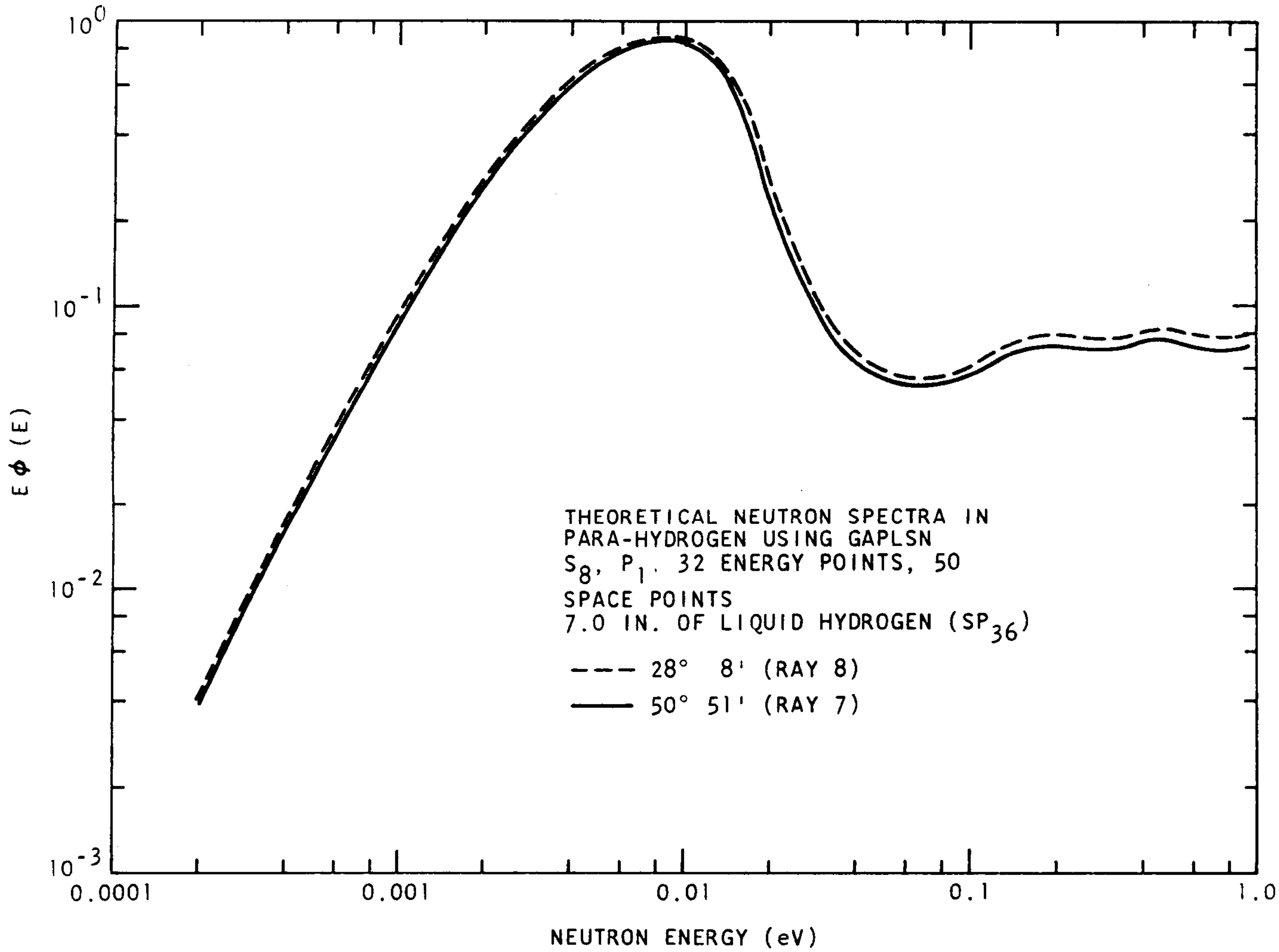


Fig. 4.23--S_8 calculation of the thermal neutron spectra for 7.0 in. of liquid hydrogen at angles of $28^o8'$ and $50^o51'$

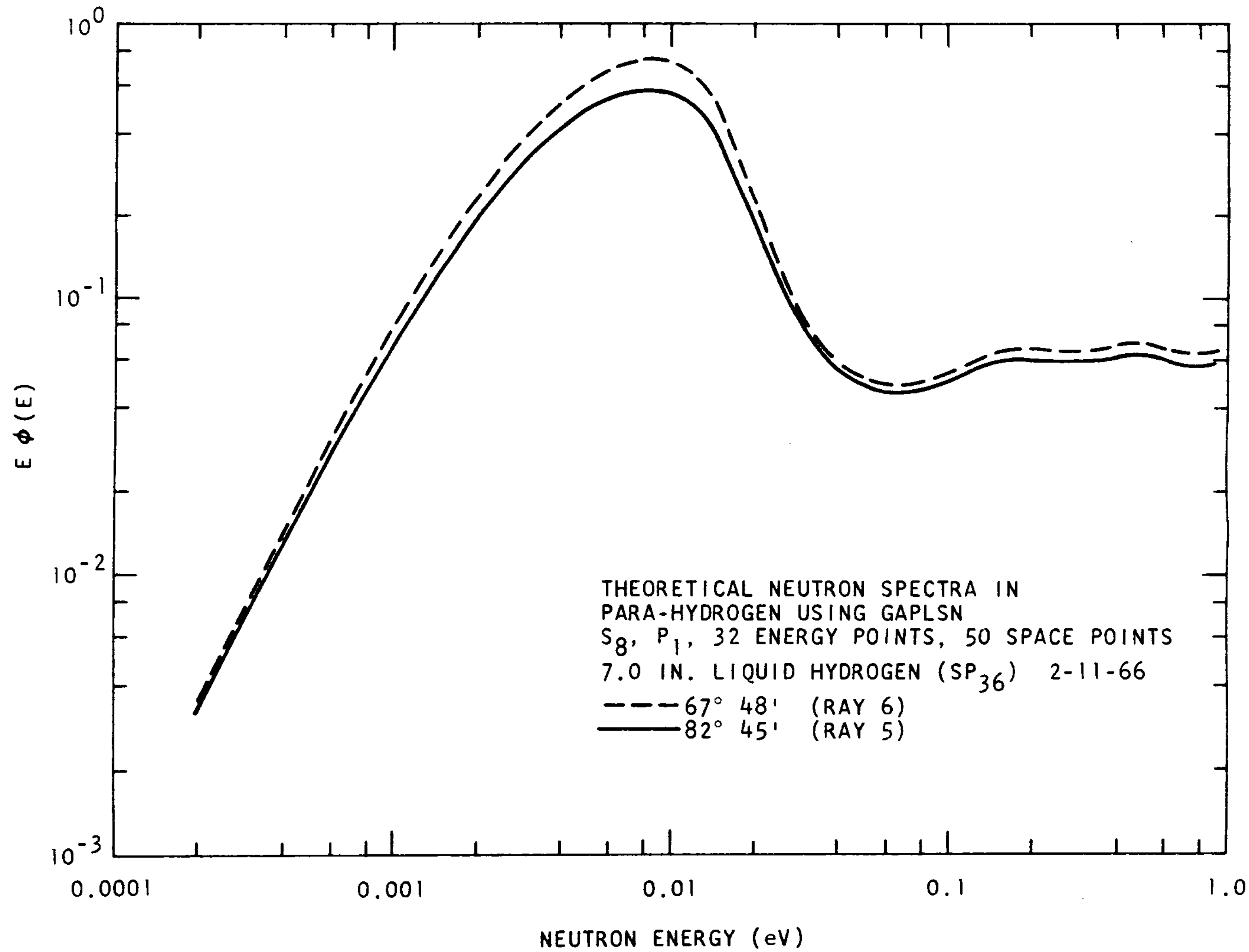


Fig. 4-24--S_8 calculation of the thermal neutron spectra for 7.0 in. of liquid hydrogen at angles of 67°48' and 82° 45'

V. DATA REDUCTION AND EXPERIMENTAL RESULTS

5.1 DATA REDUCTION

The measurements which were made in liquid hydrogen are summarized in Appendix B. The raw data, in the form of counts per time channel vs channel number, are reduced to neutrons incident per eV, versus energy, by a modified form of the basic General Atomic computer code ECTOPLASM, called HECTO. The code corrects the number of counts for deadtime losses, subtracts the background, normalizes to the source monitor, and corrects for the detector efficiency.

The flight time corresponding to the middle of the time channel is calculated and converted to energy from $E(eV) = gL^2/(t-t_0)^2$, where L is the flight path length. The zero time, t_0, includes any mean emission time or detection time delay.

The number of neutron counts per eV is found from the relationship $C(E)\Delta E = C(t)\Delta t$. Then C(E) is divided by $S(E) = G(E)T(E)$, where G(E) is the intrinsic detector efficiency and T(E) the flight path transmission. This gives N'(E), the number of neutrons per eV. To normalize to source intensity and the length of irradiation

$$N(E) = \frac{N'(E)}{M} = \frac{\text{Neutrons/eV}}{\text{Monitor Count}}$$

where M is the number of monitor counts. N(E) is proportional to the neutron flux. A more convenient method of presenting the data is to multiply by the energy, E

$$EN(E) = \frac{EN'(E)}{M} = \frac{\text{Neutrons}}{\text{Monitor Count}}$$

EN(E) is proportional to the lethargy. HECTO output prints both N(E) and EN(E) but the majority of the data is presented as EN(E) vs E.

In addition to the channel-by-channel reduced data, the code groups and prints the average N(E) and EN(E) in several channels, the first grouping to satisfy an energy resolution criterion, $\Delta E/E$, specified by the experimenter. Further grouping is done if the average N(E) or EN(E) does not meet a second criterion, the statistical error, $\Delta N/N$.

5.2 THERMAL NEUTRON EXPERIMENTAL RESULTS

The intrinsic detector efficiency, G(E), for the thermal neutron detector is given in Table 5.1. The detection efficiency between the tabulated energy points is obtained by interpolation in HECTO.

Transmission of neutrons through the flight path is calculated as $T(E) = \exp(-\sum_i N_i \sigma_i t_i)$ where i refers to the material, N_i is the atomic density, σ_i the total cross section, and t_i is the thickness. The flight path materials are tabulated in Table 5.2. These materials are composed of eight elements: hydrogen, nitrogen, oxygen, carbon, iron, chromium, nickel, and helium. The cross sections for these materials were taken from BNL-325, Suppl. 2, and KFK-120. In general, below

Table 5.1

THE INTRINSIC DETECTOR EFFICIENCY FOR THE THERMAL NEUTRON DETECTOR

E(eV)	G(E)	E(eV)	G(E)
.00010	.6255	.055	.5728
.00015	.6682	.060	.5606
.00020	.6941	.070	.5393
.00030	.7247	.080	.5213
.00040	.7423	.090	.5048
.00060	.7617	.10	.4897
.00080	.7721	.15	.4327
.0010	.7784	.20	.3935
.0015	.7864	.30	.3411
.0020	.7897	.40	.3064
.0030	.7909	.60	.2616
.0040	.7885	.80	.2329
.0045	.7865	1.0	.2123
.0050	.7736	1.5	.1787
.0055	.7771	2.0	.1576
.0060	.7736	3.0	.1316
.0065	.7624	4.0	.1156
.0070	.7660	6.0	.09591
.0075	.7652	8.0	.08388
.0080	.7629	10	.07554
.0090	.7579	15	.06235
.010	.7519	20	.05435
.013	.7284	30	.04472
.016	.7078	40	.03891
.019	.6884	60	.03195
.022	.6777	80	.02776
.025	.6673	100	.02489
.030	.6510	150	.02039
.035	.6323	200	.01770
.040	.6150	300	.01449
.045	.5995	400	.01257
.050	.5862		

Table 5.2

FLIGHT PATH MATERIALS FOR THE THERMAL NEUTRON MEASUREMENTS

Material	Thickness (cm)
Mylar	.0267
Air[a]	40.64
Stainless Steel	.474
Helium[b]	53.65

[a]Air assumed at 50° to relative humidity at 72°F, and standard atmospheric pressure.
[b]Helium assumed at 20°K and 5 psig.

.001 eV, these cross sections have not been measured, and for helium they have not been measured below 0.019 eV. The cross section of stainless steel 304 has not been measured and it was assumed a composite of its individual constituents of Ni, Cr, and Fe in the proper weight per cents. However, the cross section of Cr has not been measured below 0.006 eV and the cross sections of Fe, Ni, or Cr are not very well known in the Bragg cutoff energy region of about 0.005 eV.

The measured thermal angular neutron spectra for liquid hydrogen are presented in Figs. 5.1, 5.2, 5.3, 5.4 and 5.5 and tabulated in Appendix B.

5.3 INTERMEDIATE NEUTRON EXPERIMENTAL RESULTS

The intrinsic detector efficiency, G(E), for the intermediate neutron detector is shown in Fig. 5.6. The flight path materials are tabulated in Table 5.3 These are composed of the following eleven elements: aluminum, boron, carbon, hydrogen, oxygen, nitrogen, lead, iron, chromium, nickel, and helium. The cross sections for these materials were taken from BNL-325, Suppl. 2, and KFK-120. The computer code HECTO computes the energy at the midpoint of the channel and uses the interpolated cross section at that energy. Since in the intermediate neutron region the cross sections of Fe, Ni, and Cr contain many resonances sharper than the energy widths of the channel and an inappropriate cross section could be chosen by HECTO, these

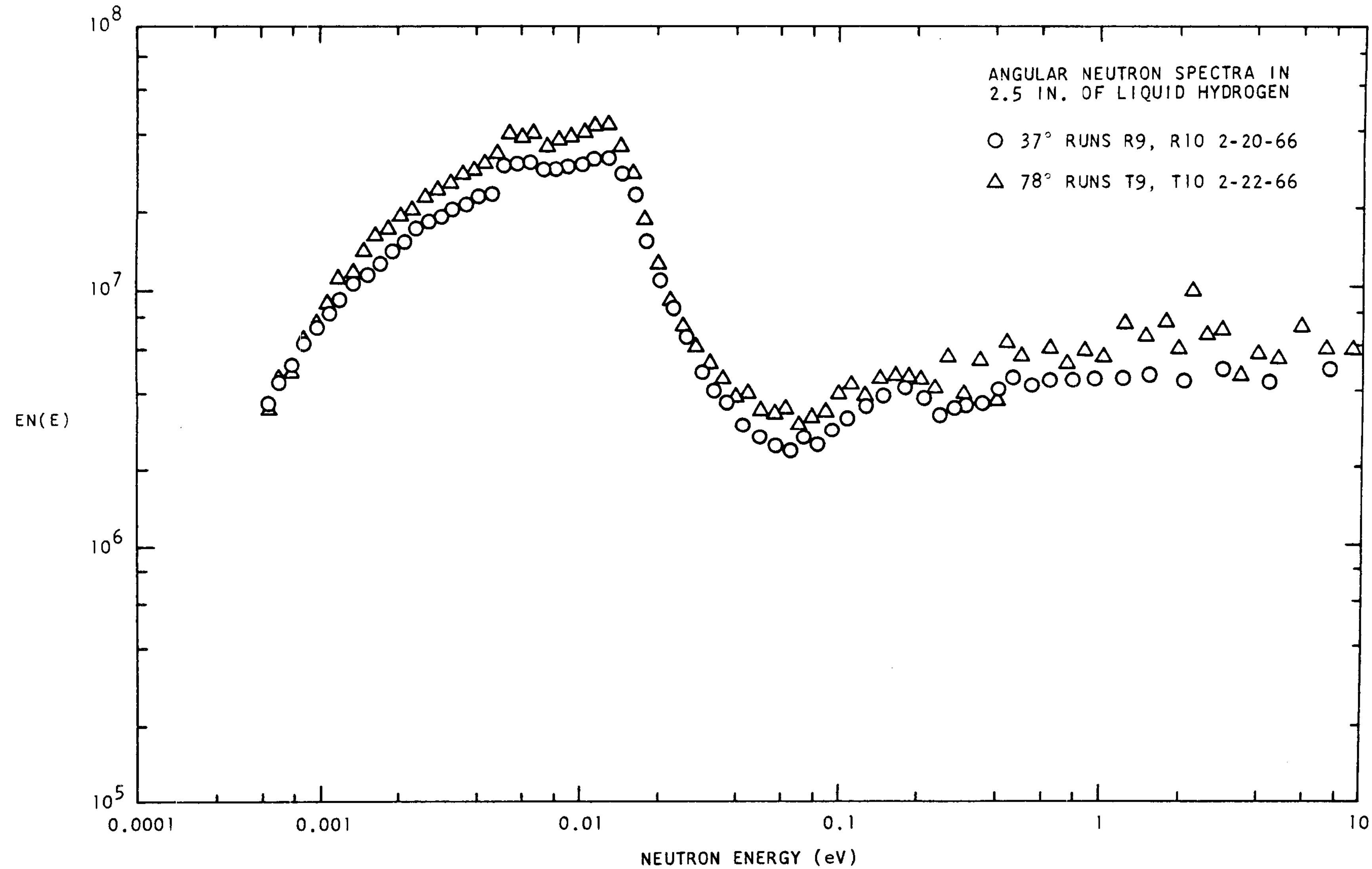


Fig. 5.1--Measured thermal neutron spectra in 2.5 in. of liquid hydrogen for 37 and 78°

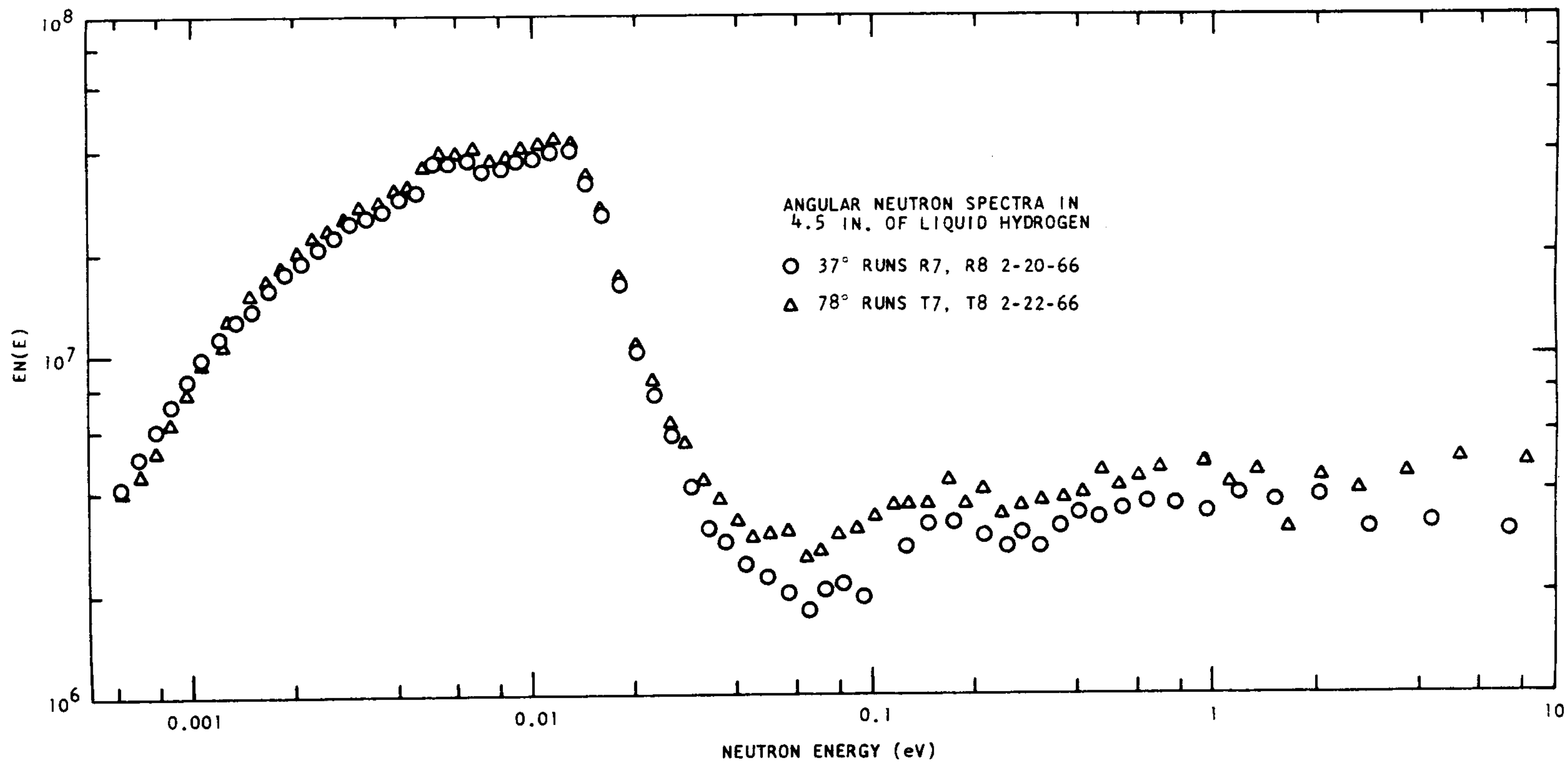


Fig. 5.2--Measured thermal neutron spectra in 4.5 in. of liquid hydrogen for 37 and 78°

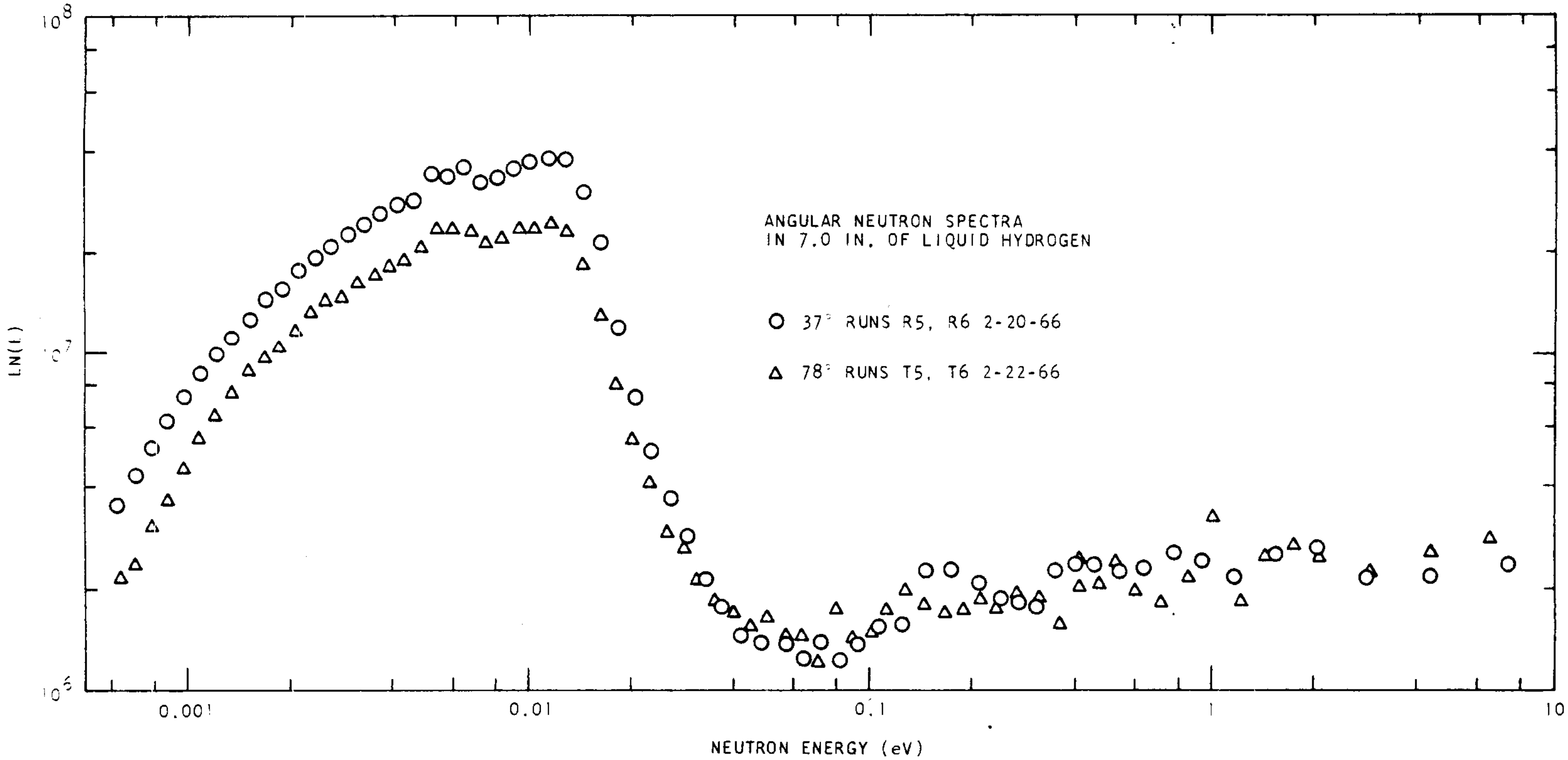


Fig. 5.3--Measured thermal neutron spectra in 7.0 in. of liquid hydrogen for 37 and 78°

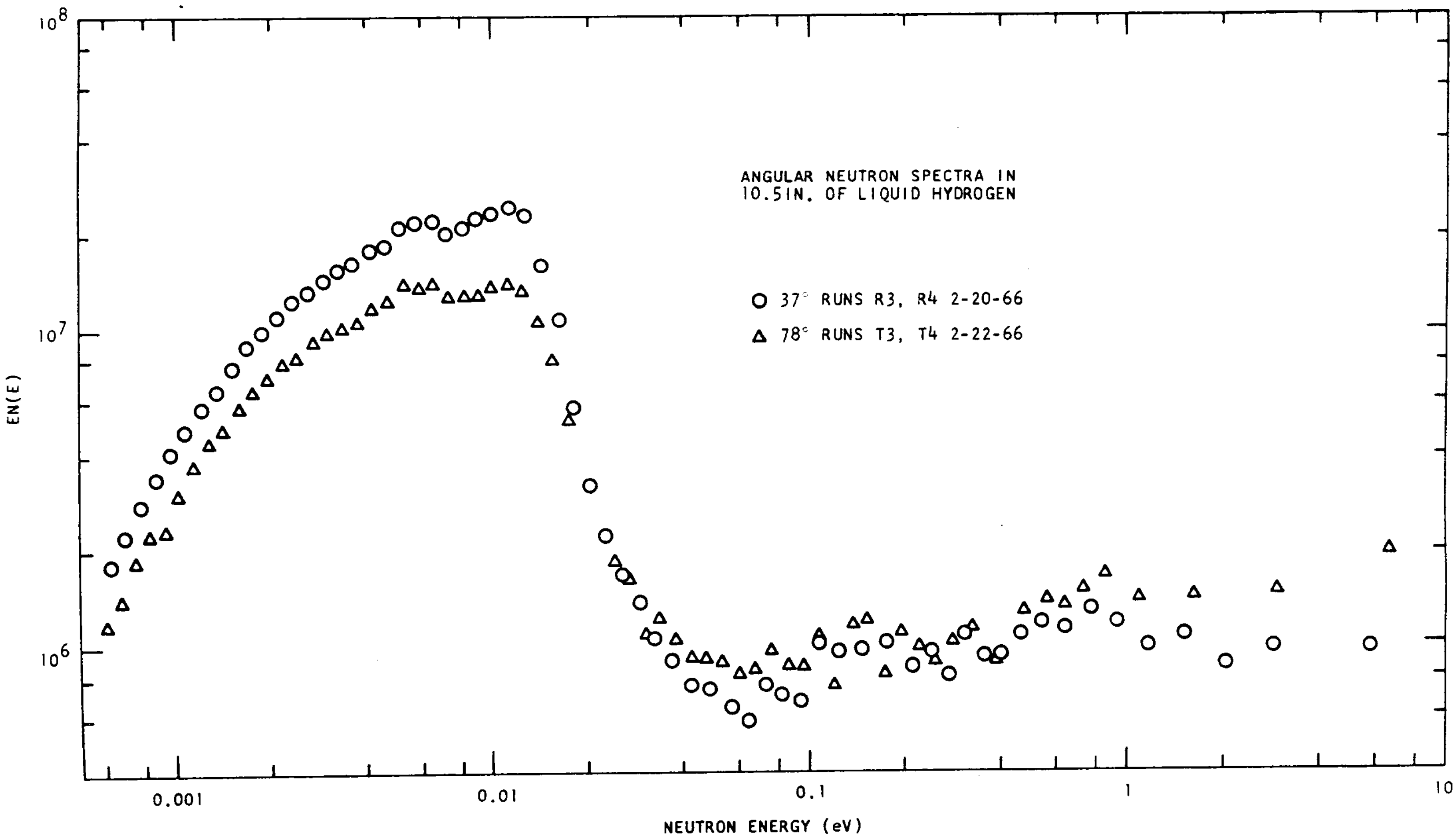


Fig. 5.4--Measured thermal neutron spectra in 10.5 in. of liquid hydrogen for 37 and 78°

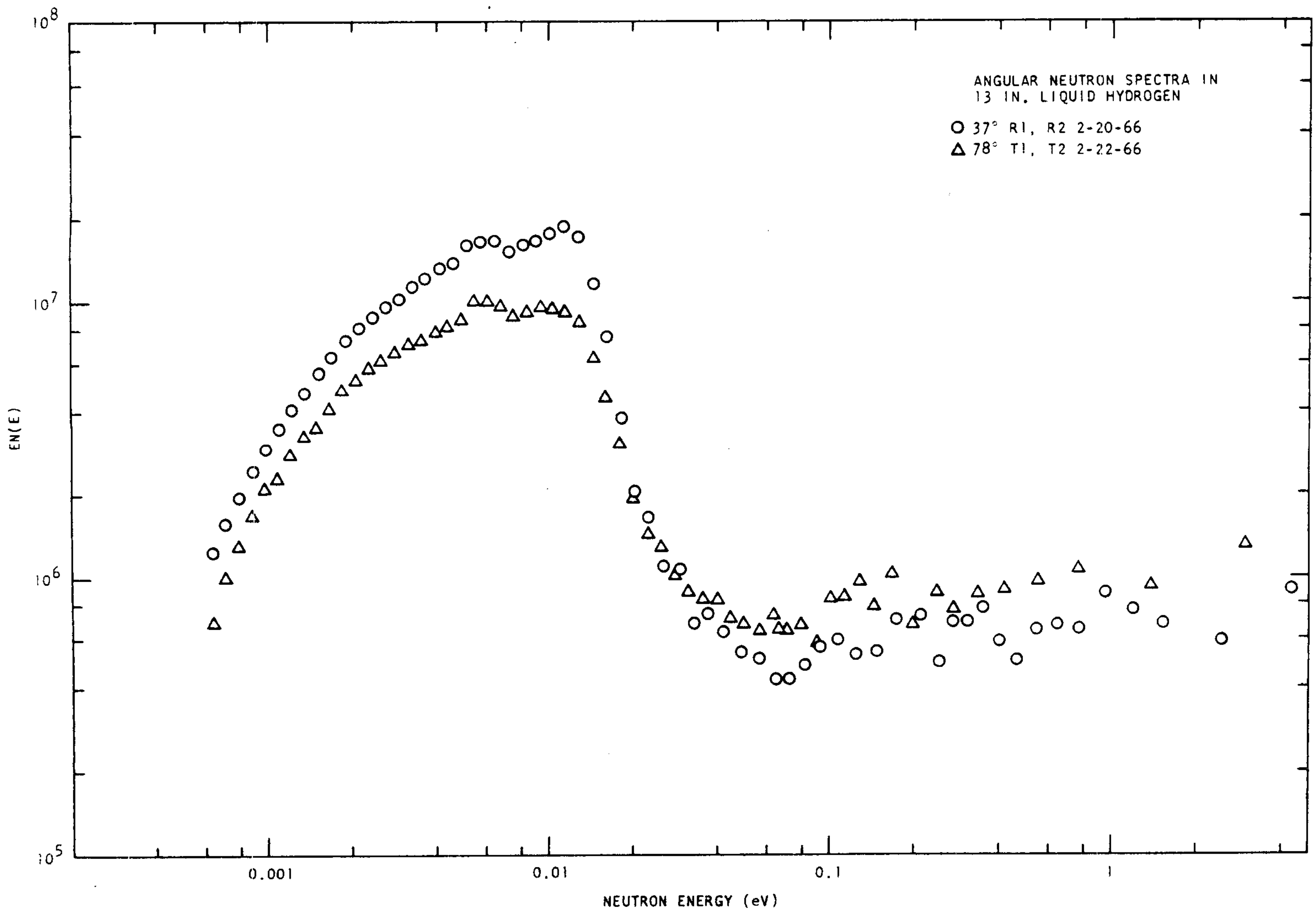


Fig. 5.5--Measured thermal neutron spectra in 13.0 in. of liquid hydrogen for 37 and 78°

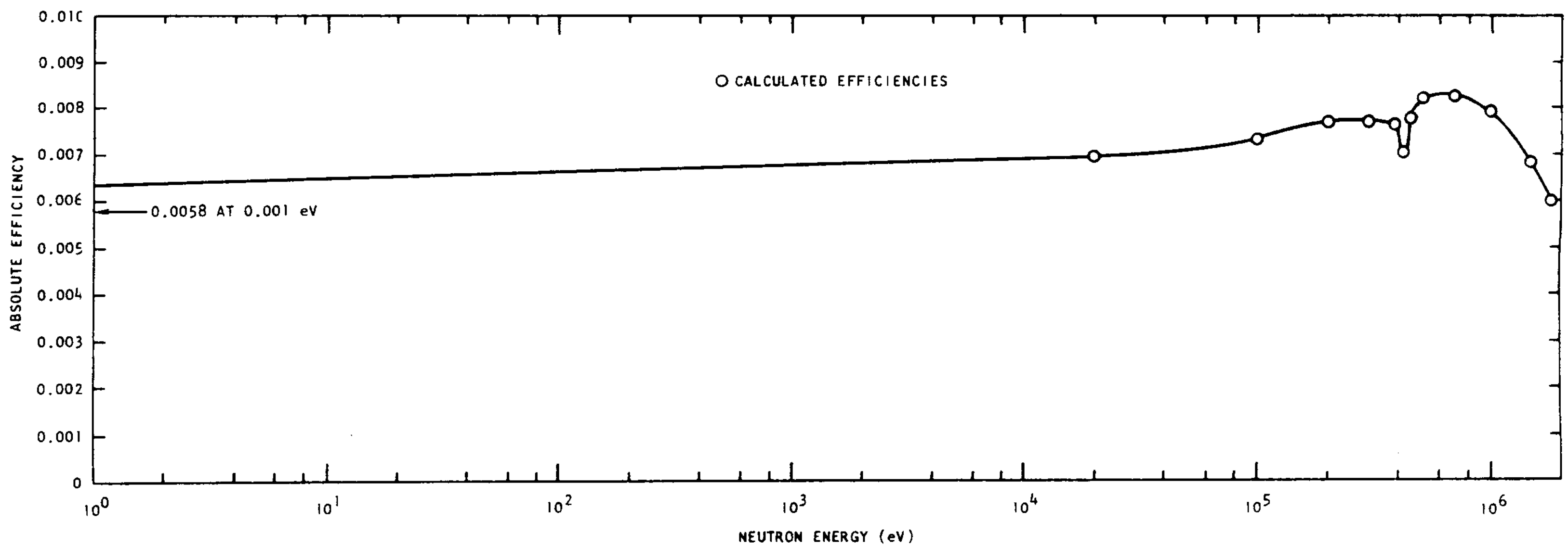


Fig. 5.6--Intrinsic detector efficiency, G(E), for the intermediate neutron detector.

Table 5.3

FLIGHT PATH MATERIALS FOR THE INTERMEDIATE NEUTRON MEASUREMENTS

Material	Thickness (cm)
Aluminum	.0254
Boron	.4455
Mylar	.0267
Air[a]	70.5
Lead	2.624
Stainless Steel	0.474
Helium[b]	53.65

[a]Air assumed at 50% relative humidity at 72^{o}F, and standard atmospheric pressure.

[b]Helium assumed at 20^{o}K and 5 psig

cross sections were averaged over the energy widths of the channels prior to use in HECTO.

The experimental results of the intermediate neutron spectra are shown in Figs. 5.7, 5.8, 5.9, 5.10, and 5.11.

5.4 FAST NEUTRON EXPERIMENTAL RESULTS

The intrinsic detector efficiency G(E) for the 5-in. diam. by 5-in. long fast neutron detector is shown in Fig. 3.14. The G(E) for the 2-in. diam. by 2.5-in. long fast neutron detector is not shown but was taken from the tabulated values of Verbinski, et al.[4] for a bias "cobalt" unit of .050. The flight path materials are tabulated in Table 5.4. These are composed of the following nine elements: carbon, hydrogen, oxygen,

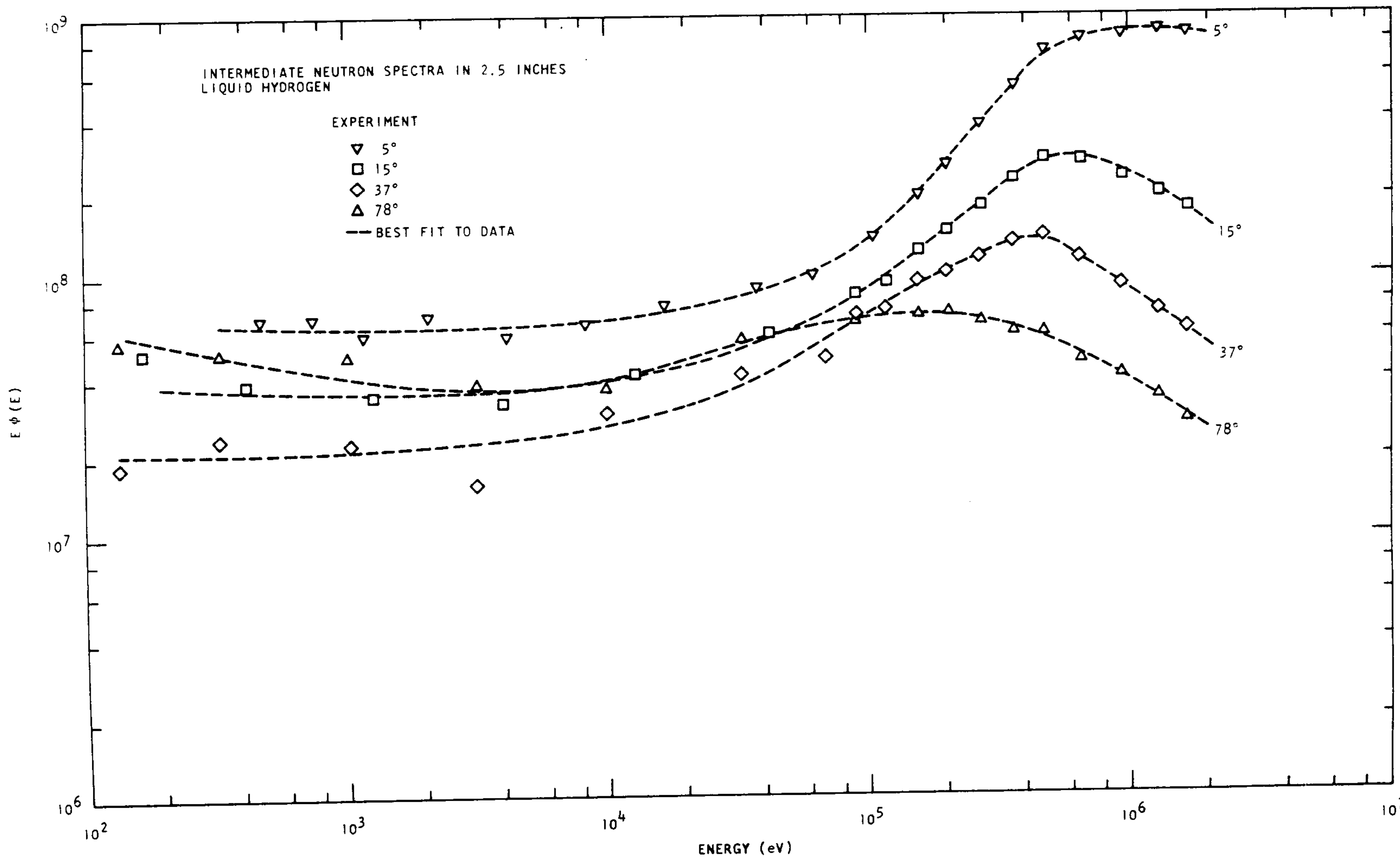


Fig. 5.7--Intermediate neutron spectra in 2.5 in. of liquid hydrogen for four angles

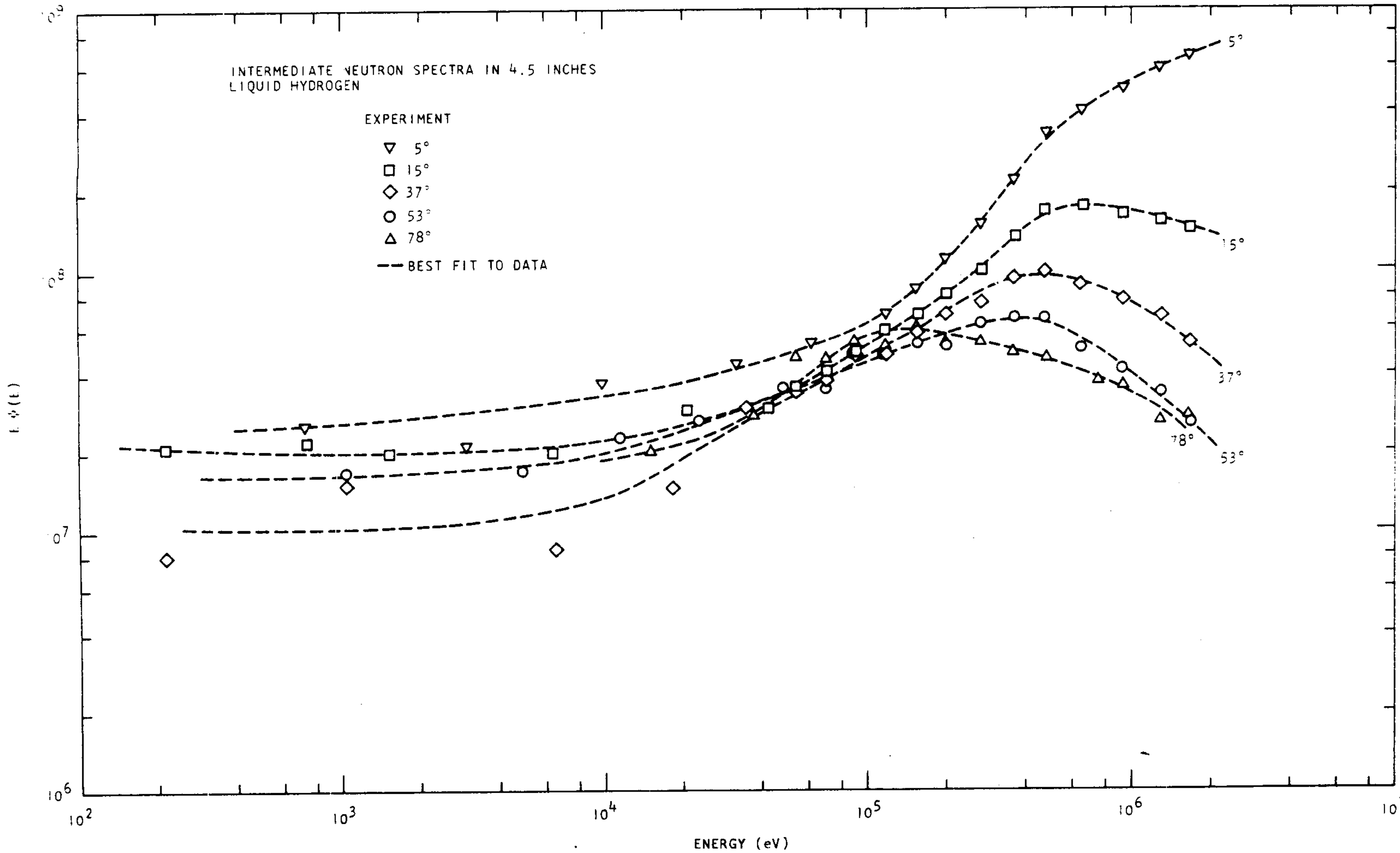


Fig. 5.8--Intermediate neutron spectra in 4.5 in. of liquid hydrogen for five angles

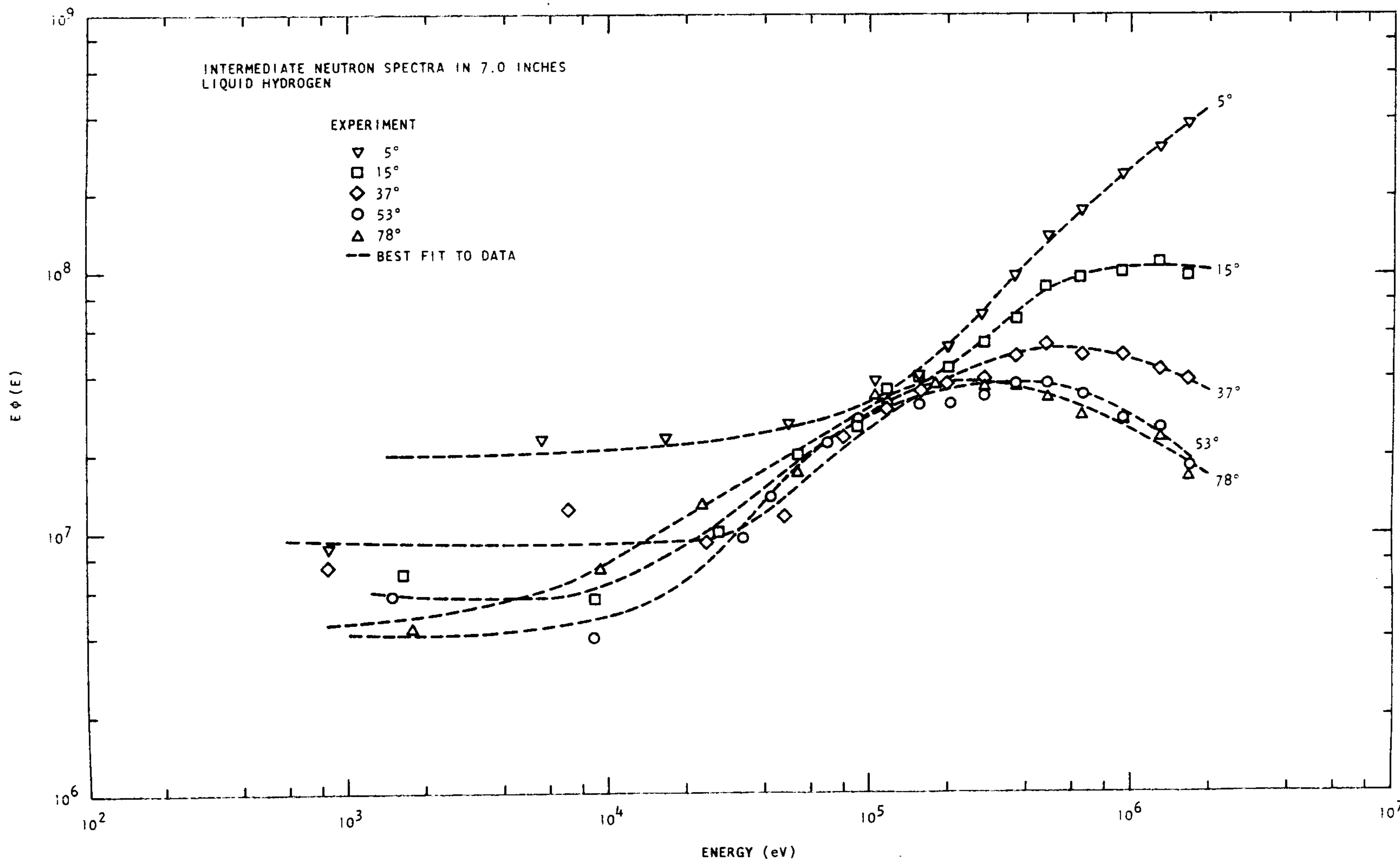


Fig. 5.9--Intermediate neutron spectra in 7.0 in. of liquid hydrogen for five angles

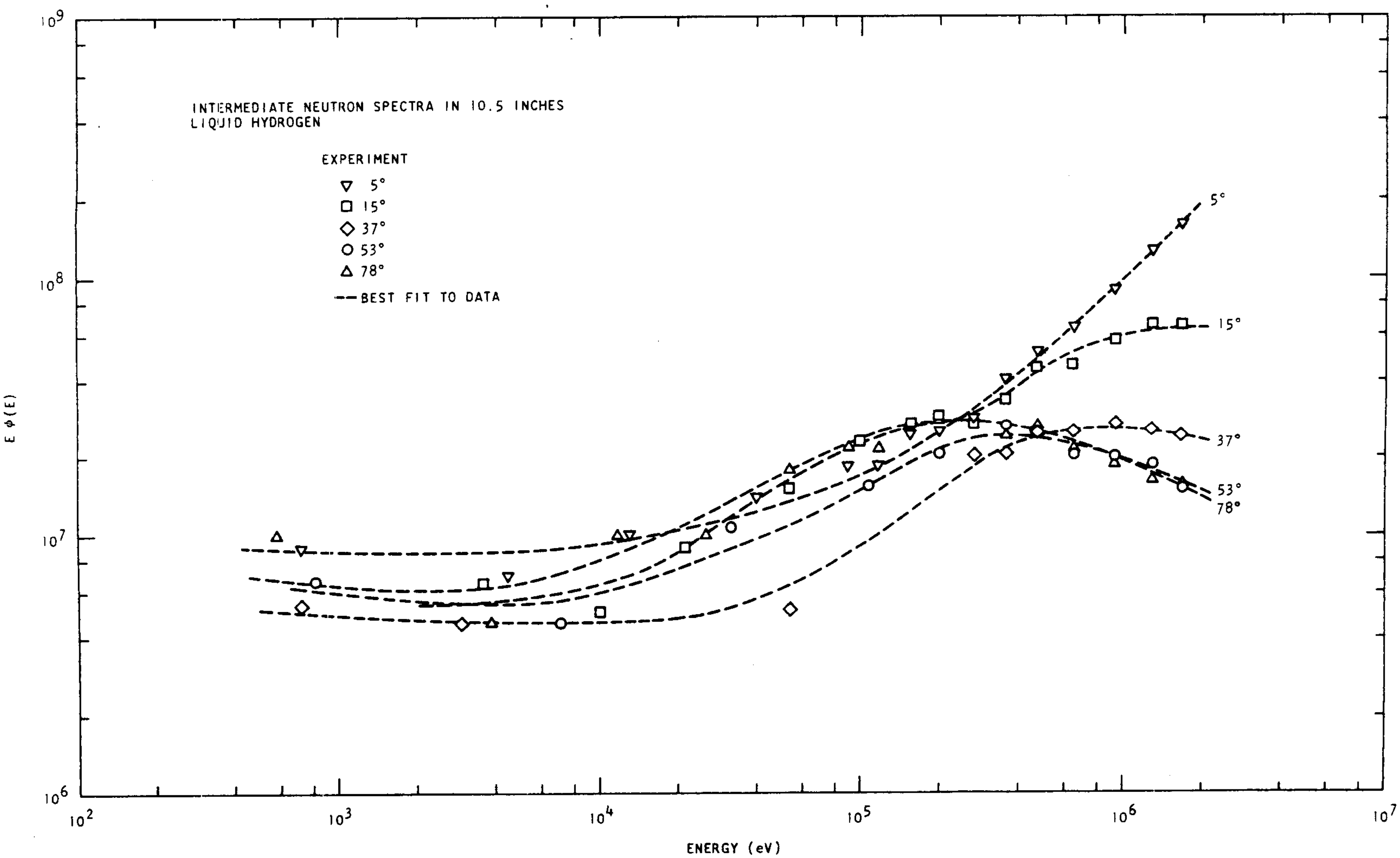


Fig. 5.10--Intermediate neutron spectra in 10.5 in. of liquid hydrogen for five angles

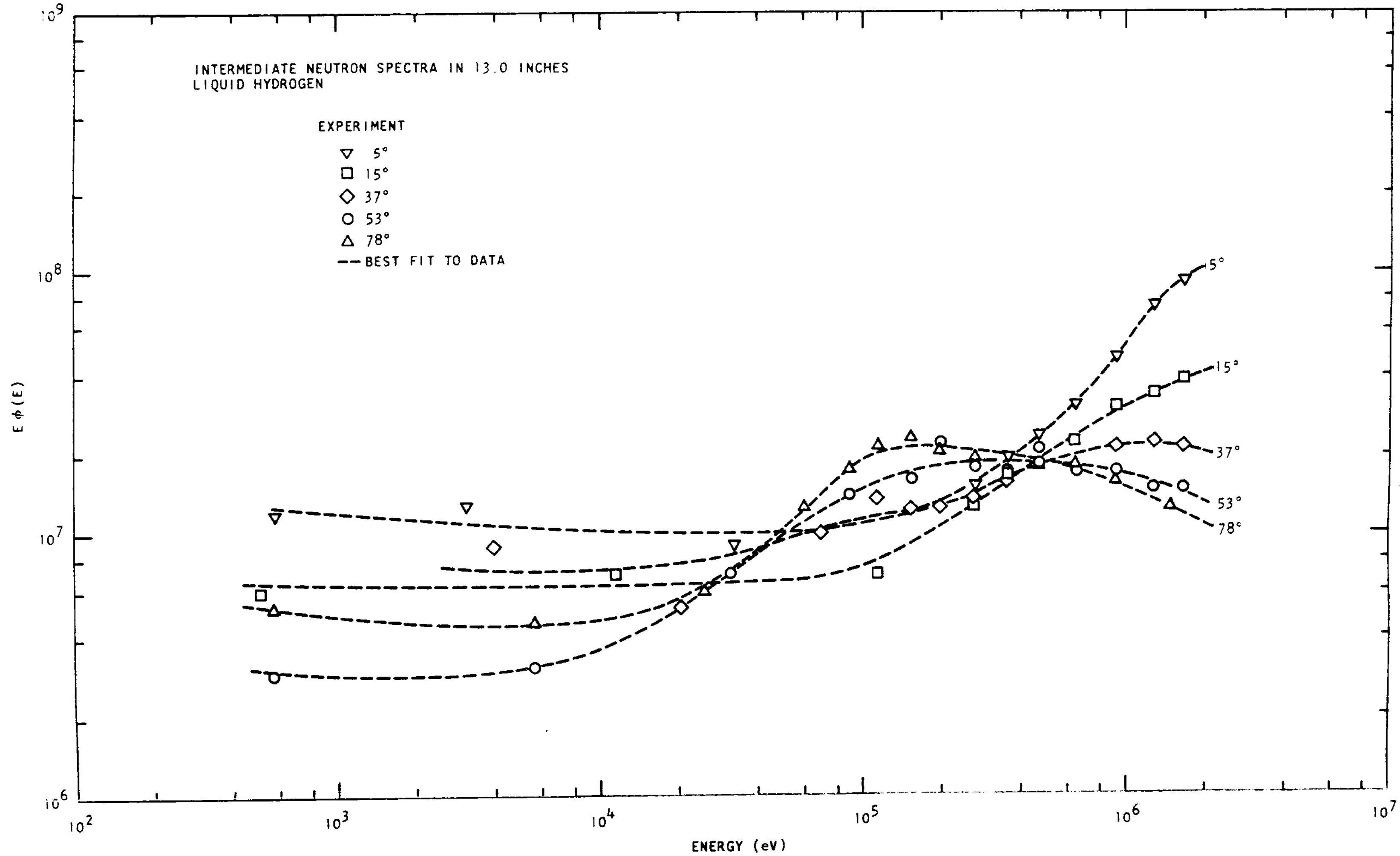


Fig. 5.11--Intermediate neutron spectra in 13.0 in. of liquid hydrogen for five angles

Table 5.4

FLIGHT PATH MATERIALS FOR THE FAST NEUTRON MEASUREMENTS

Material	Thickness for 5x5 in. Detector (cm)	Thickness for 2x2.5 in. Detector (cm)
Mylar	.0838	.0838
Poly	.020	.020
Air[a]	274.67	282.60
Stainless Steel	0.474	0.474
Uranium	3.144	3.144
Helium[b]	53.65	53.65

[a] Air assumed at 50% relative humidity at 72°F, and standard atmospheric pressure.

[b] Helium assumed at 20°K and 5 psig.

nitrogen, chromium, iron, nickel, uranium, and helium. The cross sections for these materials were taken from BNL-325, Suppl. 2, KFK-120, AWRE-0796, UCRL-5226, and KAPL-M-6452.

The experimental results for the 37° measurements are shown in Fig. 5.12 and for 0° in Fig. 5.13.

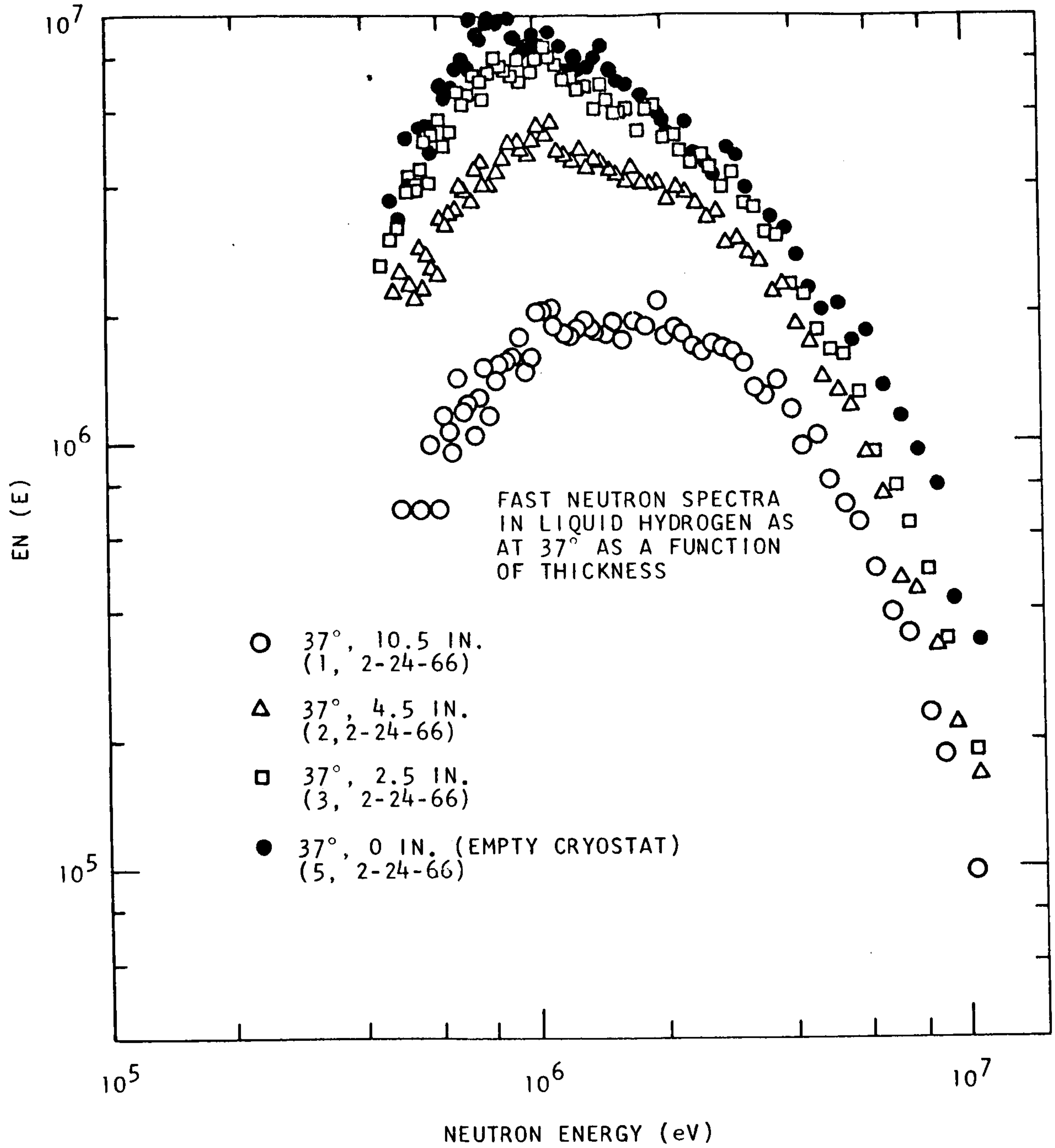


Fig. 5.12--Fast neutron spectrum measurements at 37° as a function of thickness

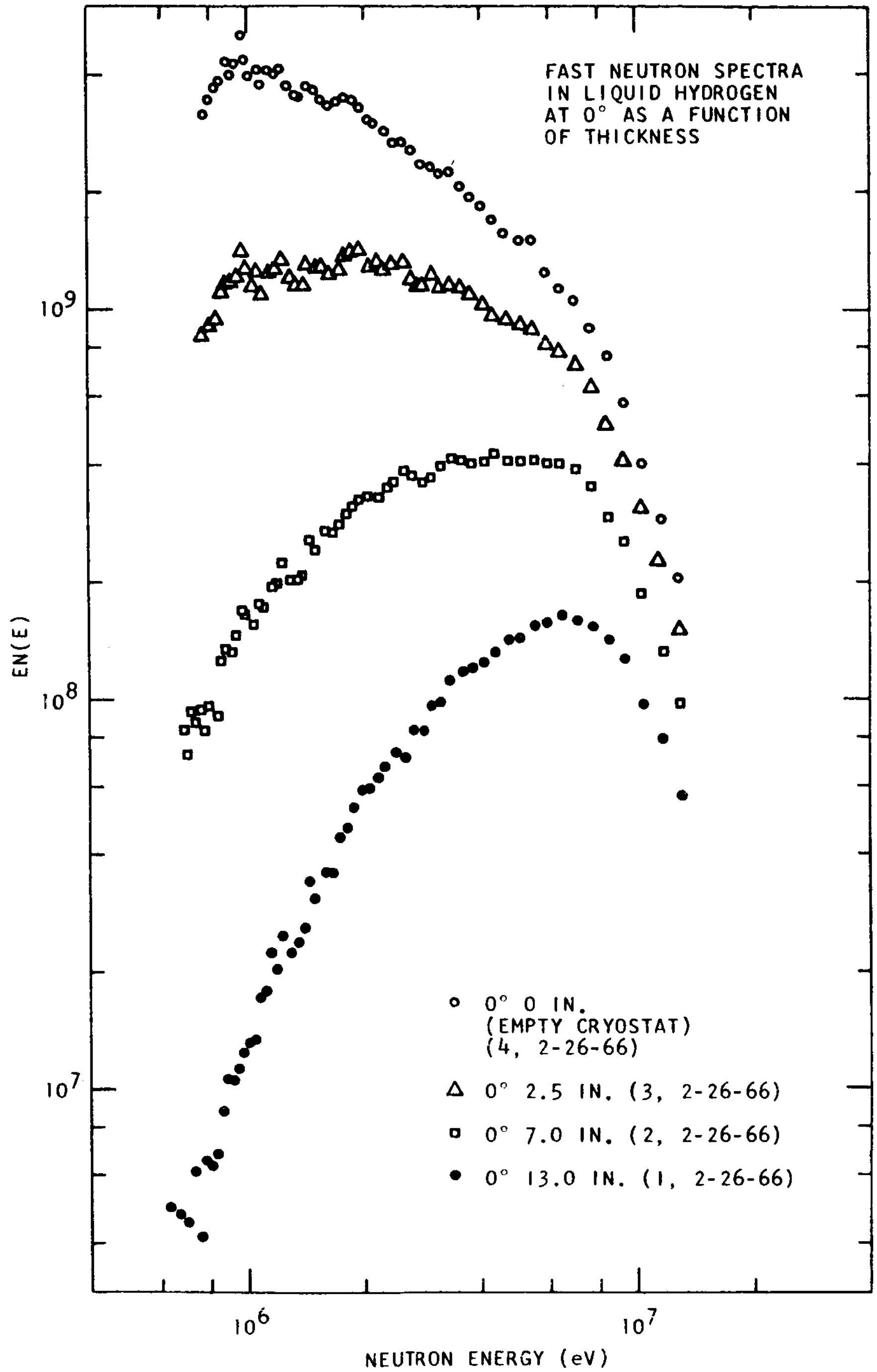


Fig. 5.13 --Fast neutron spectra at 0° as a function of thickness

VI. COMPARISON OF THEORY AND EXPERIMENT AND DISCUSSION OF RESULTS

6.1 THERMAL NEUTRON SPECTRUM MEASUREMENTS

A comparison of theory and experiment for the 2.5 and 13.0 in. thicknesses of hydrogen is presented in Figs. 6.1 and 6.2. The theory and experiment have been normalized in the 0.2 to 1 eV energy regions for the 78^{o} data. The agreement is good for the 78^{o} 13 in. thickness, however, as can be seen in the figure, the data for the 37^{o} measurement cross the data for 78^{o} at about .025 eV whereas the theory does not. At the other extreme for the 2.5 in. thickness, agreement between theory and experiment is not very good. As mentioned before the geometry for these measurements is two-dimensional represented essentially as a cylindrical container of LH_2 with an isotropic fission source at the end. The calculations were done in one-dimensional geometry (slab) with a surface source. It is not certain how much the slab geometry approximation affects the calculations. It is recommended that any further calculations be based on a two-dimensional transport or Monte Carlo theory so that the exact geometry may be included. The theory was based on an S_4 calculation and therefore represent a mean angle, e.g., the $78^{o}31'$ is a mean of $\mu = .5$ to $\mu = 0$ or $\bar{\mu} = .25$. The experimental angular resolution was between 2 to 3^{o}. The effect of the resolution used in the

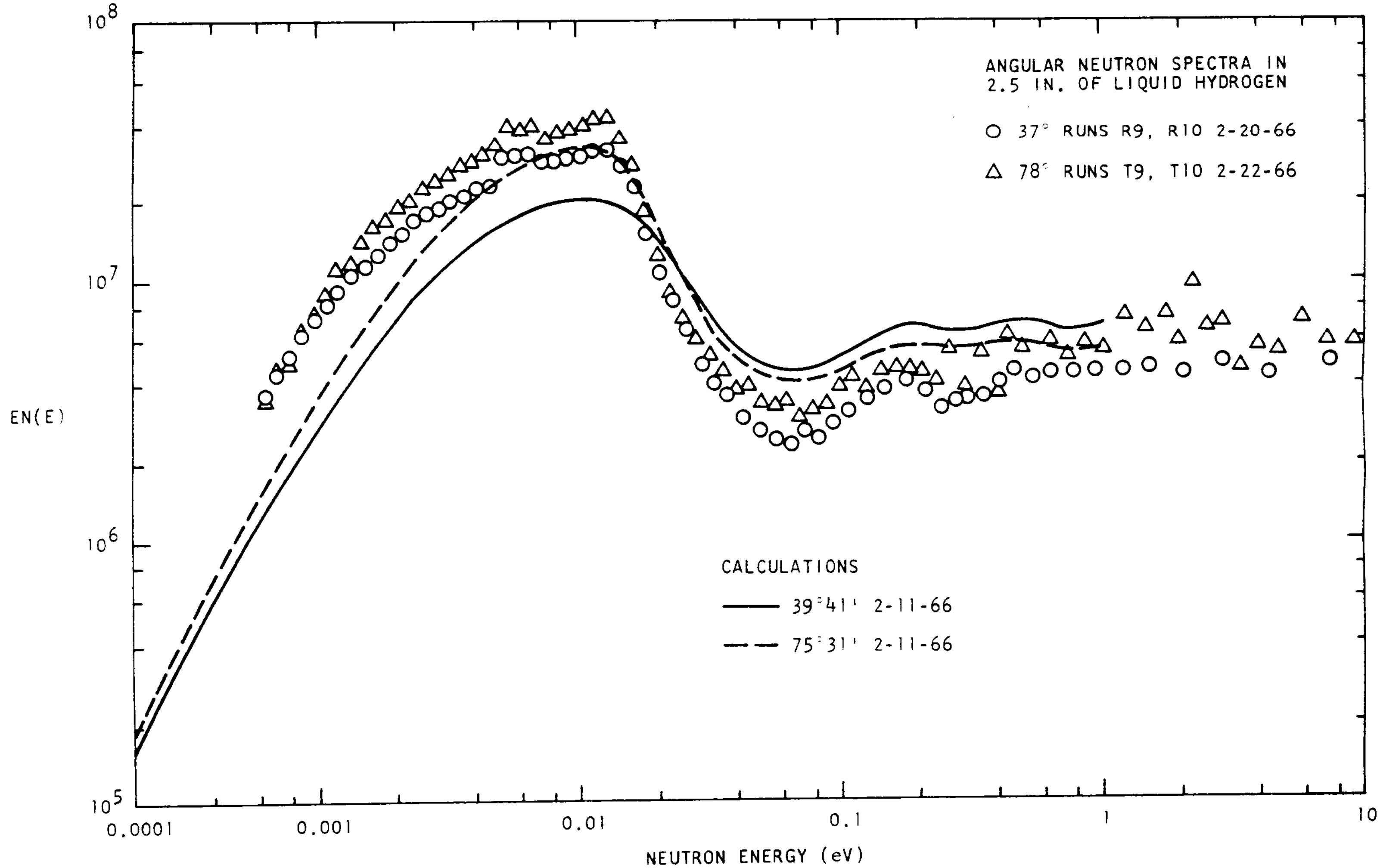


Fig. 6.1--Comparison of theory and experiment for thermal neutron spectra for 2.5 in. thickness of liquid hydrogen

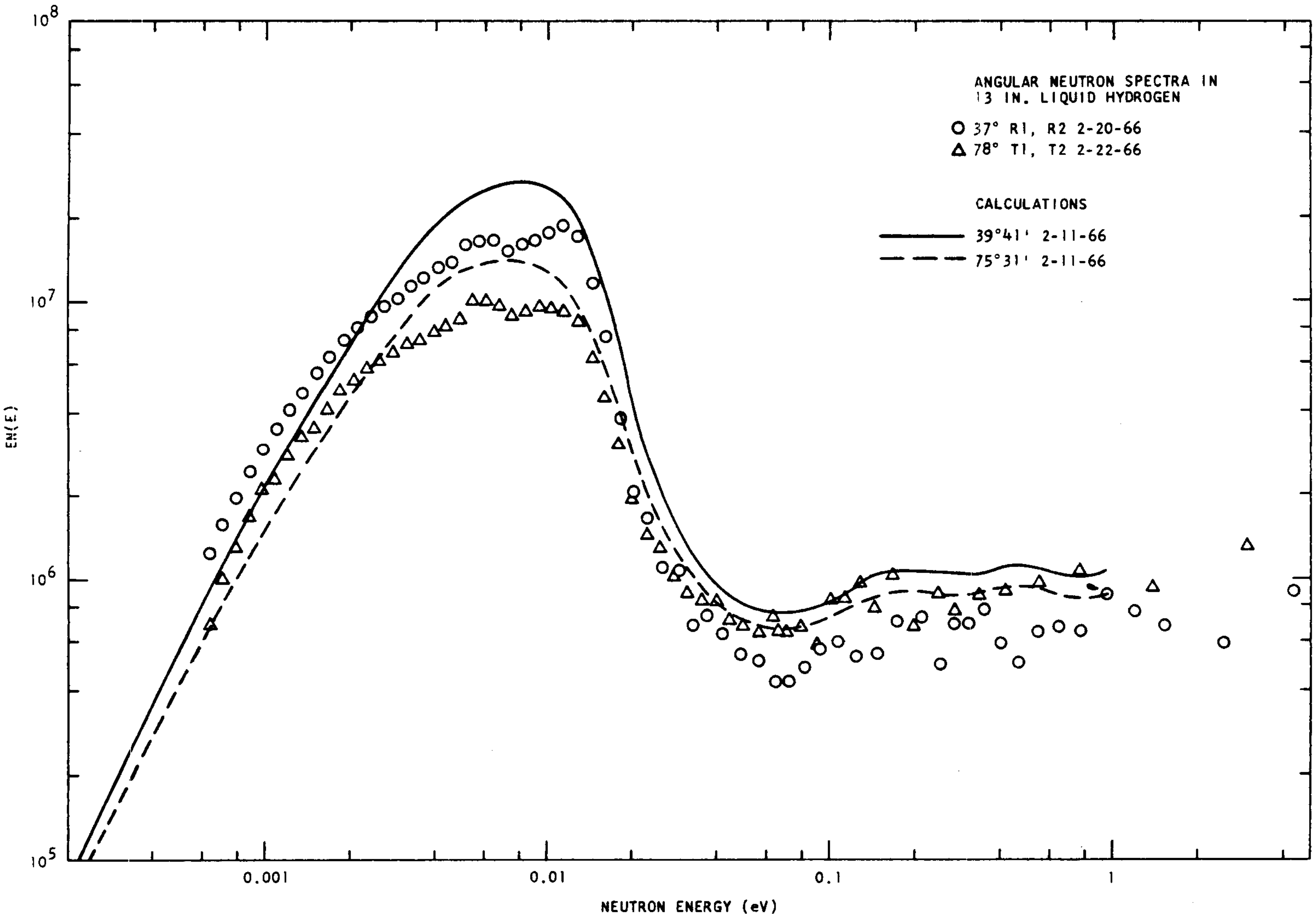


Fig. 6.2--Comparison of theory and experiment for thermal neutron spectra for 13.0 in. thickness of liquid hydrogen

calculations is about 20 to 30%, as can be seen by referring to Figs. 4.19, 4.20, 4.21, 4.22, 4.23, 4.24 for the smaller thicknesses for an S_8 calculation. It is therefore recommended that further calculations match more nearly the angular resolution of the experiment.

The Bragg cutoff energy for stainless steel is prominent in each of the measured spectra indicating that the transmission correction for the stainless steel was not correct and therefore either it cannot be appropriately described as a composite of its individual elements or the cross section in this energy region is not well known. To determine if the incorrect weight percents had been used in the transmission, pieces of the 304 stainless steel inner and outer windows used in the construction of the cryostat were chemically analyzed at General Atomic. The composition of the windows were the same within 1% and the average wt % for Fe, Ni and Cr from this analysis were used to reduce the data.

Although the agreement between theory and experiment is, in general, not the best, there is agreement concerning the rotational energy levels for the H_2 molecule. The transport cross section as calculated by Young and Koppel show rather broad maxima at energies of 0.066, .33, and .62 eV. These peaks correspond to favored spin flipping transitions in the parahydrogen. They show up in the neutron spectra as valleys and are so pronounced because the cross section is large and therefore the neutron population at these energies are low. These can be seen in Figs. 6.1 and 6.2 and in Sect. 5.2 for Figs. 5.1, 5.2, 5.3, 5.4, 5.5. It should also be noted that, in general, the 37° measurements lie below the 78° measurements in the 0.1 to 1 eV energy region whereas in the theory the converse is true.

As pointed out in Sect. 5.2 the cross sections for the flight path materials are not very well known below 0.001 eV and values for the cross sections in this region were extrapolated from existing data. In general, for Cr, Ni, and Fe these low energy cross sections were obtained by a 1/v extrapolation of the measured data. In the case of helium the cross section was calculated. These methods can result in rather large errors for the value of the cross section used in the transmission correction and is probably responsible for the discrepancy between theory and experiment in this energy region.

6.2 INTERMEDIATE NEUTRON SPECTRUM MEASUREMENTS

A comparison of theory and experiment for the intermediate neutron angular spectra is shown in Figs. 6.3, 6.4, 6.5. The angular neutron spectra for angles of 5, 15, 37, 53 and 78° are plotted for LH_2 thicknesses of 2.5, 4.5, and 7.0. All of the data are absolutely normalized for a particular thickness. The theory and experiment have been arbitrarily normalized at 1 MeV for the 15° data.

The empty cryostat angular spectra for angles of 5, 15, 37, and 78° are shown in Fig. 6.6. The empty dewar measurements enter indirectly into each measured spectrum since this is a secondary source viewed directly through the intervening thickness of LH_2 as a result of the containment vessel (cryostat). The effect of this secondary source is more prominent for the small angle, small thickness measurements. The data for the angular neutron spectra in the intermediate or fast region have not been corrected for the effect of this secondary source and are therefore

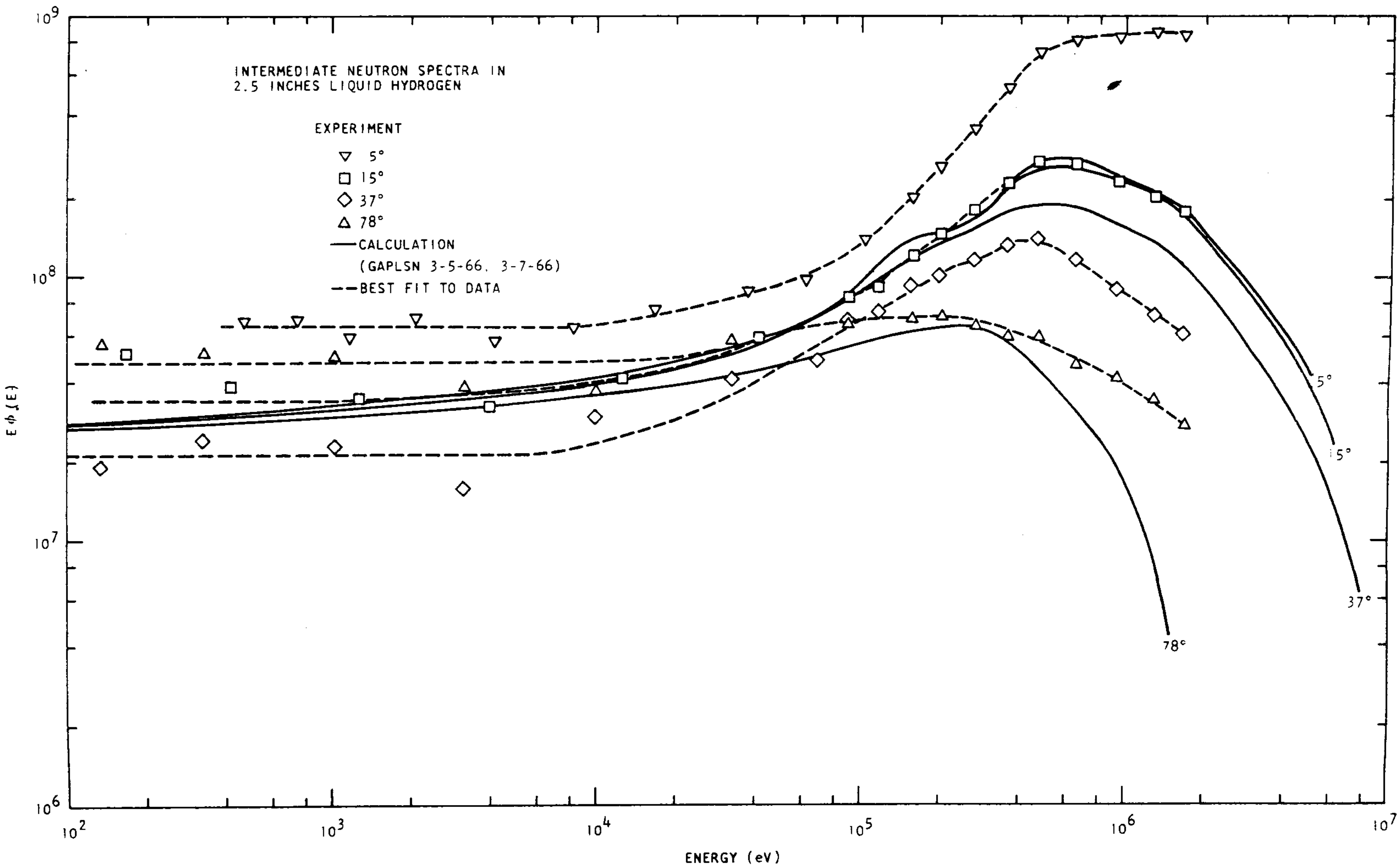


Fig. 6.3--Comparison of theory and experiment for intermediate neutron spectra for 2.5 in. thickness of liquid hydrogen

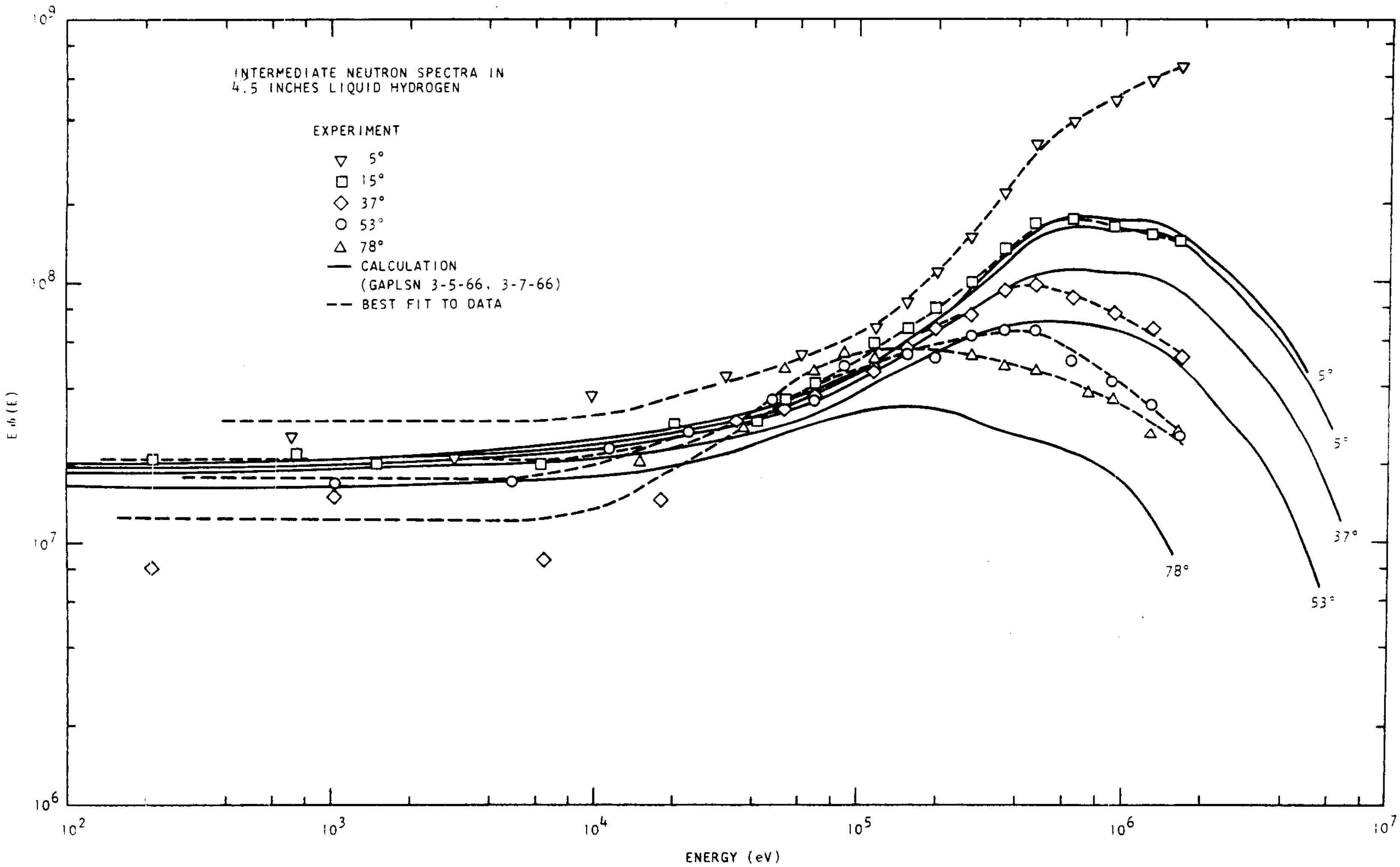


Fig. 6.4--Comparison of theory and experiment for intermediate neutron spectra for 4.5 in. thickness of liquid hydrogen

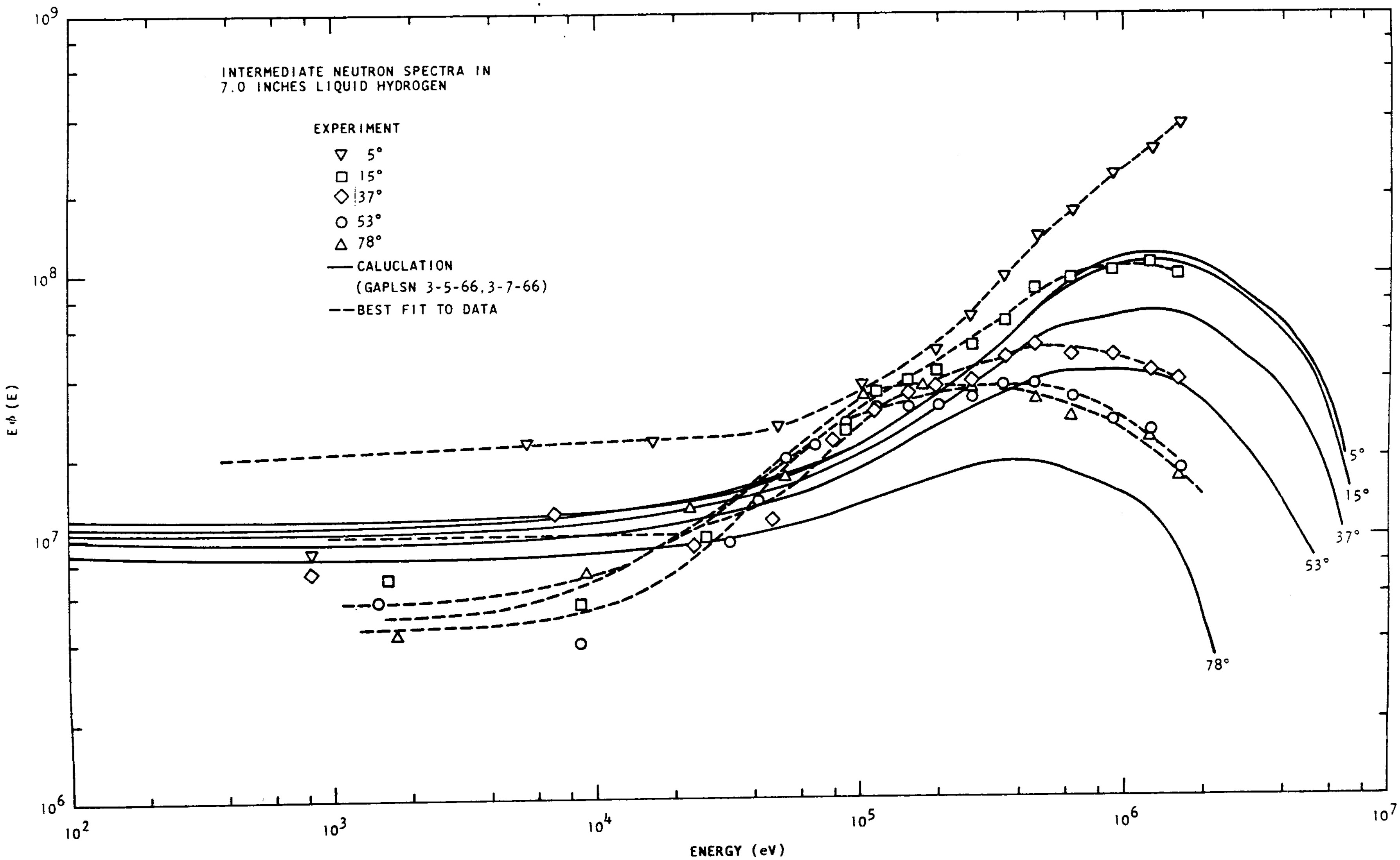


Fig. 6.5--Comparison of theory and experiment for intermediate neutron spectra for 7.0 in. thickness of liquid hydrogen

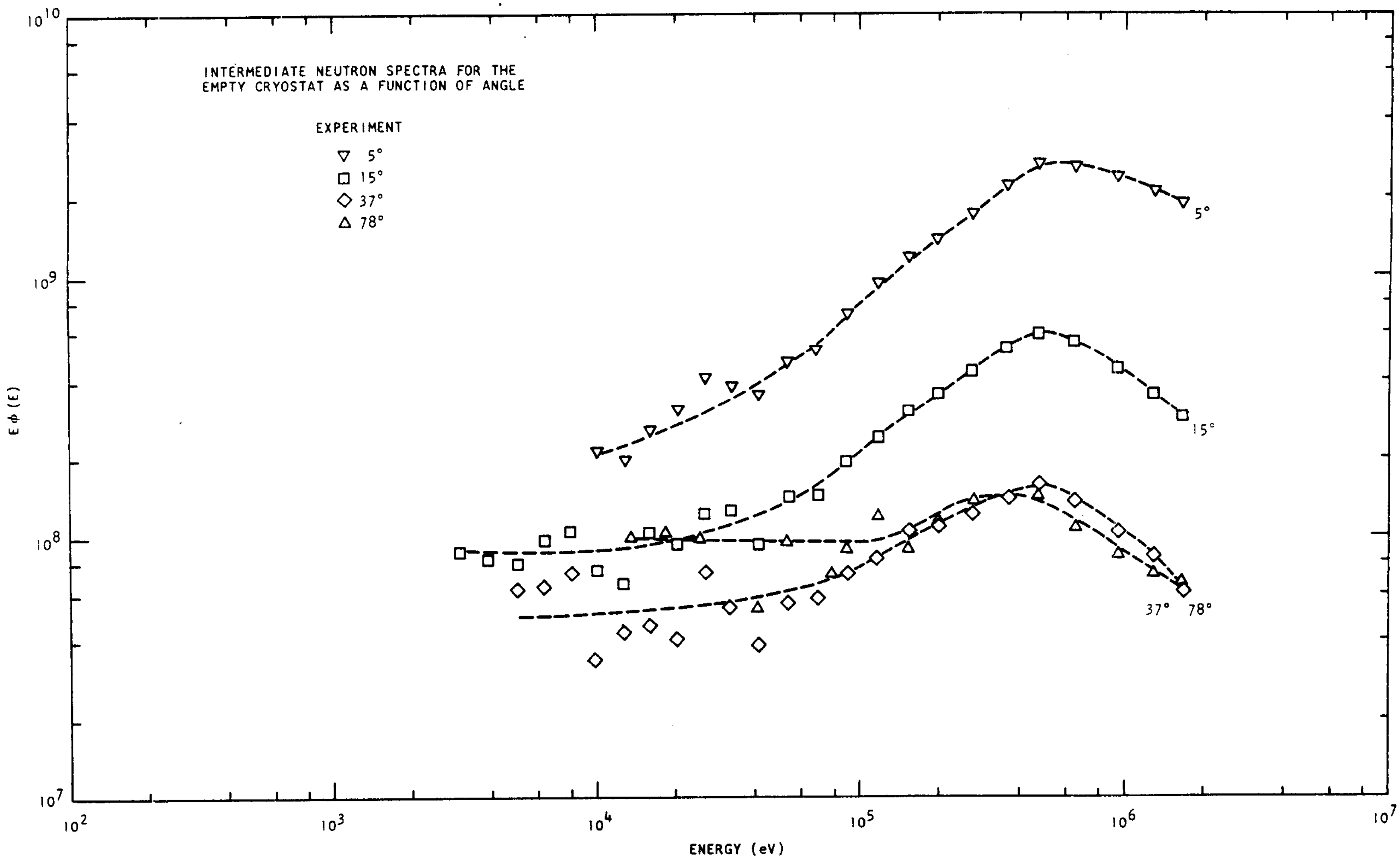


Fig. 6.6--Intermediate neutron spectra as a function of angle for the empty cryostat

consistent with the data presented in the final report on Contract NAS-34214 (NASA CR-54230). The theoretical comparison is for the calculation described in Sect. 4.2. In addition to the usual correction for ambient background, the data have also been corrected for a gamma background. In some cases this correction was significant especially at the large angle, large thickness measurements. Both theory and experiment exhibit the same shift of the spectral peak to high energies as the thickness of LH_2 increases with a gradual breaking into a 1/E tail at around 10^4 eV. However, as in the fast neutron spectra, a comparison of theory and experiment shows a more forward peak in the calculations than in the experiments. A portion of this is undoubtedly due to the fact that the secondary source has not been removed from the experiment but this effect will not account entirely for this disagreement. Therefore, it must be concluded that slab geometry is not an accurate description of the geometry of the experiment and it is recommended that a two-dimensional calculation be used for any further theory-experiment comparison.

6.3 FAST NEUTRON SPECTRUM MEASUREMENTS

A comparison of theory and experiment for thicknesses of 2.5, 4.5, and 10.5 in. of liquid hydrogen at an angle of 37° is shown in Fig. 6.7. The theoretical comparison is the 11-9-65 GGSN spherical

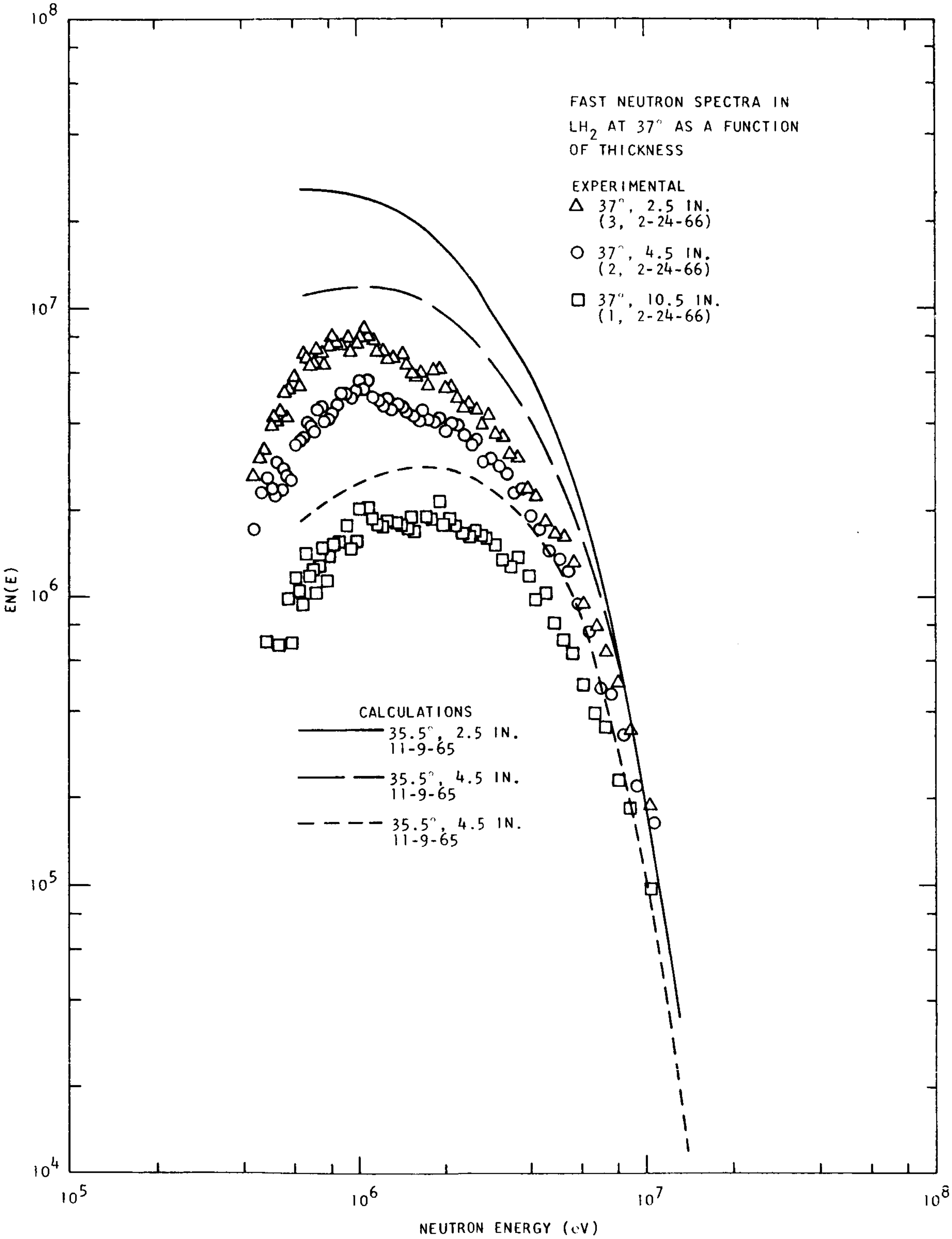


Fig. 6.7--Comparison of theory and experiment for fast neutron spectra at 37°

calculation described in Sect. 4.1.1 and plotted here as EN(E) vs E. In general, agreement in shape is good, even so, the angular distribution has apparently not been calculated accurately. Similar theoretical calculations using slab geometry (not shown) also show approximately the same disagreement. As described in Sect. 4.1 attempts to calculate these spectra in one-dimensional transport theory using GAPLSN have not been successful. In the case of spherical geometry the source description is perhaps more accurate but the geometry, i.e., representing plane surfaces as spherical, is not. In the case of the slab calculation the geometry is described accurately but the true angular distribution of the neutrons incident in the experiment cannot be reproduced exactly, since the input description does not allow for radial dependence of angle or intensity.

Comparison of experiment and theory shows that the angular distribution is considerably more forward peaked in the calculations than in the experiments.

Our conclusion is that neither the sphere or the slab calculations are able to represent the geometry of the experiment, and two-dimensional calculations are needed.

In Fig. 5.13 the 0° measurements are shown for thicknesses of 2.5, 7.0, and 13.0 in. The empty cryostat spectrum is also shown for reference. From these data it can be concluded that even in the worse case of 13 in. and 1 MeV, the measured spectrum is the uncollided flux to within a few percent. The data in Fig. 5.13 are absolutely normalized with respect to each other and represent essentially a fairly good geometry transmission experiment for LH_2. The 0^o empty cryostat spectrum takes into account the stainless steel of the heads, baffles, and windows of the probe tube such that the 0^o measurements for the thicknesses is just the transmission for those thicknesses. The significance of this is that in the 0^o direction the spectrum is composed essentially of uncollided neutrons.

APPENDIX A

CHECKOFF LIST AND OPERATIONAL AND EMERGENCY PROCEDURES

VENTILATION CHECK SIGNED ____________________

1. ____________ Turn on 18 in. hole blower. Switch at panel by console.

2. ____________ Turn on 6 in. hole blower and direct flow down 6 in. hole. Switch at panel by console.

3. ____________ Turn on room pressurizing blower, switch at panel by console.

4. ____________ Check to see that all seams in sheet metal building are taped and still holding.

5. ____________ Check that flexible trunk for room pressurizing blower is in position inside sheet metal building. Check that small trunks are in position.

6. ____________ Check to see that valve package and dewar liquid air drip pans are in place.

7. ____________ Check air flow patterns.

8. ____________ Turn off Linac accelerator room exhaust.

EXPERIMENTAL SETUP CHECK SIGNED ____________________

(A) DEWAR POSITIONING

1. ____________ Open probe tube tower valve, probe tube helium valve, and vacuum relief valve. Set probe tube helium bottle at 5 psig, then purge with helium. Close probe tube helium valve and vacuum relief valve.

2. ____________ Turn on vacuum pump at electrical junction box.

3. ____________ Open tower probe valve, make sure tower dewar valve is closed, and open valve package probe valve.

4. ____________ Set dewar to angle to be measured and lock.

5. ____________ Check probe alignment with room marks.

6. ____________ Vacuum/Helium cycle four times. Leave probe tube at vacuum by closing probe tube tower valve, probe tube helium valve. Open vacuum relief valves and let vacuum pump up to helium, then close vacuum relief valve.

7. ____________ Check dewar height and level.

8. ____________ Check that proper beam tube/window has been installed.

(B) SOURCE POSITIONING

1. ____________ Test monitor positioning and seating device.

2. ____________ Mount 3 in. water cooled depleted uranium source.

3. ____________ Hook up air cooling line on beam tube window.

4. ____________ Hook up water cooling lines on depleted uranium source. Turn on pump and check for leaks - set water flow at 5 gpm.

5. ____________ Hook up target lead for depleted uranium source.

6. ____________ Check condition of stainless steel scintillator screen.

7. ____________ Check to see that source thermocouple is hooked up with proper polarity.

EXPERIMENTAL SETUP CHECK (Contd.)

(C) INTERIOR FLIGHT PATH AND COLLIMATION

1. ____________ Check that correct collimators are installed.

2. ____________ Check background plug.

3. ____________ Check that shielding is in place around collimators.

(D) TV SYSTEM

1. ____________ Observe and approve the operator's TV pictures.

ELECTRICAL CHECK   SIGNED ____________________

1. ____________ Turn on explosion proof lights and check.

____________ Experimental Room (4)

____________ Bottle Farm

2. ____________ Turn on back area outdoor lights

____________	HP door	____________	Boron Building
____________	Cooling Tower	____________	Filling Station
____________	Stairway	____________	16 Meter Building
____________	Bottle Farm	____________	Stairway (bottom at back area)

3. ____________ Inspect velostat cover over α-magnet and steering magnets.

4. ____________ Inspect velostat cover over all three TV systems.

5. ____________ Inspect velostat cover over cave water pump system.

6. ____________ Check all experimental room experimental areas to be sure no detectors, preamps, amplifiers, etc., have any power on.

7. ____________ Tape all experimental room terminal board connections with signs saying "Do not use until LH_2 experiment is finished."

TRAILER AREA CHECK SIGNED ____________________

1. ____________ Attach grounding cable to trailer.

2. ____________ Post "No Smoking" signs at trailer.

3. ____________ Check level of LH_2 in trailer - __________ gals.

4. ____________ Attach 110 vac. extension cord for supply trailer vacuum pump. (Do not disconnect until after shut down.) Check vacuum.

5. ____________ Put LOX drip pan under supply trailer.

6. ____________ Check that pressure on supply trailer is between 4 and 5 psia.

7. ____________ Close transfer bypass and open dewar purge valve. Then open fill valve and leave open so as to purge transfer line while making connection to supply trailer.

8. ____________ Connect transfer line to trailer and tighten with spanner wrench.

9. ____________ Close fill valve.

BOTTLE FARM CHECK SIGNED ____________________

1. ____________ Check bottle supplies at bottle farm and tower to see that bottles are full; all bottles except the first one in the valve operator and emergency purge systems should be wide open.

2. ____________ Gas Bottle Check.

   ____________ Bottle nitrogen on magnet, TV system, and cave water purge.

   ____________ Bottle nitrogen on valve operators.

2A. ____________ Check helium tank trailer to see that valve is open.

3. ____________ Set pressure regulators.

   ____________ Main purge system at 35 psig.

   ____________ Magnet, etc., purge system at 20 psig.

   ____________ Transfer regulator at 8 psig.

   ____________ Valve operators at 50 psig.

4. ____________ Check that all manual by-pass valves are closed.

5. ____________ Adjust helium flow on micropurges with needlevalves.

   ____________ Dewar micropurge - make sure all valves are closed except dewar micropurge and vent isolation valve, then adjust dewar micropurge to _____ ft^3/hr. Then close dewar micropurge and vent isolation valve.

   ____________ Vent micropurge - open vent micropurge valve and adjust flow to _____ ft^3/hr.

   ____________ Dump micropurge - open dump micropurge valve and adjust flow to _____ ft^3/hr.

6. ____________ Vent line flapper valve operation.

ELECTRICAL POWER REMOVAL CHECK

SIGNED ____________________

1. ____________ Put switch located on Linac Control Console in C-LH position and turn key for LH interlock.

This switch removes power to V6, deactivates the radiation sign on the "B" - "C-D" wall on the "C-D" side, shorts out all "red button" scrams in the "B" and "C-D" area but allows scrams in the "A" area to be activated, removes power to the "red lights" on the scrams, and removes power to the interlocks for the north tunnel door.

2. ____________ Turn off the following circuit breakers on the panel in the "B" area at the corner of the entrance from the main shield door to the "red" door. These are all labeled "LH". The following are on the right hand side of the breaker panel:

____________ #8 controls 208 VAC under 12m-70m precollimators.

____________ #10 controls 110 VAC outlets under α-magnet.

____________ #12

____________ #14 controls north tunnel door power and 110 VAC outlets below cave water panel.

____________ #16

____________ #18b (bottom) controls the 110 VAC circuits by 16 MFP and Juno alarm circuits.

____________ #20

____________ #26A (top) controls 110 VAC outlets under the 12 and 70 MFP and also 110 VAC outlets in corner near four target storage pigs.

ELECTRICAL POWER REMOVAL CHECK (Contd.)

The following are on the left hand side of the breaker panel:

_________ #9

_________ #15

_________ #19 controls 3Ø on 208 VAC outlet near APFA area.

_________ #25A (top) controls 110 VAC outlet marked 25 located in APFA area.

_________ #27B (bottom) controls 110 VAC outlet marked 27 located in APFA area.

3. _________ The following other switches and functions must be done.

A. _________ Shut off pump stand 4 switch.

B. _________ Shut off circuit 5 marked "Clydes".

C. _________ Shut off pump stand 4 ionization gauge power supply.

D. _________ Shut off pump stand 3 ionization gauge power supply.

E. _________ Turn on pump stand 3 main power.

F. _________ Turn on ionization gauge power supply 3. Put switch in pump stand 3 position.

G. _________ Unplug Clyde's controller system on top of magnet control rack.

H. _________ Pull Whittemore's air and water flow plug.

I. _________ Pull Haddad's water pressure plug and put in shorting plug.

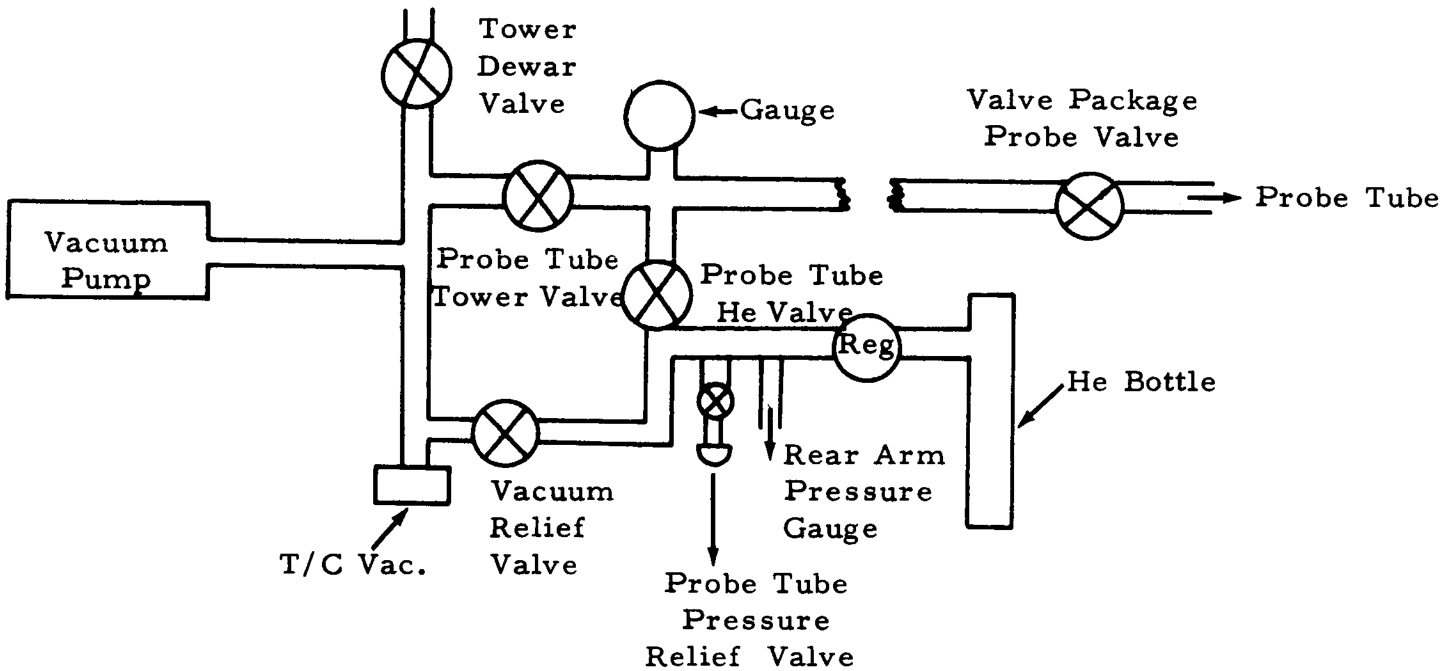
J. _________ Jumper CO 118-36 to CO 118-37. (This shorts out north tunnel door switch and allows completion of interlock chain.)

K. _________ Put cave water selector switch in cave position.

L. _________ Lift CO 116-30 wire (turns off green lite in "C-D" area which indicates the Linac is on).

M. _________ Lift two wires on back of trigger generator marked RE-1 normally open and closed (this controls the chimes on single pulsing).

TOWER AREA CHECK SIGNED ____________________



1. ____________ Check that probe tube bottle is helium, and regular is set at 5 psig.

2. ____________ Check aluminum monitor operation.

3. ____________ Check boron filter background plug operation.

4. ____________ Turn on blower for wooden shack and check flow.

5. ____________ Evaluate alignment port.

WARNING AND SAFETY SYSTEM CHECK

SIGNED ____________________

1. ____________ Turn on H_2 sensor panel at least 24 hours before start of experiment.

2. ____________ Check out all H_2 sensors with lecture bottle.

   ________ Rear Area ________ Tower

   ________ 18 in. Hole ________ Roof Cavity

   ________ Valve Package

3. ____________ Check adjustments so that TV camera views the dewar and vent lines.

4. ____________ Observe Operator's TV picture and approve.

5. ____________ Vacuum Checks

   ________ Dewar Insulation Space.

   ________ Dewar Alignment Port - Battery operated thermocouple gauge at tower.

   ________ Storage Dewar Insulation Space.

6. ____________ Thermocouples

   ________ Position chart in place at recorders

   ________ Calibration chart at recorders.

   ________ Cu/Con reference dewar filled with LN_2.

   ________ Thermocouple operation.

WARNING AND SAFETY SYSTEM CHECK (Contd.)

Cu/Con		Fe/Con		
______ 1	______ 7	______ 1	______ 7	______ 13
______ 2	______ 8	______ 2	______ 8	______ 14
______ 3	______ 9	______ 3	______ 9	______ 15
______ 4	______ 10	______ 4	______ 10	______ 16
______ 5	______ 11	______ 5	______ 11	
______ 6	______ 12	______ 6	______ 12	

7. ____________ Check operation of the Fe/Con T/C Linac interlock. (Red light on panel is on when interlock is complete.)

8. ____________ Turn on liquid level indicators and visually check panel for damage.

9. ____________ Check all intercom elements for operation.

    ____________ 50 meter flight path
    ____________ 16 meter flight path
    ____________ 12 meter flight path
    ____________ Gas bottle area
    ____________ Rear entrance area
    ____________ Tower area
    ____________ Linac Operator

10. ____________ Disconnect dewar area intercom and sound powered phones.

11. ____________ Thermocouple resistors (record resistance).

____________ 1C	____________ 3C	____________ 5C
____________ 1B	____________ 3B	____________ 5B
____________ 1A	____________ 3A	____________ 5A
____________ 2C	____________ 4C	____________ 6C
____________ 2B	____________ 4B	
____________ 2A	____________ 4A	

VALVE PACKAGE CHECK SIGNED ____________________

1. ____________ Visually inspect all gas and liquid lines, for damage.

2. ____________ Visually inspect all welded and threaded gas and liquid lines connections for damage and tightness.

3. ____________ Visually inspect pneumatic valves for damage.

4. ____________ Check to see that all manual over-ride valves are closed and all manual bleed valves are open. Check to see that the stuffing box vent valves are open.

5. ____________ Visually and physically check liquid level cables at dewar.

6. ____________ System leak check.

   (a) __________ Close the following valves; dump, vent No. 1, vent isolation.

   (b) __________ Open dewar purge valve and pressurize to 20 psig.

   (c) __________ "Snoop" test all soldered joints and fittings.

   (d) __________ Record pressure at the end of 1/2 hour_____.

   (e) __________ Open all gauge valves and check agreement of all pressure gauges.

   (f) __________ Drop pressure in dewar to 2 psig by opening vent No. 1, dump valve, and vent isolation valve, then closing valves. This is done so that LH_2 can be transferred from trailer.

OPERATOR'S CHECKOFF LIST

1. ____________ Put on the beam tube and window required for the experiment.

2. ____________ Check that ring signal power for ring #3 is run in from the "B" area.

3. ____________ Unplug or disconnect:

   __________ Russell's magnet power supply.

   __________ Whittemore's magnet power supply.

   __________ Graphite magnet power supply.

4. ____________ Check that straight-ahead beam stopper is open.

5. ____________ Check the LH_2 experiment magnets for operation and polarity.

6. ____________ Set up and adjust the TV systems to the satisfaction of Jerry Trimble.

7. ____________ Remove the portable emergency lights from the experimental room.

8. ____________ Deactivate the wired-in emergency lights in the experimental room.

9. ____________ Close the rear door.

10. ____________ Turn off all the experimental area wall plugs at the junction box except those in the VVL area.

11. ____________ Turn off all lights in the experimental area at the switch in the "B" area.

12. ____________ Check the target lead.

13. ____________ Turn the area switch into position #3.

14. ____________ Turn Jerry's interlock key.

OPERATOR'S CHECKOFF LIST (Contd.)

15. ____________ Carefully check over the Linac so that the fewest entries possible will have to be made.

16. ____________ Close and lock the Red Door.

TURN THIS COMPLETED LIST INTO G. D. TRIMBLE

CONSOLE FOR LIQUID HYDROGEN SIGNED ____________________

1. ____________ Turn on valve package control panel power and check operation of all valve package valves, position indicator lights, and control switches. This check must be done simultaneously by one man at the control panel and one man at the valve package.

Control Panel	Valve Package	Valve
__________	__________	Fill valve
__________	__________	Dump valve
__________	__________	No. 1 vent valve
__________	__________	No. 2 vent valve
__________	__________	No. 3 vent valve
__________	__________	No. 4 vent valve
__________	__________	No. 5 vent valve
__________	__________	No. 6 vent valve
__________	__________	Vent isolation valve
__________	__________	Vacuum purge valve

ON NEXT FOUR VALVES LISTEN FOR GAS FLOW

__________	__________	Transfer bypass
__________	__________	Dewar emergency Purge
__________	__________	Vent emergency purge
__________	__________	Dump emergency purge

2. ____________ Check fail-safe position of all valves by turning off the valve package control panel master switch. Valve position indicator lights should indicate the normal position of each valve. Turn master switch back on.

LH_2 FILLING PROCEDURE

1. (a) Have storage dewar operator build up transfer pressure to 10 psig.

   (b) Have rear area man evacuate the probe tube and shut off vacuum pump.

   (c) Record dewar temp thermocouple (bottom) __________ .

2. Start with valves in the following positions:

Closed	Open
Dump Purge	Vent Line Micropurge
Vent Purge	Dump Line Micropurge
Dewar Purge	Vent Isolation
Vacuum Purge	Fill
All Vents	Magnet & Pump Purges
Dump	
Transfer Bypass	
Dewar Micropurge	

The dewar should be at ~ 2 psig He_2.

3. Have the storage dewar operator crack his liquid transfer valve to cool the line, then open the valve slowly to the wide open position to permit liquid flow. Continually watch the dewar pressure gauge; when it rises above 6 psig, begin opening vent valves, starting from chamber #6 and working back to #1, to lower the dewar pressure and control it to between 1 psig and 6 psig. As the LH_2 flows into the first compartment, much of it will flash into gas; try to keep as many vent valves closed as possible so that this cold gas may be used to cool the other compartments, but keep the dewar pressure within the stated limits to allow a good flow rate without excessive back pressure. The temperature of the open vent line nearest chamber #1 should be monitored continuously, and the vent valve for that line should be closed if the line's temperature approaches the oxygen liquification point (indicated on the thermocouple calibration curve). The H_2 gas warning monitors should be

observed during all operations where liquid or gaseous hydrogen gas is present in the dewar.

Time filling started ___________ .

4. Monitor the filling rate in chamber #1 by observing the liquid level indicators and thermocouples in that chamber. The thermocouple/liquid level reader should keep a record of the liquid level resistor resistance as a function of time to obtain an approximate depth calibration as a function of resistance in all chambers. The chamber #1 indicator levels are as follows:

1/2" liquid - level indicator "C" light	Time ___________
5-1/2" liquid - thermocouple #3	Time ___________
21" liquid - thermocouple #2	Time ___________
36" liquid - thermocouple #1	Time ___________
39" liquid - level indicator "B" light	Time ___________
40" liquid - level indicator "A" light	Time ___________

The vent #1 valve must remain closed once the liquid levelis above the #1 thermocouple to prevent entrained liquid in the flash gas from entering the vent line.

5. Immediately after the "1A" liquid level indicator is reached the LH_2 will overflow into chamber #2 causing a sudden small pressure rise. If the #2 vent valve is not already closed, close this valve now.

ΔT in chamber #1 ___________

6. Continue to fill the dewar making sure that each chamber's vent valve is closed when the chamber starts to fill and continuously observing the vent line temperatures; to keep liquid air from forming, it may be necessary to reduce the LH_2 flow as well as closing most of the vent valves.

ΔT in chamber #2 __________

ΔT in chamber #3 __________

ΔT in chamber #4 __________

ΔT in chamber #5 __________

7. When chamber #6 begins to fill, leave the #6 vent valve open and closely observe the #6 vent line temperature. At a vent line temperature of $125^{\circ}K$ (200 on scale) close the fill valve.

ΔT in chamber #6 __________

8. When the initial fill is completed, allow the dewar to complete its cooldown. While monitoring the vent line temperatures, open the vent valves one at a time, starting with #5 and working back to #1. This will reduce the pressure in the dewar and assist in the cooldown. Keep the vent lines above the air liquification temperature, if possible, by closing the vent valve on any line which rapidly approaches the liquid air temperature. When the dewar liquid level indicators appear relatively stable and all the vent valves may be left open with a small positive pressure of ~ 1 inch of water indicated, the dewar is cooled down.

9. To adjust the liquid levels in the dewar so that chamber six is essentially empty and the five main chambers are full, excess liquid must be transferred out of chamber six. Close the #6 vent valve and the transfer bypass valve, and open the dewar purge valve. Chamber five will fill first; as its "5A" light goes on, the #5 vent valve should be closed. As each subsequent chamber fills, the corresponding vent valve should be closed until chamber #1 is reached. Now observe the resistance of the "6C" liquid level indicator and the "5A" indicator light. (a) If "6C" indicates that the chamber #6 liquid-gas interface is near the bottom, and/or if the "5A' light is blinking, close the dewar purge valve and quickly

open all the vent valves; after the pressure relieves, reclose the chamber #6 vent valve and leave it closed. (b) If the liquid level in chamber #6 still appears to be well above the "6C" indicator with all the upper-level indicators in all chambers lit, close the #1 vent valve and open the dump valve. Allow the LH_2 to dump until the level in chamber #6 approaches "6C". Then, close the dewar purge valve and the dump valve, and begin opening the vent valves, starting with chamber #6 and working slowly back to chamber #1 to keep from dripping liquid air from the vent lines; when the dewar pressure is down to 35 inches of H_2O or less, the #1 vent valve may be opened and left open and the #1 vent line will not be likely to drip liquid air. Now repeat the back-transfer process from chamber #6 to top off all the chambers. (c) If the liquid in chamber #6 is insufficient to top off all the chambers without emptying chamber #6 and going down into chamber #5 well below the "5B" indicator, close the dewar purge valve and quickly open all the vent valves. Then, open the dump valve, close the #1 vent valve, and open the fill valve. When a good flow of cold gas comes from the dump stack, close the dump valve and again transfer liquid into the dewar. Fill as before, closing the vent valve for each chamber as it indicates full, until chamber #6 begins to fill. Attempt to fill chamber #6 to about 6" from the bottom. Then close the fill valve and open all the vents as quickly as possible without over-cooling the vent lines. When the dewar has once more reached a steady condition, top back as before from chamber #6 to reach an "all full" condition.

Time finished and topped off ___________

Total elapsed fill time _______________

LH_2 Filling Procedure

10. Have the rear area man let the probe tube up to +5 psig helium. The dewar is now ready for the experiment.

Confirmed by ____________

VENT LINE TEMP AT MID RUN

CHAMBER	RUN	RUN	RUN	RUN	RUN	RUN	RUN
6							
5							
4							
3							
2							
2 mid							
1							
1 mid							

BOIL OFF

LIGHT	RUN	Chamber 5	Chamber 4	Chamber 3	Chamber 2	Chamber 1	
Light A							
Light B							
Light A							
Light B							
Light A							
Light B							
Light A							
Light B							
Light A							
Light B							
Light A							
Light B							
Light A							
Light B							
Light A							
Light B							
Light A							
Light B							

LH_2 CHAMBER CHANGE PROCEDURE

Close the vent valves for all compartments which are "empty" (defining empty as being filled with only a few inches of LH_2) and for the last "full" compartment, leaving all the other full-compartment vents open. Open the dewar purge valve and watch the indicator lights closely. When the upper indicator light in the next-to-last "full" compartment goes on, close that compartment's vent valve; continue this process for each subsequent compartment until all the upper level indicator lights in the "full" compartments are lit.

(a) If the low-level indicator resistor in the compartment being emptied shows that the vapor-liquid interface is close to the bottom, or the upper indicators in the first full compartment are blinking, close the dewar purge valve, do not close the #1 vent valve, and open all the vent valves in the "full" compartments quickly to reduce their pressures. Keep the vent valves on the "empty" chambers closed; the pressure generated will help keep the "full" chambers topped off.

(b) If the low indicator in the compartment being emptied does not show that the vapor-liquid interface is close to the bottom and the upper lights in the first "full" compartment are not blinking, close the #1 vent valve and open the dump valve. Watch for the blinking lights and the low level indication in the chamber being emptied; when they come, close the dump valve and the dewar purge valve simultaneously and open the vent valves in the "full" compartments as quickly as possible to reduce the pressure. The #1 vent valve will have to be operated carefully to avoid over-cooling the vent line. If any of the "full" chambers appear to be a little low, top off with the liquid in the chamber just emptied.

<u>LH_2 CHAMBER CHANGE PROCEDURE</u> Page 2

(c) If the low-level indicator in the chamber being emptied and the upper level indicators in the first full chamber go out before the "full" chambers all indicate completely full, close the dewar purge valve and open all the vent valves to reduce the pressure. Then close the #1 vent valve, open the dump valve, and open the fill valve. When a good flow of very cold gas is coming from the dump stack, close the dump valve and transfer liquid into the dewar. As the chambers fill close their vent valves; when the first "empty" chamber has filled to a depth of 4-6" close the fill valve and open the vent valves as quickly as possible without overcooling the vent lines. Allow the dewar to settle down, then transfer back from the first "empty" compartment to top off any low compartments; leave the vent valves on the "empty" compartments closed to help keep the full chambers topped off. The dewar is now ready for the experiment.

BETWEEN-RUNS PURGING PROCEDURE

1. After transferring the LH_2 back into the storage dewar, open the dewar purge valve and the dump valve and purge the dewar with warm helium until the temperature has risen to 30°K at the #3 thermocouple in chamber #1. Watch the pressure gauges carefully and make sure the dewar is always at a positive pressure. If necessary, increase the gas flow by opening the transfer bypass valve.

2. Close the dewar purge valve and dump valve simultaneously and turn on the vacuum pump. Have the rear area man open the tower dewar evacuation valve, and drop the dewar pressure to 2 psig by momentarily opening the dump valve. Open the vacuum purge valve and evacuate the dewar to 30 inches Hg.

3. Close the vacuum purge valve and open the dewar purge valve and pressurize the dewar to 15 psig. Valve off the vacuum pump and let the line up to helium. The valves should be left in the following positions:

Closed	Open
Vent Purge	Vent Line Micropurge
Dump Purge	Dump Line Micropurge
Dewar Purge	Fill
Transfer Bypass	
All Vents	
Dump	
Dewar Micropurge	
Vacuum Purge	

4. Check the babysitter's list with him.

LH_2 EMPTYING PROCEDURE

1. Reduce storage dewar pressure to + 4 psig and have operator stand by to continually vent storage dewar during back-transfer to keep the back pressure between +4 and +5 psig.

2. Close all vent valves and dump valve, and open dewar purge valve and transfer bypass valve. Pressurize dewar to __10__ psig.

3. Open fill valve and begin transfer of LH_2 back into storage dewar. Continually monitor chamber #1 thermocouples and level indicators, and check LH_2 sniffer devices. Have rear area man carefully observe the transfer lines and storage dewar while the storage dewar operator controls the back pressure. When the liquid level in the dewar reaches the "1C" indicator, close the dewar purge valve, the fill valve, and the transfer bypass valve.

4. Have the storage dewar operator close his liquid transfer valve; then open the fill valve. The dewar is now ready for purging.

EMERGENCY PROCEDURES

There are three categories under which an emergency condition may exist. These are: (1) a hydrogen fire, (2) loss of vacuum either between the inner and outer dewar shell or in the transfer lines, and (3) overheating the uranium target.

I. Hydrogen Fire

These fires are determined mainly by Fe/Con thermocouples placed in the following places:

(1) Experimental dewar
(2) Valve Package - three thermocouples
(3) Supply trailer
(4) Vent stack on supply trailer
(5) Vent stack for the experimental dewar
(6) Dump stack for the experimental dewar

However, there are very many local places where hydrogen fires could occur such as the transfer lines from the supply trailer to the experimental dewar and the bottle farm.

In case of fire, the Linac will be automatically shut off which will be indicated by turning off a red light located at the LH_2 Console. The location of the fire can be determined by scanning the chart recorder for the number of the Fe/Con thermocouple which has caused this.

The following procedures are to be followed if a hydrogen fire occurs at the following discrete places and will in general cover most areas where a fire could happen.

A. Fire at the exhaust of the vent stack -

(1) Do not use the emergency dump.

(2) Open the vent and dump purge valves and continue the purge until the Fe/Con T/C recorder indicates the temperature is normal.

(3) Close vent 1 and the vent isolation valve. These may be closed temporarily or for a longer period of time depending upon the operation which is in process at the time of the fire. Make sure dewar micropurge is closed.

(4) Make sure the dump valve is closed.

(5) Since a pure hydrogen fire cannot be visually observed, continue to purge the dump and vent lines for a period of time after the fire has been extinguished.

(6) Alert all intercom areas to the location of the fire.

(7) Close the fill valve.

(8) If the Linac has not been shut off by the Fe-Con fire interlock - turn off the Linac.

(9) Shut off the water pump motor, TV system, quads and α-magnets.

B. Fire at the Dump Stack

(1) Close the dump valve.

(2) Close the fill valve.

(3) Open the vent and dump purge valves and continue the purge until the Fe/Con T/C recorder indicates the temperature is normal.

(4) Since a hydrogen fire cannot be visually observed, continue to purge the dump and vent lines for a period of time after the fire has been extinguished.

(5) Close vent 1 and the vent isolation valve. These valves may be closed temporarily or for a longer period of time depending upon the operation which is in process at the time of the fire. Make sure the dewar micropurge is closed.

C. Fire at the top or connectors to the experiment dewar -

(1) Open the experimental dewar nitrogen manifold and the valve package nitrogen manifold.

(2) Close fill valve and all vents open except the valve or valves to the leaking connector.

(3) Shut off the air intake motor switch located on the electrical junction box behind the control console. Leave on the exhaust fan motor located on the same electrical junction box.

(4) After the fire is out continue the nitrogen purge and USE THE EMERGENCY DUMP.

(5) After "1C" light goes out turn the valve panel console on and open the dump purge valve and purge for a few minutes.

(6) Alert all intercom areas of this emergency dump.

(7) After the flow of hydrogen has been stopped and the dewar is empty turn on the air intake motor at the electrical junction box and purge the experimental room (sheet metal enclosure). Close fill valve - leave vents open - close off leaky line.

(8) If the Linac has not been shut off by the Fe/Con fire interlock - turn off the Linac.

(9) Shut off the water pump motor, TV system, quads and α-magnets.

D. Fire at the valve package -

(1) Turn on the valve package and experimental dewar nitrogen manifold.

(2) Close the fill and dump valves.

(3) Refer to the Fe/Con T/C recorder to determine which of the three areas in the valve package the fire is located.

(4) Close the vent isolation valve and vent 1 valve. This may be temporary or permanent depending upon the operation.

(5) If the fire is not in the area of the dump line, then dump the liquid hydrogen.

(6) Shut off the air intake motor at the electrical junction box.

(7) After the liquid hydrogen has been dumped completely purge the experimental room (sheet metal enclosure) by turning on the intake and exhaust motors.

(8) If the Linac has not been shut off by the Fe/Con fire interlock - turn off the Linac.

(9) Shut off the water pump motor, TV system, quads and α-magnets.

E. Fire at the supply trailer vent stack -

(1) Shut off the vent valve on the supply trailer.

(2) If the vent valve on the supply trailer cannot be shut off because of the heat use CO_2 to extinguish the fire. Then close supply trailer vent valve.

(3) Close the experimental dewar fill valve.

F. Fire at the supply trailer -

(1) If the fire is small try to extinguish with CO_2.

(2) Close the experimental dewar fill valve.

(3) If the fire is large, evacuate the rear entrance area and notify the General Atomic Fire Department.

II. Loss of Vacuum

A. Between inner and outer shell -

(1) The existence of such a failure will be noticed by a sudden large pressure rise within the experimental dewar.

(2) USE THE EMERGENCY DUMP.

(3) After the "1C" light goes out on the liquid level panel, turn the valve console on and open the dump purge valve and purge for a few minutes and open all the vent valves.

B. Vacuum loss in the transfer lines -

(1) This will be obvious due to frosting on the main body of the transfer lines.

(2) Open the vacuum valves on the two 25 ft. transfer line which is nearest supply trailer.

(3) Evacuate personnel from this area during warm-up of the transfer lines.

III. Overheating Uranium Target

(1) The existence of target failure or overheating will be noticed by a sudden or rapid rise in the air monitor. In some cases the air monitor may rise to a high value. In this case shut off the Linac and observe if the air monitor shows a decrease. If so, the target has not failed. If not the target has failed and normal procedures for transferring of the liquid hydrogen to the supply trailer will be necessary.

(2) The Fe/Con T/C will also detect overheating. Should the thermocouple show a temperature rise above 500°F, shut off the Linac. Follow the normal procedures for transferring the liquid hydrogen to the supply trailer.

IV. Maximum Credible Accident

(1) The maximum credible accident would be caused by a fire or minor explosion at the connection of the vent #1 line to the experimental dewar or at the valve package resulting in the inability to pressurize the dewar to the extent the liquid hydrogen could not be transferred out of the experimental dewar.

(2) In this case the only method which can be used is to evaporate the liquid hydrogen. The procedure to be used is as follows:

(a) Open the dump and vent purge valves to minimize cryopumping.

(b) Open all vent valves but close vent 1 valve.

(c) Open the experimental and dewar CO_2 manifolds. Shut off the intake blower. Leave exhaust blower on.

(d) Open the alignment window pump out valve and pressure with helium.

(e) Pure the experimental dewar with helium gas to evaporate the liquid hydrogen.

(f) If the Linac has not been shut off by the Fe-Con fire interlock - turn off the Linac.

(g) Shut off the water pump motor, TV system, quads and α-magnets.

APPENDIX B

TABULATED DATA OF THE SPECTRAL MEASUREMENTS

HEMISPHERE INTEGRATED 95 DEGREE SPECTRUM
FOR THE 3-INCH DIAMETER
WATER COOLED DEPLETED URANIUM SOURCE.

LEAD FILTER 4-9-66 RUN 8

ENERGY (EV)	N(E)	DELTA(N)/N	ENERGY (EV)	N(E)	DELTA(N)/N
1.1370+07	1.5809-01	9.2580-02	1.8610+06	5.1680+01	1.7890-02
9.9220+06	4.1901-01	7.5720-02	1.7800+06	5.6046+01	1.7660-02
8.9590+06	7.3911-01	6.0260-02	1.7030+06	5.8334+01	1.7690-02
8.1300+06	1.1614+00	5.1270-02	1.6320+06	5.6741+01	1.8500-02
7.4110+06	2.1122+00	4.0710-02	1.5650+06	6.3658+01	1.7970-02
6.7830+06	3.0589+00	3.5840-02	1.5010+06	7.8730+01	1.6620-02
6.2320+06	4.6811+00	3.1680-02	1.4420+06	8.6282+01	1.6490-02
5.7450+06	5.4685+00	3.1240-02	1.3860+06	8.7552+01	1.7090-02
5.3130+06	7.0231+00	2.9590-02	1.3340+06	9.6011+01	1.7110-02
4.9280+06	8.5082+00	2.8600-02	1.2840+06	1.0435+02	1.6850-02
4.5840+06	1.0223+01	2.7940-02	1.2370+06	1.0889+02	1.7170-02
4.2740+06	1.1495+01	2.7430-02	1.1920+06	1.2038+02	1.6970-02
3.9950+06	1.3238+01	2.6640-02	1.1500+06	1.2633+02	1.6790-02
3.7420+06	1.5284+01	2.5630-02	1.1100+06	1.2381+02	1.6780-02
3.5130+06	1.6133+01	2.4540-02	1.0720+06	1.2139+02	1.7220-02
3.3040+06	2.1434+01	2.4150-02	1.0360+06	1.5678+02	1.6830-02
3.1130+06	2.0517+01	2.4540-02	1.0020+06	1.4589+02	1.7370-02
2.9380+06	2.4217+01	2.3100-02	9.6960+05	1.4498+02	1.7650-02
2.7770+06	2.5707+01	2.2730-02	9.3870+05	1.5970+02	1.7800-02
2.6300+06	2.8915+01	2.2130-02	9.0910+05	1.5063+02	1.7840-02
2.4940+06	2.9097+01	2.1630-02	8.8100+05	1.7694+02	1.7130-02
2.3680+06	3.2933+01	2.0620-02	8.5410+05	2.3844+02	1.6940-02
2.2510+06	3.5600+01	2.0140-02	8.2850+05	2.4822+02	1.7710-02
2.1430+06	3.6315+01	2.0130-02	8.0400+05	2.0174+02	1.9090-02
2.0420+06	4.1513+01	1.9100-02	7.8050+05	1.8289+02	2.0720-02
1.9490+06	4.5423+01	1.9090-02	7.5810+05	2.7705+02	1.8750-02

HEMISPHERE INTEGRATED 95 DEGREE SPECTRUM
FOR THE 3-INCH DIAMETER
WATER COOLED DEPLETED URANIUM SOURCE.

LEAD FILTER 4-9-66 RUN 5

ENERGY (EV)	N(E)	DELTA(N)/N	ENERGY (EV)	N(E)	DELTA(N)/N
1.3320+06	7.6160+01	1.3520-02	9.3030+04	3.8510+02	6.4040-02
1.1480+06	9.0970+01	1.1820-02	8.9350+04	3.0690+02	7.5770-02
9.9920+05	1.3010+02	1.0760-02	8.5870+04	3.3560+02	7.5110-02
8.7770+05	1.7310+02	1.0410-02	8.2600+04	3.1280+02	8.0460-02
7.7710+05	1.8480+02	1.0270-02	7.8040+04	2.2860+02	7.3220-02
6.9280+05	2.0300+02	1.0580-02	7.3820+04	3.1470+02	8.5860-02
6.2160+05	2.2810+02	1.1020-02	7.1200+04	3.0590+02	9.0130-02
5.6070+05	2.1820+02	1.1470-02	6.8720+04	2.9470+02	9.8110-02
5.0840+05	2.1860+02	1.1070-02	6.6370+04	4.2030+02	8.1560-02
4.6310+05	3.0870+02	1.2370-02	6.4140+04	3.3160+02	9.5060-02
4.2360+05	3.2320+02	1.4660-02	6.2020+04	3.5290+02	9.5890-02
3.8900+05	3.0200+02	1.5800-02	6.0000+04	3.7490+02	9.5890-02
3.5840+05	4.5700+02	1.8160-02	5.7160+04	3.1080+02	8.1610-02
3.3130+05	2.7080+02	1.7810-02	5.3670+04	4.1020+02	7.8030-02
3.0710+05	3.5330+02	1.8350-02	5.0480+04	4.4080+02	8.5730-02
2.8550+05	3.5710+02	2.0490-02	4.7570+04	5.2870+02	8.6880-02
2.6610+05	3.1290+02	2.2720-02	4.4290+04	2.8790+02	9.0910-02
2.4860+05	3.1740+02	2.3750-02	4.0770+04	3.3110+02	8.1570-02
2.3280+05	3.1440+02	2.5320-02	3.8140+04	3.7680+02	9.8010-02
2.1850+05	3.1370+02	2.6960-02	3.5760+04	4.0280+02	8.2070-02
2.0540+05	3.2720+02	2.8310-02	3.3190+04	4.3750+02	8.2310-02
1.9350+05	3.1750+02	3.0750-02	3.0890+04	4.3280+02	8.8990-02
1.8260+05	3.2890+02	3.2550-02	2.8500+04	3.8240+02	9.2960-02
1.7250+05	3.4330+02	3.4430-02	2.6080+04	3.9950+02	9.2910-02
1.6330+05	3.2610+02	3.8290-02	2.3960+04	4.1480+02	9.9550-02
1.5480+05	3.3130+02	4.0750-02	2.2090+04	4.9470+02	9.6480-02
1.4700+05	3.3440+02	4.3160-02	2.0240+04	4.8650+02	9.7240-02
1.3970+05	3.6700+02	4.3650-02	1.8120+04	4.8500+02	9.5200-02
1.3300+05	3.6010+02	4.5420-02	1.5770+04	5.3870+02	9.1940-02
1.2670+05	3.5990+02	5.0910-02	1.3520+04	5.6870+02	9.9360-02
1.2090+05	3.6610+02	5.1130-02	1.1480+04	6.5360+02	9.8340-02
1.1540+05	3.5550+02	5.4250-02	9.3150+03	7.1890+02	9.9410-02
1.1030+05	3.7670+02	5.4920-02	7.2660+03	1.0760+03	9.8080-02
1.0560+05	3.5950+02	5.8890-02	5.6510+03	1.4030+03	9.8180-02
1.0110+05	3.5040+02	6.2360-02	4.2920+03	1.6070+03	9.8310-02
9.6960+04	3.7590+02	6.2440-02	3.0310+03	2.1770+03	9.9870-02

HEMISPHERE INTEGRATED 95 DEGREE SPECTRUM
FOR THE 3-INCH DIAMETER
WATER COOLED DEPLETED URANIUM SOURCE.

URANIUM FILTER 1-30-66 RUN 2

ENERGY (EV)	N(E)	DELTA(N)/N	ENERGY (EV)	N(E)	DELTA(N)/N
1.5520+07	2.5471-02	8.3720-02	2.0120+06	3.3271+01	1.1150-02
1.3250+07	7.5785-02	6.6960-02	1.9210+06	3.5571+01	1.1140-02
1.1790+07	1.5549-01	4.9750-02	1.8360+06	3.9476+01	1.0910-02
1.0550+07	3.1070-01	3.7800-02	1.7560+06	4.2444+01	1.0830-02
9.5040+06	5.7508-01	2.9950-02	1.6820+06	4.4773+01	1.0820-02
8.6040+06	9.5777-01	2.5480-02	1.6120+06	4.9345+01	1.0690-02
7.6260+06	1.4981+00	2.1710-02	1.5460+06	5.2469+01	1.0620-02
7.1490+06	2.1144+00	1.9490-02	1.4840+06	5.6303+01	1.0590-02
6.5560+06	2.8340+00	1.7870-02	1.4260+06	6.0350+01	1.0560-02
6.0330+06	3.5339+00	1.6530-02	1.3720+06	6.3190+01	1.0700-02
5.5710+06	4.6647+00	1.5890-02	1.3200+06	6.6584+01	1.0830-02
5.1600+06	5.5607+00	1.5340-02	1.2710+06	7.1525+01	1.0640-02
4.7930+06	6.5760+00	1.4810-02	1.2250+06	7.7731+01	1.0610-02
4.4640+06	7.6155+00	1.4540-02	1.1810+06	8.2885+01	1.0660-02
4.1670+06	8.6165+00	1.4060-02	1.1400+06	8.8665+01	1.0750-02
3.8990+06	1.0274+01	1.3600-02	1.1010+06	9.3663+01	1.1000-02
3.6570+06	1.1360+01	1.3460-02	1.0630+06	9.8860+01	1.1050-02
3.4360+06	1.2915+01	1.3060-02	1.0280+06	1.0556+02	1.1220-02
3.2340+06	1.4370+01	1.2780-02	9.9440+05	1.0896+02	1.1430-02
3.0500+06	1.6316+01	1.2340-02	9.6240+05	1.1924+02	1.1180-02
2.8810+06	1.7433+01	1.2340-02	9.3190+05	1.2712+02	1.1230-02
2.7260+06	2.0391+01	1.1790-02	9.0280+05	1.3871+02	1.1220-02
2.5830+06	2.1655+01	1.1820-02	8.7510+05	1.4484+02	1.1460-02
2.4510+06	2.3996+01	1.1570-02	8.4860+05	1.1275+02	1.3510-02
2.3290+06	2.6469+01	1.1360-02	8.2330+05	1.6387+02	1.1730-02
2.2150+06	2.6840+01	1.1270-02	7.9920+05	1.7154+02	1.2000-02
2.1100+06	3.0743+01	1.1270-02	7.7600+05	1.8815+02	1.2200-02

HEMISPHERE INTEGRATED 95 DEGREE SPECTRUM
FOR THE 3-INCH DIAMETER
WATER COOLED DEPLETED URANIUM SOURCE.

URANIUM FILTER 1-30-66 RUN 4

ENERGY (EV)	N(E)	DELTA(N)/N	ENERGY (EV)	N(E)	DELTA(N)/N
1.3920+06	6.5500+01	1.3230-02	1.5450+05	2.7025+02	5.0800-02
1.2420+06	7.4450+01	1.3100-02	1.4960+05	2.6875+02	5.2810-02
1.1140+06	9.0600+01	1.2890-02	1.4310+05	2.6850+02	5.4920-02
1.0060+06	1.0962+02	1.2730-02	1.3780+05	2.7450+02	5.6380-02
9.1210+05	1.2082+02	1.2590-02	1.3290+05	2.7325+02	5.8760-02
8.3100+05	1.4440+02	1.2760-02	1.2820+05	2.5925+02	6.2780-02
7.6030+05	1.6572+02	1.2960-02	1.2370+05	2.8900+02	6.1460-02
6.9820+05	1.8525+02	1.3510-02	1.1950+05	2.9150+02	6.3530-02
6.4340+05	2.0290+02	1.4010-02	1.1550+05	2.6450+02	6.9520-02
5.9490+05	2.1480+02	1.4770-02	1.1160+05	2.2365+02	7.9030-02
5.5160+05	2.2990+02	1.5410-02	1.0800+05	2.5125+02	7.6910-02
5.1290+05	2.3000+02	1.6670-02	1.0460+05	2.5925+02	7.8550-02
4.7810+05	2.3957+02	1.7830-02	1.0130+05	2.7725+02	7.8550-02
4.4670+05	2.4907+02	1.9710-02	9.6120+04	2.8100+02	8.0810-02
4.1840+05	2.4955+02	2.1300-02	9.5130+04	2.6950+02	8.5670-02
3.9260+05	2.3742+02	2.1840-02	9.2270+04	2.8575+02	8.5670-02
3.6920+05	2.6325+02	2.1840-02	8.9530+04	2.3757+02	9.8260-02
3.4780+05	2.5475+02	2.3220-02	8.6920+04	2.9900+02	8.8970-02
3.2820+05	2.4482+02	2.4810-02	8.4420+04	2.7150+02	9.6890-02
3.1020+05	2.3567+02	2.6430-02	8.2020+04	2.8500+02	9.7340-02
2.9370+05	2.3132+02	2.7940-02	7.9360+04	2.7900+02	8.8450-02
2.7840+05	2.4590+02	2.8510-02	7.6470+04	3.1000+02	8.6790-02
2.6430+05	2.4232+02	3.0300-02	7.3730+04	2.9325+02	9.3240-02
2.5120+05	2.5275+02	3.1310-02	7.0820+04	2.6875+02	9.2170-02
2.3910+05	2.4380+02	3.3780-02	6.7500+04	2.4240+02	9.5010-02
2.2790+05	2.5575+02	3.4400-02	6.4400+04	2.9250+02	9.7590-02
2.1740+05	2.4262+02	3.7050-02	6.1520+04	2.6875+02	9.8990-02
2.0760+05	2.4205+02	3.8860-02	5.8810+04	3.7350+02	9.3350-02
1.9850+05	2.5200+02	3.9960-02	5.6070+04	2.8925+02	9.8020-02
1.9000+05	2.5600+02	4.1800-02	5.2710+04	2.8200+02	9.5250-02
1.8200+05	2.5775+02	4.3960-02	4.9440+04	3.2350+02	9.9760-02
1.7450+05	2.7525+02	4.4610-02	4.6310+04	3.1275+02	9.8960-02
1.6740+05	2.6425+02	4.7540-02	4.2880+04	3.3575+02	9.4760-02
1.6080+05	2.6325+02	4.9600-02	3.9410+04	3.5200+02	9.7800-02

RUN T41 (3-20-66)

INTERMEDIATE NEUTRON SPECTRUM

EMPTY DEWAR AT 5 DEGREES

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.4620+08	3.9550+01	5.7822+09	1.0670-02
4.6810+06	3.8090+02	1.7830+09	1.2100-02
3.1140+06	6.3120+02	1.9656+09	1.3180-02
2.2190+06	8.8540+02	1.9647+09	1.3780-02
1.6620+06	1.1660+03	1.9379+09	1.3760-02
1.2900+06	1.6730+03	2.1582+09	1.3710-02
9.3680+05	2.6050+03	2.4404+09	9.3650-03
6.4730+05	4.1500+03	2.6863+09	9.5250-03
4.7400+05	5.7910+03	2.7449+09	1.0760-02
3.6210+05	6.2630+03	2.2678+09	1.3480-02
2.7130+05	6.5220+03	1.7694+09	1.3780-02
2.0030+05	7.0500+03	1.4121+09	1.8350-02
1.5390+05	7.7740+03	1.1964+09	2.3750-02
1.1790+05	8.0900+03	9.5381+08	2.6990-02
9.0130+04	8.0750+03	7.2780+08	3.9990-02
6.9290+04	7.6280+03	5.2854+08	4.9050-02
5.3520+04	9.0460+03	4.8414+08	6.3130-02
4.1730+04	8.6210+03	3.5975+08	8.2160-02
3.2770+04	1.1830+04	3.8767+08	1.2260-01
2.6000+04	1.6090+04	4.1834+08	1.8310-01
2.0500+04	1.5140+04	3.1037+08	1.2640-01
1.6140+04	1.6100+04	2.5985+08	2.2410-01
1.2730+04	1.5810+04	2.0126+08	3.0220-01
1.0080+04	2.1250+04	2.1420+08	3.5050-01

RUN T40 (3-20-66)

INTERMEDIATE NEUTRON SPECTRUM

2.5 IN. LIQUID HYDROGEN AT 5 DEGREES.

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.6620+06	5.1396+02	8.5420+08	1.3900-02
1.2900+06	6.7388+02	8.6930+08	1.4500-02
9.3680+05	8.9176+02	8.3540+08	1.0700-02
6.4730+05	1.2524+03	8.1070+08	1.1600-02
4.7400+05	1.5466+03	7.3310+08	1.3900-02
3.6210+05	1.4819+03	5.3660+08	1.8800-02
2.7130+05	1.3962+03	3.7880+08	2.0900-02
2.0030+05	1.3320+03	2.6680+08	3.1400-02
1.5390+05	1.3216+03	2.0340+08	4.5600-02
1.0400+05	1.3442+03	1.3980+08	7.1900-02
6.1410+04	1.6300+03	1.0010+08	1.1190-01
3.7250+04	2.4000+03	8.9400+07	1.4880-01
1.6140+04	4.1115+03	6.6360+07	2.1620-01
8.0290+03	8.0820+03	6.4890+07	2.7480-01
4.0030+03	1.4602+04	5.8450+07	3.4830-01
2.0250+03	3.4923+04	7.0720+07	3.7880-01
1.1580+03	5.1347+04	5.9460+07	4.7960-01
7.3570+02	9.3326+04	6.8660+07	5.4470-01
4.6920+02	1.4710+05	6.9020+07	6.9060-01

RUN T39 (3-20-66)

INTERMEDIATE NEUTRON SPECTRUM

4.5 IN. LIQUID HYDROGEN AT 5 DEGREES.

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.6620+06	3.9774+02	6.6104+08	1.1800-02
1.2900+06	4.5467+02	5.8652+08	1.3100-02
9.3680+05	5.2014+02	4.8727+08	1.0400-02
6.4730+05	6.3782+02	4.1286+08	1.2100-02
4.7400+05	7.0137+02	3.3245+08	1.5300-02
3.6210+05	6.0072+02	2.1752+08	2.1700-02
2.7130+05	5.4674+02	1.4833+08	2.3900-02
2.0030+05	5.4893+02	1.0995+08	3.3500-02
1.5390+05	5.3622+02	8.2524+07	4.5700-02
1.1790+05	5.7572+02	6.7877+07	5.0600-02
7.0980+04	7.4852+02	5.3130+07	6.8100-02
3.0250+04	1.4648+03	4.4310+07	8.2200-02
9.7340+03	3.8401+03	3.7380+07	1.0000-01
2.9430+03	7.2511+03	2.1340+07	1.1860-01
7.1530+02	3.5663+04	2.5510+07	1.7300-01

RUN T38 (3-19-66)

INTERMEDIATE NEUTRON SPECTRUM

7.0 IN. LIQUID HYDROGEN AT 5 DEGREES.

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.6620+06	2.2819+02	3.7926+08	1.3400-02
1.2900+06	2.3584+02	3.0423+08	1.5800-02
9.3680+05	2.5479+02	2.3869+08	1.2800-02
6.4730+05	2.7406+02	1.7740+08	1.5900-02
4.7400+05	2.9226+02	1.3853+08	2.0400-02
3.6210+05	2.6953+02	9.7596+07	2.7700-02
2.7130+05	2.5573+02	6.9379+07	2.9900-02
2.0030+05	2.5640+02	5.1356+07	4.0700-02
1.5390+05	2.5660+02	3.9491+07	5.1300-02
1.0400+05	3.7019+02	3.8500+07	5.4200-02
4.9330+04	5.3760+02	2.6520+07	6.3800-02
1.6460+04	1.4016+03	2.3070+07	6.7400-02
5.6120+03	3.2716+03	1.8360+07	7.3100-02
8.4900+02	1.0342+04	8.7800+06	9.6500-02

RUN T37 (3-19-66)

INTERMEDIATE NEUTRON SPECTRUM

10.5 IN. LIQUID HYDROGEN AT 5 DEGREES.

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.6620+06	9.7413+01	1.6190+08	1.9900-02
1.2900+06	9.8891+01	1.2757+08	2.3400-02
9.3680+05	9.6858+01	9.0737+07	2.0100-02
6.4730+05	9.9286+01	6.4268+07	2.5300-02
4.7400+05	1.1043+02	5.2343+07	3.1300-02
3.6210+05	1.1387+02	4.1231+07	3.8900-02
2.7130+05	1.0662+02	2.8926+07	4.1000-02
2.0030+05	1.2487+02	2.5012+07	4.7900-02
1.5390+05	1.6027+02	2.4666+07	5.2700-02
1.1790+05	1.6072+02	1.8949+07	5.3600-02
9.0130+04	2.0526+02	1.8500+07	5.7000-02
4.0640+04	3.4818+02	1.4150+07	5.6600-02
1.2980+04	8.5593+02	1.1110+07	5.6000-02
4.4610+03	1.6465+03	7.3450+06	5.6800-02
7.1540+02	1.3128+04	9.3920+06	6.7800-02

RUN T34 (3-19-66)

INTERMEDIATE NEUTRON SPECTRUM

13.0 IN. LIQUID HYDROGEN AT 5 DEGREES.

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.6620+06	5.6063+01	9.3177+07	2.5700-02
1.2900+06	5.7969+01	7.4780+07	2.9600-02
9.3680+05	5.0888+01	4.7672+07	2.6300-02
6.4730+05	4.8477+01	3.1379+07	3.2800-02
4.7400+05	5.0468+01	2.3922+07	3.9500-02
3.6210+05	5.3853+01	1.9500+07	4.4600-02
2.7160+05	5.6940+01	1.5465+07	4.1900-02
3.2770+04	2.7873+02	9.1340+06	4.5000-02
3.1980+03	4.1379+03	1.3233+07	4.0100-02
5.8740+02	1.9731+04	1.1590+07	5.2400-02

RUN T32 (3-19-66)

INTERMEDIATE NEUTRON SPECTRUM

EMPTY DEWAR AT 15 DEGREES

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.4620+08	5.9850+00	8.7501+08	1.9430-02
4.6810+06	9.4290+01	4.4137+08	1.6610-02
3.1140+06	1.7250+02	5.3717+08	1.7200-02
2.2190+06	1.1130+02	2.4697+08	2.6730-02
1.6620+06	1.7530+02	2.9135+08	2.4290-02
1.2900+06	2.8130+02	3.6288+08	2.2810-02
9.3680+05	4.8100+02	4.5060+08	1.4860-02
6.4730+05	8.7730+02	5.6788+08	1.4060-02
4.7400+05	1.3020+03	6.1715+08	1.5360-02
3.6210+05	1.4970+03	5.4206+08	1.8600-02
2.7130+05	1.6110+03	4.3706+08	1.8730-02
2.0030+05	1.8000+03	3.6054+08	2.4620-02
1.5390+05	2.0150+03	3.1011+08	3.1790-02
1.1790+05	2.0880+03	2.4618+08	3.6430-02
9.0130+04	2.1860+03	1.9702+08	5.3170-02
6.9290+04	2.0740+03	1.4371+08	6.4410-02
5.3520+04	2.6700+03	1.4290+08	7.7470-02
4.1730+04	2.2690+03	9.4685+07	1.1330-01
3.2770+04	3.9010+03	1.2784+08	1.3250-01
2.6000+04	4.7550+03	1.2363+08	2.0390-01
2.0500+04	4.5980+03	9.4259+07	1.5110-01
1.6140+04	6.5090+03	1.0506+08	1.9250-01
1.2730+04	5.2340+03	6.6629+07	3.1000-01
1.0080+04	7.4220+03	7.4814+07	3.1060-01
8.0290+03	1.3080+04	1.0502+08	3.9940-01
6.3840+03	1.5240+04	9.7292+07	5.2240-01
5.0440+03	1.5740+04	7.9393+07	5.8550-01
3.9060+03	2.1190+04	8.2768+07	5.9780-01
3.0350+03	2.8860+04	8.7590+07	5.7860-01

RUN T31 (3-19-66)

INTERMEDIATE NEUTRON SPECTRUM

2.5 IN. LIQUID HYDROGEN AT 15 DEGREES.

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.6620+06	1.0937+02	1.8178+08	1.8700-02
1.2900+06	1.6174+02	2.0865+08	1.8300-02
9.3680+05	2.5363+02	2.3760+08	1.2500-02
6.4730+05	4.2937+02	2.7793+08	1.2200-02
4.7400+05	6.0333+02	2.8598+08	1.3700-02
3.6210+05	6.4902+02	2.3501+08	1.7200-02
2.7130+05	6.8330+02	1.8538+08	1.7700-02
2.0030+05	7.4493+02	1.4921+08	2.3600-02
1.5390+05	8.0513+02	1.2391+08	3.1300-02
1.1790+05	8.0170+02	9.4521+07	3.7200-02
9.0130+04	9.4283+02	8.4977+07	4.7900-02
4.1730+04	1.4244+03	5.9440+07	7.6400-02
1.2730+04	3.3244+03	4.2320+07	1.0560-01
4.0030+03	8.3337+03	3.3360+07	1.3560-01
1.2880+03	2.3385+04	3.0120+07	1.6060-01
4.1660+02	9.4479+04	3.9360+07	2.0240-01
1.6900+02	3.0538+05	5.1610+07	2.7440-01

RUN T30 (3-19-66)

INTERMEDIATE NEUTRON SPECTRUM

4.5 IN. LIQUID HYDROGEN AT 15 DEGREES.

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.6620+06	8.6631+01	1.4398+08	2.1000-02
1.2900+06	1.1847+02	1.5283+08	2.1400-02
9.3680+05	1.7296+02	1.6203+08	1.5100-02
6.4730+05	2.6765+02	1.7325+08	1.5500-02
4.7400+05	3.5968+02	1.7049+08	1.7800-02
3.6210+05	3.7271+02	1.3496+08	2.2800-02
2.7130+05	3.6644+02	9.9416+07	2.4600-02
2.0030+05	3.9860+02	7.9840+07	3.3000-02
1.5390+05	4.3196+02	6.6478+07	4.2300-02
1.1790+05	5.0345+02	5.9357+07	4.4800-02
9.0130+04	5.4749+02	4.9345+07	5.7500-02
6.9290+04	6.0460+02	4.1893+07	5.9700-02
5.3520+04	6.7593+02	3.6176+07	6.8700-02
3.3500+04	8.7209+02	2.9215+07	7.2700-02
2.0500+04	1.3922+03	2.8540+07	7.9500-02
6.3840+03	3.2440+03	2.0710+07	7.8800-02
1.6150+03	1.3375+04	2.1600+07	9.1000-02
6.8740+02	3.2077+04	2.2050+07	1.0500-01
2.1210+02	9.9387+04	2.1080+07	1.2660-01

RUN T29 (3-19-66)

INTERMEDIATE NEUTRON SPECTRUM

7.0 IN. LIQUID HYDROGEN AT 15 DEGREES.

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.6620+06	6.0403+01	1.0039+08	2.5900-02
1.2900+06	8.6124+01	1.1110+08	2.5800-02
9.3680+05	1.0982+02	1.0288+08	1.9600-02
6.4730+05	1.5056+02	9.7459+07	2.1500-02
4.7400+05	1.8857+02	8.9382+07	2.5500-02
3.6210+05	1.8468+02	6.6874+07	3.3800-02
2.7130+05	1.9964+02	5.4163+07	3.4900-02
2.0030+05	2.1575+02	4.3214+07	4.5300-02
1.5390+05	2.5901+02	3.9861+07	5.3600-02
1.1790+05	3.0514+02	3.5976+07	5.5400-02
9.0130+04	2.8294+02	2.5501+07	6.8400-02
6.9290+04	2.8798+02	1.9954+07	7.0000-02
5.3520+04	4.1997+02	2.2477+07	7.2500-02
3.3500+04	5.6758+02	1.9014+07	7.1900-02
2.6420+04	3.7990+02	1.0037+07	7.8700-02
8.9160+03	6.2752+02	5.5950+06	8.1200-02
1.6460+03	4.2412+03	6.9810+06	8.7500-02

RUN T28 (3-19-66)

INTERMEDIATE NEUTRON SPECTRUM

10.5 IN. LIQUID HYDROGEN AT 15 DEGREES.

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.6620+06	3.9584+01	6.5788+07	3.3300-02
1.2900+06	5.1393+01	6.6297+07	3.4700-02
9.3680+05	6.1598+01	5.7705+07	2.7400-02
6.4730+05	7.1333+01	4.6174+07	3.2500-02
4.7400+05	9.4977+01	4.5019+07	3.7500-02
3.6210+05	9.4366+01	3.4170+07	4.7400-02
2.7160+05	9.9845+01	2.7118+07	4.8100-02
2.0030+05	1.4513+02	2.9070+07	5.2400-02
1.5390+05	1.7634+02	2.7138+07	5.9500-02
1.0400+05	2.2078+02	2.2961+07	6.3300-02
5.4850+04	2.7925+02	1.5317+07	6.7600-02
2.3250+04	3.7789+02	8.7860+06	7.0400-02
1.0080+04	4.9702+02	5.0100+06	7.0000-02
3.2630+03	2.0074+03	6.5500+06	7.0100-02

RUN T27 (3-19-66)

INTERMEDIATE NEUTRON SPECTRUM

13.0 IN. LIQUID HYDROGEN AT 15 DEGREES.

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.6620+06	2.3312+01	3.8744+07	4.3400-02
1.2900+06	2.6581+01	3.4289+07	4.7600-02
9.3680+05	3.2901+01	3.0822+07	3.7200-02
6.4730+05	3.4871+01	2.2572+07	4.4200-02
4.7400+05	3.8878+01	1.8428+07	5.1600-02
3.6210+05	4.6310+01	1.6769+07	6.0500-02
2.7160+05	4.7095+01	1.2791+07	5.8600-02
1.1790+05	5.6132+01	6.6180+06	6.7600-02
1.1410+04	5.9264+02	6.7620+06	8.8900-02
5.2180+02	1.2476+04	6.5100+06	9.8700-02

RUN T25 (3-19-66)

INTERMEDIATE NEUTRON SPECTRUM

EMPTY DEWAR AT 37 DEGREES

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
2.2910+07	6.7610+00	1.5489+08	1.7670-02
4.6810+06	6.5720+01	3.0764+08	1.7140-02
3.1140+06	1.2790+02	3.9828+08	1.7180-02
2.2190+06	2.8660+01	6.3597+07	4.7080-02
1.6620+06	3.7930+01	6.3040+07	4.6720-02
1.2900+06	6.7510+01	8.7088+07	4.1210-02
9.3680+05	1.1500+02	1.0773+08	2.6910-02
6.4730+05	2.1640+02	1.4008+08	2.4910-02
4.7400+05	3.4630+02	1.6415+08	2.6150-02
3.6210+05	3.9540+02	1.4317+08	3.2090-02
2.7130+05	4.6210+02	1.2537+08	3.1720-02
2.0030+05	5.6860+02	1.1389+08	4.0670-02
1.5390+05	7.0000+02	1.0773+08	5.1010-02
1.1790+05	7.2170+02	8.5088+07	6.2340-02
9.0130+04	8.2170+02	7.4060+07	8.8170-02
6.9290+04	8.6210+02	5.9735+07	1.0480-01
5.3520+04	1.0660+03	5.7052+07	1.3750-01
4.1730+04	9.3970+02	3.9214+07	1.9980-01
3.2770+04	1.6580+03	5.4333+07	2.2450-01
2.6000+04	2.9010+03	7.5426+07	2.6840-01
2.0500+04	1.9850+03	4.0693+07	2.5900-01
1.6140+04	2.8690+03	4.6306+07	3.2600-01
1.2730+04	3.4700+03	4.4173+07	3.3200-01
1.0080+04	3.3360+03	3.3627+07	5.1060-01
8.0290+03	9.2080+03	7.3931+07	4.2770-01
6.3840+03	1.0280+04	6.5628+07	5.4100-01
5.0440+03	1.2570+04	6.3403+07	4.8380-01

RUN T24 (3-19-66)

INTERMEDIATE NEUTRON SPECTRUM

2.5 IN. LIQUID HYDROGEN AT 37 DEGREES.

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.6620+06	3.7463+01	6.2263+07	2.8800-02
1.2900+06	5.6433+01	7.2799+07	2.7800-02
9.3680+05	9.8606+01	9.2374+07	1.8000-02
6.4730+05	1.8316+02	1.1856+08	1.6800-02
4.7400+05	3.0230+02	1.4329+08	1.7400-02
3.6210+05	3.7354+02	1.3526+08	2.0300-02
2.7130+05	4.4029+02	1.1945+08	1.9800-02
2.0030+05	5.1837+02	1.0383+08	2.5400-02
1.5390+05	6.1912+02	9.5283+07	3.1400-02
1.1790+05	4.0228+02	4.7429+07	3.6500-02
9.0130+04	7.8097+02	7.0389+07	4.6100-02
6.9290+04	7.1150+02	4.9300+07	5.4300-02
3.2770+04	1.2869+03	4.2171+07	7.5500-02
1.0080+04	2.9842+03	3.0081+07	9.8300-02
3.1980+03	5.1479+03	1.6463+07	1.1960-01
1.0270+03	2.2606+04	2.3216+07	1.3250-01
3.3250+02	7.1188+04	2.3670+07	1.7080-01
1.3520+02	1.3951+05	1.8862+07	2.4880-01

RUN T23 (3-18-66)

INTERMEDIATE NEUTRON SPECTRUM

4.5 IN. LIQUID HYDROGEN AT 37 DEGREES.

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.6620+06	3.1507+01	5.2364+07	3.2700-02
1.2900+06	5.1677+01	6.6663+07	6.0400-02
9.3680+05	8.2226+01	7.7029+07	2.0700-02
6.4730+05	1.3645+02	8.8325+07	2.0500-02
4.7400+05	2.0752+02	9.8364+07	2.2100-02
3.6210+05	2.5997+02	9.4135+07	2.5500-02
2.7130+05	2.7838+02	7.5525+07	2.6100-02
2.0030+05	3.3687+02	6.7475+07	3.2300-02
1.5390+05	3.7578+02	5.7833+07	4.0800-02
1.1790+05	4.0023+02	4.7187+07	4.4300-02
9.0130+04	5.3117+02	4.7874+07	5.1200-02
6.9290+04	5.4520+02	3.7777+07	5.3400-02
5.3520+04	6.2524+02	3.3463+07	6.0700-02
3.3500+04	8.7919+02	2.9453+07	6.7700-02
1.8320+04	8.0513+02	1.4750+07	7.4100-02
6.4980+03	1.3352+03	8.6760+06	7.9800-02
1.0270+03	1.4736+04	1.5134+07	9.0200-02
2.1210+02	4.1348+04	8.7700+06	1.3690-01

RUN T22 (3-18-66)

INTERMEDIATE NEUTRON SPECTRUM

7.0 IN. LIQUID HYDROGEN AT 37 DEGREES.

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.6620+06	2.3758+01	3.9486+07	3.9100-02
1.2900+06	3.3367+01	4.3044+07	3.9200-02
9.3680+05	5.3029+01	4.9678+07	2.6900-02
6.4730+05	7.6356+01	4.9425+07	2.8600-02
4.7400+05	1.1422+02	5.4138+07	3.1000-02
3.6210+05	1.3455+02	4.8719+07	3.6500-02
2.7130+05	1.4519+02	3.9391+07	3.6700-02
2.0030+05	1.8698+02	3.7453+07	4.3000-02
1.5390+05	2.2982+02	3.5369+07	4.9200-02
1.1790+05	2.5445+02	3.0000+07	5.1100-02
7.9710+04	2.9198+02	2.3274+07	5.8800-02
4.7630+04	2.3941+02	1.1403+07	6.5500-02
2.3850+04	3.8914+02	9.2810+06	6.7400-02
7.0670+03	1.7478+03	1.2352+07	6.4600-02
8.3410+02	8.9222+03	7.4420+06	7.7700-02

RUN T21 (3-18-66)

INTERMEDIATE NEUTRON SPECTRUM

10.5 IN. LIQUID HYDROGEN AT 37 DEGREES.

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.6620+06	1.4505+01	2.4107+07	4.8200-02
1.2900+06	1.9907+01	2.5680+07	4.8800-02
9.3680+05	2.9135+01	2.7294+07	3.5300-02
6.4730+05	3.9217+01	2.5385+07	3.8600-02
4.7400+05	5.2876+01	2.5063+07	4.2900-02
3.6210+05	5.7523+01	2.0829+07	5.1000-02
2.7130+05	7.4655+01	2.0254+07	4.6900-02
2.9390+04	1.7285+02	5.0800+06	6.0900-02
2.9400+03	1.5517+03	4.5620+06	5.9800-02
7.2250+02	7.0035+03	5.0600+06	6.6700-02

RUN T17 (3-17-66)

INTERMEDIATE NEUTRON SPECTRUM

4.5 IN. LIQUID HYDROGEN AT 53 DEGREES.

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.6620+06	1.5560+01	2.5860+07	5.8000-02
1.2900+06	2.6453+01	3.4125+07	5.3100-02
9.3680+05	4.4661+01	4.1838+07	3.5800-02
6.4730+05	7.8420+01	5.0761+07	3.4400-02
4.7400+05	1.3853+02	6.5664+07	3.4200-02
3.6210+05	1.8434+02	6.6748+07	3.8100-02
2.7130+05	2.3352+02	6.3354+07	3.5800-02
2.0030+05	2.5876+02	5.1830+07	4.6100-02
1.5390+05	3.4224+02	5.2670+07	5.2100-02
1.1790+05	4.0315+02	4.7531+07	5.3800-02
9.0130+04	5.4131+02	4.8788+07	6.1000-02
6.9290+04	5.1707+02	3.5828+07	6.4300-02
4.7630+04	7.5043+02	3.5743+07	6.9000-02
2.3140+04	1.1494+03	2.6596+07	7.6900-02
1.1410+04	2.0167+03	2.3011+07	7.9700-02
4.8670+03	3.5558+03	1.7306+07	8.5700-02
1.0270+03	1.6789+04	1.7242+07	9.6700-02

RUN T16 (3-17-66)

INTERMEDIATE NEUTRON SPECTRUM

7.0 IN. LIQUID HYDROGEN AT 53 DEGREES.

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.6620+06	1.0845+01	1.8025+07	4.2800-02
1.2900+06	1.9590+01	2.5271+07	3.8600-02
9.3680+05	2.9839+01	2.7953+07	2.7600-02
6.4730+05	5.3569+01	3.4675+07	2.6500-02
4.7400+05	8.0405+01	3.8112+07	2.8300-02
3.6210+05	1.0529+02	3.8124+07	3.1400-02
2.7130+05	1.2632+02	3.4271+07	3.0000-02
2.0030+05	1.5702+02	3.1452+07	3.5200-02
1.5390+05	2.0251+02	3.1166+07	3.9100-02
1.1790+05	2.6332+02	3.1045+07	3.7900-02
9.0130+04	3.0453+02	2.7447+07	4.2800-02
6.9290+04	3.2160+02	2.2284+07	4.2400-02
5.3520+04	3.7257+02	1.9940+07	4.5700-02
4.1730+04	3.3206+02	1.3857+07	4.6000-02
3.2770+04	2.9525+02	9.6755+06	4.8800-02
2.6000+04	3.8785+02	1.0084+07	4.7800-02
8.8650+03	4.4647+02	3.9580+06	4.7700-02
1.4890+03	3.8039+03	5.6640+06	5.0000-02

RUN T15 (3-17-66)

INTERMEDIATE NEUTRON SPECTRUM

10.5 IN. LIQUID HYDROGEN AT 53 DEGREES.

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.6620+06	9.1937+00	1.5280+07	4.5000-02
1.2900+06	1.4783+01	1.9070+07	4.2800-02
9.3680+05	2.1656+01	2.0287+07	3.1500-02
6.4730+05	3.1860+01	2.0623+07	3.3000-02
4.7400+02	5.3137+04	2.5187+07	3.3500-02
3.6210+05	7.3314+01	2.6547+07	3.6100-02
2.7130+05	7.7195+01	2.0943+07	3.6000-02
2.0030+05	1.0193+02	2.0416+07	4.0000-02
1.0780+05	1.4499+02	1.5630+07	4.5000-02
3.1780+04	3.3826+02	1.0750+07	4.6700-02
7.0670+03	6.4667+02	4.5700+06	4.5600-02
8.1840+02	8.1061+03	6.6340+06	5.0800-02

RUN T14 (3-17-66)

INTERMEDIATE NEUTRON SPECTRUM

13.0 IN. LIQUID HYDROGEN AT 53 DEGREES.

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.6620+06	8.9813+00	1.4927+07	5.8800-02
1.2900+06	1.1771+01	1.5185+07	6.0600-02
9.3680+05	1.8921+01	1.7725+07	4.3300-02
6.4730+05	2.7031+01	1.7497+07	4.6100-02
4.7400+05	4.5437+01	2.1537+07	4.7100-02
3.6210+05	4.8133+01	1.7429+07	5.4700-02
2.7160+05	6.8943+01	1.8725+07	4.9000-02
2.0030+05	1.1446+02	2.2927+07	5.0600-02
1.5390+05	1.1097+02	1.7078+07	5.9200-02
9.0130+04	1.6014+02	1.4433+07	5.9000-02
3.2770+04	2.0012+02	6.5580+06	6.1600-02
5.7140+03	4.8967+02	2.7980+06	5.9300-02
5.8740+02	4.8553+03	2.8520+06	6.8400-02

RUN T11 (3-17-66)

INTERMEDIATE NEUTRON SPECTRUM

EMPTY DEWAR AT 78 DEGREES

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.4620+08	2.8230+01	4.1272+09	1.8610-02
4.6810+06	3.7120+02	1.7376+09	1.8170-02
3.1140+06	7.3650+02	2.2935+09	1.8140-02
2.2190+06	2.1230+01	4.7109+07	1.5340-01
1.6620+06	4.1180+01	6.8441+07	1.2030-01
1.2900+06	5.7580+01	7.4278+07	1.2110-01
9.3680+05	9.3740+01	8.7816+07	8.1880-02
6.4730+05	1.7150+02	1.1101+08	7.6430-02
4.7400+05	3.1280+02	1.4827+08	7.3580-02
3.6210+05	3.7880+02	1.3716+08	8.9960-02
2.7130+05	5.2180+02	1.4156+08	8.2980-02
2.0030+05	5.7570+02	1.1531+08	1.1600-01
1.5390+05	5.9550+02	9.1647+07	1.7160-01
1.1790+05	1.0360+03	1.2214+08	1.4320-01
9.0130+04	1.0190+03	9.1842+07	2.3820-01
6.9290+04	1.0610+03	7.3517+07	3.0560-01
5.3520+04	1.8080+03	9.6764+07	2.8260-01
4.1730+04	1.2910+03	5.3873+07	5.3230-01
3.2770+04	4.0270+03	1.3196+08	3.5430-01
2.5200+04	3.9850+03	1.0042+08	5.0720-01
1.8320+04	5.6550+03	1.0360+08	5.1560-01
1.3690+04	7.4030+03	1.0135+08	5.4460-01

RUN T10 (3-17-66)

INTERMEDIATE NEUTRON SPECTRUM

2.5 IN. LIQUID HYDROGEN AT 78 DEGREES.

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.6620+06	1.6791+01	2.7906+07	5.4500-02
1.2900+06	2.6476+01	3.4154+07	5.1800-02
9.3680+05	4.4590+01	4.1772+07	3.5200-02
6.4730+05	7.3498+01	4.7575+07	3.5200-02
4.7400+05	1.2804+02	6.0690+07	3.5400-02
3.6210+05	1.6868+02	6.1080+07	3.9600-02
2.7130+05	2.7047+02	7.3379+07	3.5200-02
2.0030+05	3.5223+02	7.0552+07	3.9300-02
9.0130+04	7.4905+02	6.7512+07	4.5900-02
3.2770+04	1.7603+03	5.7684+07	5.0500-02
1.0080+04	3.5597+03	3.5882+07	6.1100-02
3.1980+03	1.2318+04	3.9394+07	7.2800-02
1.0270+03	4.8832+04	5.0150+07	7.6800-02
3.3250+02	1.5605+05	5.1886+07	8.5700-02
1.3520+02	4.1627+05	5.6280+07	1.0880-01

RUN T8 (3-17-66)

INTERMEDIATE NEUTRON SPECTRUM

4.5 IN. LIQUID HYDROGEN AT 78 DEGREES.

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.6620+06	1.6553+01	2.7511+07	5.1500-02
1.2900+06	2.0217+01	2.6080+07	5.4300-02
9.3680+05	3.9118+01	3.6646+07	3.5800-02
6.4730+05	5.8432+01	3.7823+07	3.7100-02
4.7400+05	9.7540+01	4.6234+07	3.7700-02
3.6210+05	1.3533+02	4.9004+07	4.0800-02
2.7130+05	1.9919+02	5.4041+07	3.6000-02
2.0030+05	2.6728+02	5.3537+07	4.1100-02
1.5390+05	3.9181+02	6.0300+07	4.3200-02
1.1790+05	4.5803+02	5.4002+07	4.3500-02
9.0130+04	6.2410+02	5.6250+07	4.7400-02
6.9290+04	6.9899+02	4.8433+07	4.6700-02
5.3520+04	9.3298+02	4.9933+07	4.8900-02
2.7790+04	1.1675+03	3.2444+07	5.2900-02
9.3100+03	3.2230+03	3.0006+07	5.2800-02

RUN T6 (3-17-66)

INTERMEDIATE NEUTRON SPECTRUM

7.0 IN. LIQUID HYDROGEN AT 78 DEGREES.

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.6620+06	1.0067+01	1.6731+07	5.5200-02
1.2900+06	1.8384+01	2.3716+07	5.0100-02
9.3680+05	2.9560+01	2.7692+07	3.5600-02
6.4730+05	4.3848+01	2.8383+07	3.7100-02
4.7400+05	6.9977+01	3.3169+07	3.8700-02
3.6210+05	1.0296+02	3.7282+07	4.0400-02
2.7130+05	1.3428+02	3.6430+07	3.7500-02
1.7710+05	2.1110+02	3.7385+07	4.3500-02
1.0400+05	3.2998+02	3.4318+07	4.6700-02
5.3520+04	5.1741+02	2.7692+07	5.2700-02
2.3140+04	5.5838+02	1.2921+07	5.2900-02
9.3050+03	7.7808+02	7.2400+06	5.3100-02
1.8030+03	2.3960+03	4.3200+06	5.8200-02

RUN T4 (3-16-66)

INTERMEDIATE NEUTRON SPECTRUM

10.5 IN. LIQUID HYDROGEN AT 78 DEGREES.

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.6620+06	9.3135+00	1.5479+07	5.2000-02
1.2900+06	1.2574+01	1.6220+07	5.3200-02
9.3680+05	2.0188+01	1.8912+07	3.8100-02
6.4730+05	3.2822+01	2.1246+07	3.7800-02
4.7400+05	5.6352+01	2.6711+07	3.8500-02
3.6210+05	6.7343+01	2.4385+07	4.5000-02
2.7160+05	1.0532+02	2.8604+07	3.9200-02
2.0030+05	1.4254+02	2.8551+07	4.5200-02
1.5390+05	1.7152+02	2.6397+07	5.2700-02
1.1790+05	1.8593+02	2.1921+07	5.5500-02
9.0130+04	2.4310+02	2.1911+07	6.1200-02
5.3520+04	3.3016+02	1.7670+07	6.3500-02
2.6000+04	5.6385+02	1.4660+07	6.8800-02
1.1740+04	8.4804+02	9.9560+06	7.0100-02
3.8670+03	1.1844+03	4.5800+06	7.3300-02
5.8740+02	1.7518+04	1.0290+07	8.7000-02

RUN T2 (3-16-66)

INTERMEDIATE NEUTRON SPECTRUM

13.0 IN. LIQUID HYDROGEN AT 78 DEGREES.

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.4760+06	8.5705+00	1.2650+07	6.5300-02
9.3680+05	1.7121+01	1.6039+07	4.5600-02
6.4730+05	2.8719+01	1.8590+07	4.4900-02
4.7400+05	4.3734+01	2.0730+07	4.8500-02
3.6210+05	5.3811+01	1.9485+07	5.7100-02
2.7130+05	7.2857+01	1.9766+07	5.3900-02
2.0030+05	1.0400+02	2.0832+07	6.1400-02
1.5390+05	1.5198+02	2.3389+07	6.7000-02
1.1790+05	1.8305+02	2.1582+07	7.0400-02
9.0130+04	1.9465+02	1.7544+07	8.5000-02
6.1410+04	2.0495+02	1.2586+07	9.2500-02
2.6000+04	2.3138+02	6.0160+06	1.0260-01
5.7140+03	7.9979+02	4.5700+06	1.1010-01
5.8740+02	8.8372+03	5.1910+06	1.4110-01

RUN T5 (2-24-66)

FAST NEUTRON SPECTRUM

EMPTY DEWAR AT 37 DEGREES

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N	ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.0810+07	3.1790-02	3.4365+05	1.2900-01	1.2950+06	5.9250+00	7.6729+06	5.0410-02
9.4540+06	4.5350-02	4.2874+05	1.4390-01	1.2470+06	6.4910+00	8.0943+06	4.9540-02
8.5500+06	9.3690-02	8.0105+05	1.0550-01	1.2020+06	6.2910+00	7.5618+06	5.2310-02
7.7690+06	1.2300-01	9.5559+05	1.0060-01	1.1590+06	7.4290+00	8.6102+06	5.0670-02
7.0910+06	1.6270-01	1.1537+06	9.5000-02	1.1180+06	9.3070+00	1.0405+07	4.8880-02
6.4970+06	2.0780-01	1.3501+06	9.1370-02	1.0790+06	8.6200+00	9.3010+06	5.3040-02
5.9750+06	3.0800-01	1.8403+06	7.9640-02	1.0430+06	8.4180+00	8.7800+06	5.4270-02
5.5140+06	3.2310-01	1.7816+06	8.3130-02	1.0080+06	9.0670+00	9.1395+06	5.1880-02
5.1040+06	4.1900-01	2.1386+06	7.7000-02	9.7490+05	8.9770+00	8.7517+06	5.2450-02
4.7380+06	4.3640-01	2.0677+06	8.0150-02	9.4340+05	8.9020+00	8.3981+06	5.4190-02
4.4100+06	5.3500-01	2.3593+06	7.6330-02	9.1340+05	9.7930+00	8.9449+06	5.3720-02
4.1150+06	6.7370-01	2.7723+06	7.0780-02	8.8480+05	1.1480+01	1.0158+07	5.1470-02
3.8490+06	8.3630-01	3.2189+06	6.6580-02	8.5750+05	1.2430+01	1.0659+07	5.1070-02
3.6080+06	9.5260-01	3.4370+06	6.4740-02	8.3150+05	1.1920+01	9.9115+06	5.3960-02
3.3880+06	1.0930+00	3.7031+06	6.2800-02	8.0670+05	1.2500+01	1.0084+07	5.4350-02
3.1890+06	1.2600+00	4.0181+06	6.0350-02	7.8290+05	1.2860+01	1.0068+07	5.5340-02
3.0060+06	1.6020+00	4.8156+06	5.5260-02	7.6020+05	1.1890+01	9.0388+06	5.9710-02
2.8380+06	1.7580+00	4.9892+06	5.4510-02	7.3840+05	1.2480+01	9.2152+06	6.0570-02
2.6850+06	1.6230+00	4.3578+06	5.8770-02	7.1760+05	1.4160+01	1.0161+07	5.8970-02
2.5430+06	1.8620+00	4.7351+06	5.6750-02	6.9760+05	1.1240+01	7.8410+06	6.9070-02
2.4120+06	2.0430+00	4.9277+06	5.5860-02	6.7850+05	1.1800+01	8.0063+06	7.0080-02
2.2910+06	2.4880+00	5.7000+06	5.2310-02	6.6010+05	1.1590+01	7.6506+06	7.3600-02
2.1790+06	2.4510+00	5.3407+06	5.4510-02	6.4250+05	1.0830+01	6.9583+06	7.9390-02
2.0750+06	2.6690+00	5.5382+06	5.3880-02	6.2560+05	1.0560+01	6.6063+06	8.3710-02
1.9780+06	3.0280+00	5.9894+06	5.2090-02	6.0930+05	1.1380+01	6.9338+06	8.4000-02
1.8880+06	3.3330+00	6.2927+06	5.1330-02	5.9370+05	9.6400+00	5.7233+06	9.6300-02
1.8040+06	3.6840+00	6.6459+06	5.0540-02	5.7860+05	8.4240+00	4.8741+06	1.0980-01
1.7260+06	3.7180+00	6.4173+06	5.1680-02	5.6410+05	9.9350+00	5.6043+06	1.0660-01
1.6520+06	4.2650+00	7.0458+06	4.9780-02	5.5020+05	1.0100+01	5.5570+06	1.1320-01
1.5830+06	4.5620+00	7.2216+06	4.9850-02	5.3670+05	7.5070+00	4.0290+06	1.4240-01
1.5180+06	5.0300+00	7.6355+06	4.8600-02	5.2070+05	7.9140+00	4.1208+06	1.2400-01
1.4570+06	5.9170+00	8.6211+06	4.6100-02	5.0520+05	1.0490+01	5.2995+06	1.4240-01
1.4000+06	5.7930+00	8.1102+06	4.7920-02	4.8770+05	7.0840+00	3.4549+06	1.4320-01
1.3460+06	5.7530+00	7.7435+06	4.9780-02	4.6300+05	8.1640+00	3.7799+06	1.4260-01

RUN T3 (2-24-66)

FAST NEUTRON SPECTRUM

2.5 IN.LIQUID HYDROGEN AT 37 DEGREES

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.0530+07	1.8000-02	1.8954+05	1.3150-01
8.9850+06	3.8910-02	3.4961+05	1.3360-01
8.1450+06	6.2050-02	5.0540+05	1.1420-01
7.4180+06	8.7820-02	6.5145+05	1.0340-01
6.7840+06	1.1700-01	7.9373+05	9.7420-02
6.2280+06	1.5220-01	9.4790+05	9.1570-02
5.7380+06	2.2840-01	1.3106+06	7.9040-02
5.3030+06	3.0680-01	1.6270+06	7.2180-02
4.9160+06	3.4540-01	1.6980+06	7.1810-02
4.5700+06	4.1330-01	1.8888+06	6.9350-02
4.2590+06	5.3090-01	2.2611+06	6.4310-02
3.9790+06	6.0450-01	2.4053+06	6.2770-02
3.7250+06	8.3670-01	3.1167+06	5.5670-02
3.4960+06	9.0570-01	3.1663+06	5.5580-02
3.2860+06	1.1040+00	3.6277+06	5.2010-02
3.0950+06	1.2070+00	3.7357+06	5.1320-02
2.9200+06	1.4930+00	4.3596+06	4.7750-02
2.7600+06	1.4530+00	4.0103+06	5.0080-02
2.6120+06	1.7200+00	4.4926+06	4.7590-02
2.4760+06	1.9360+00	4.7935+06	4.6290-02
2.3510+06	1.9330+00	4.5445+06	4.7800-02
2.2340+06	2.1970+00	4.9081+06	4.6440-02
2.1260+06	2.4790+00	5.2704+06	4.5100-02
2.0260+06	2.6240+00	5.3162+06	4.5190-02
1.9330+06	3.2490+00	6.2803+06	4.1900-02
1.8460+06	3.3500+00	6.1841+06	4.2700-02
1.7640+06	3.1300+00	5.5213+06	4.5620-02
1.6880+06	3.6500+00	6.1612+06	4.3410-02
1.6170+06	3.7070+00	5.9942+06	4.4650-02
1.5500+06	3.9320+00	6.0946+06	4.4560-02
1.4870+06	4.3890+00	6.5264+06	4.3330-02
1.4280+06	4.9480+00	7.0657+06	4.1940-02
1.3730+06	4.5620+00	6.2636+06	4.5060-02
1.3200+06	5.1890+00	6.8495+06	4.3700-02
1.2710+06	5.3940+00	6.8558+06	4.3870-02

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.2240+06	5.9040+00	7.2265+06	4.3410-02
1.1800+06	6.0630+00	7.1543+06	4.4650-02
1.1380+06	6.8700+00	7.8181+06	4.4780-02
1.0990+06	7.4330+00	8.1689+06	4.6240-02
1.0610+06	8.1300+00	8.6259+06	4.5060-02
1.0250+06	7.8240+00	8.0196+06	4.6150-02
9.9120+05	7.5630+00	7.4964+06	4.6540-02
9.5890+05	7.5070+00	7.1985+06	4.7640-02
9.2820+05	8.5820+00	7.9658+06	4.6100-02
8.9890+05	8.2310+00	7.3988+06	4.9110-02
8.7100+05	8.6490+00	7.5333+06	4.9530-02
8.4440+05	9.1090+00	7.6916+06	4.9900-02
8.1890+05	9.9040+00	8.1104+06	4.9410-02
7.9460+05	9.4660+00	7.5217+06	5.2150-02
7.7140+05	8.4360+00	6.5075+06	5.7280-02
7.4920+05	9.6160+00	7.2043+06	5.5580-02
7.2790+05	1.0050+01	7.3154+06	5.6550-02
7.0750+05	9.2600+00	6.5514+06	6.1340-02
6.8800+05	9.2550+00	6.3674+06	6.3780-02
6.6920+05	1.0100+01	6.7589+06	6.3400-02
6.5120+05	1.0660+01	6.9418+06	6.4170-02
6.3390+05	8.5350+00	5.4103+06	7.5170-02
6.1740+05	8.1460+00	5.0293+06	8.0300-02
6.0140+05	9.7700+00	5.8757+06	7.6250-02
5.8610+05	9.0410+00	5.2989+06	8.3880-02
5.7130+05	7.3630+00	4.2065+06	9.9800-02
5.5710+05	9.3480+00	5.2078+06	9.3540-02
5.4340+05	8.1280+00	4.4168+06	1.0810-01
5.3020+05	7.6700+00	4.0666+06	1.1970-01
5.1750+05	8.2160+00	4.2518+06	1.2420-01
5.0230+05	7.9130+00	3.9747+06	1.1500-01
4.8480+05	6.7300+00	3.2627+06	1.4200-01
4.6560+05	6.5590+00	3.0539+06	1.4510-01
4.3780+05	6.1250+00	2.6815+06	1.4970-01

RUN T2 (2-24-66)

FAST NEUTRON SPECTRUM

4.5 IN.LIQUID HYDROGEN AT 37 DEGREES

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.0810+07	1.5250-02	1.6485+05	1.3400-01
9.4540+06	2.3170-02	2.1905+05	1.4290-01
8.5500+06	3.9200-02	3.3516+05	1.1680-01
7.7690+06	5.9530-02	4.6249+05	1.0160-01
7.0910+06	6.8420-02	4.8517+05	1.0370-01
6.4970+06	1.1790-01	7.6600+05	8.4090-02
5.9750+06	1.5940-01	9.5241+05	7.6870-02
5.5140+06	2.2330-01	1.2313+06	6.8830-02
5.1040+06	2.6670-01	1.3612+06	6.6670-02
4.7380+06	3.0650-01	1.4522+06	6.5660-02
4.4100+06	3.9460-01	1.7402+06	6.0980-02
4.1150+06	4.6380-01	1.9085+06	5.8740-02
3.8490+06	6.2610-01	2.4099+06	5.2800-02
3.6080+06	6.3290-01	2.2835+06	5.4660-02
3.3880+06	7.9930-01	2.7080+06	5.0400-02
3.1890+06	9.0480-01	2.8854+06	4.8870-02
3.0060+06	1.0140+00	3.0481+06	4.7690-02
2.8380+06	1.0520+00	2.9856+06	4.8470-02
2.6850+06	1.3290+00	3.5684+06	4.4560-02
2.5430+06	1.3570+00	3.4509+06	4.5620-02
2.4120+06	1.5240+00	3.6759+06	4.4340-02
2.2910+06	1.7360+00	3.9772+06	4.2930-02
2.1790+06	1.8470+00	4.0246+06	4.3050-02
2.0750+06	1.8450+00	3.8284+06	4.4470-02
1.9780+06	2.1210+00	4.1953+06	4.2740-02
1.8880+06	2.1840+00	4.1234+06	4.3540-02
1.8040+06	2.3020+00	4.1528+06	4.3910-02
1.7260+06	2.6310+00	4.5411+06	4.2160-02
1.6520+06	2.5790+00	4.2605+06	4.3960-02
1.5830+06	2.7340+00	4.3279+06	4.4260-02
1.5180+06	2.9210+00	4.4341+06	4.3830-02
1.4570+06	3.2000+00	4.6624+06	4.3090-02
1.4000+06	3.3780+00	4.7292+06	4.3130-02
1.3460+06	3.3620+00	4.5253+06	4.4790-02
1.2950+06	3.7880+00	4.9055+06	4.3290-02

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.2470+06	3.7650+00	4.6950+06	4.4740-02
1.2020+06	4.0230+00	4.8356+06	4.4920-02
1.1590+06	4.2400+00	4.9142+06	4.6150-02
1.1180+06	5.1150+00	5.7186+06	4.5380-02
1.0790+06	4.9100+00	5.2979+06	4.8360-02
1.0430+06	5.4550+00	5.6896+06	4.6290-02
1.0080+06	5.2050+00	5.2466+06	4.7110-02
9.7490+05	5.0830+00	4.9554+06	4.7970-02
9.4340+05	5.2390+00	4.9425+06	4.8590-02
9.1340+05	5.6050+00	5.1196+06	4.8820-02
8.8480+05	5.8340+00	5.1619+06	4.9770-02
8.5750+05	5.4960+00	4.7128+06	5.3020-02
8.3150+05	5.3220+00	4.4252+06	5.5750-02
8.0670+05	5.0600+00	4.0819+06	5.9250-02
7.8290+05	5.2110+00	4.0797+06	6.0210-02
7.6020+05	6.0650+00	4.6106+06	5.7660-02
7.3840+05	6.1600+00	4.5485+06	5.9570-02
7.1760+05	5.2600+00	3.7746+06	6.7260-02
6.9760+05	5.6880+00	3.9679+06	6.7260-02
6.7850+05	6.0240+00	4.0873+06	6.7880-02
6.6010+05	5.4220+00	3.5791+06	7.4700-02
6.4250+05	5.4780+00	3.5196+06	7.7560-02
6.2560+05	5.3230+00	3.3301+06	8.2100-02
6.0930+05	5.6180+00	3.4230+06	8.3220-02
5.9370+05	4.2740+00	2.5375+06	1.0160-01
5.7860+05	4.5580+00	2.6373+06	1.0430-01
5.6410+05	4.9680+00	2.8024+06	1.0600-01
5.5020+05	4.2860+00	2.3582+06	1.2360-01
5.3670+05	5.4660+00	2.9336+06	1.1610-01
5.2380+05	4.2830+00	2.2434+06	1.4430-01
5.0830+05	4.6760+00	2.3768+06	1.2380-01
4.9050+05	5.3120+00	2.6055+06	1.3070-01
4.7100+05	4.9100+00	2.3126+06	1.3820-01
4.3790+05	3.9720+00	1.7393+06	1.4610-01

RUN T1 (2-24-66)

FAST NEUTRON SPECTRUM

10.5 IN.LIQUID HYDROGEN AT 37 DEGREES

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N	ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.0530+07	9.3530-03	9.8487+04	1.3820-01	1.4280+06	1.2710+00	1.8150+06	5.7890-02
8.9850+06	2.0720-02	1.8617+05	1.3460-01	1.3730+06	1.3480+00	1.8508+06	5.7890-02
8.1450+06	2.8510-02	2.3221+05	1.2270-01	1.3200+06	1.4600+00	1.9272+06	5.7600-02
7.4180+06	4.8070-02	3.5658+05	9.9500-02	1.2710+06	1.4530+00	1.8468+06	5.9080-02
6.7840+06	5.8770-02	3.9870+05	9.8100-02	1.2240+06	1.4660+00	1.7944+06	6.1020-02
6.2280+06	8.0710-02	5.0266+05	8.8630-02	1.1800+06	1.5360+00	1.8125+06	6.2300-02
5.7380+06	1.1310-01	6.4897+05	7.8890-02	1.1380+06	1.6600+00	1.8891+06	6.4050-02
5.3030+06	1.3580-01	7.2015+05	7.6570-02	1.0990+06	1.8960+00	2.0837+06	6.4440-02
4.9160+06	1.6720-01	8.2196+05	7.2490-02	1.0610+06	1.9310+00	2.0488+06	6.5120-02
4.5700+06	2.2880-01	1.0456+06	6.4850-02	1.0250+06	1.9840+00	2.0336+06	6.4440-02
4.2590+06	2.3200-01	9.8809+05	6.8200-02	9.9120+05	1.6180+00	1.6038+06	7.1390-02
3.9790+06	3.0030-01	1.1949+06	6.2060-02	9.5890+05	1.5350+00	1.4719+06	7.5070-02
3.7250+06	3.7980-01	1.4148+06	5.7410-02	9.2820+05	1.9230+00	1.7849+06	6.8830-02
3.4960+06	3.7510-01	1.3113+06	6.0240-02	8.9890+05	1.7880+00	1.6072+06	7.5070-02
3.2860+06	4.1640-01	1.3683+06	5.9180-02	8.7100+05	1.7920+00	1.5608+06	7.7710-02
3.0950+06	4.9660-01	1.5370+06	5.5620-02	8.4440+05	1.8250+00	1.5410+06	7.9870-02
2.9200+06	5.5930-01	1.6332+06	5.4220-02	8.1890+05	1.7400+00	1.4249+06	8.5100-02
2.7600+06	6.0570-01	1.6717+06	5.3900-02	7.9460+05	1.4580+00	1.1585+06	9.7640-02
2.6120+06	6.6340-01	1.7328+06	5.3210-02	7.7140+05	1.9740+00	1.5227+06	8.5100-02
2.4760+06	6.6640-01	1.6500+06	5.5030-02	7.4920+05	1.7160+00	1.2856+06	9.6310-02
2.3510+06	7.3540-01	1.7289+06	5.3900-02	7.2790+05	1.4180+00	1.0322+06	1.1260-01
2.2340+06	8.1430-01	1.8191+06	5.2990-02	7.0750+05	1.7620+00	1.2466+06	1.0350-01
2.1260+06	8.8100-01	1.8730+06	5.2550-02	6.8800+05	1.7330+00	1.1923+06	1.0930-01
2.0260+06	8.8630-01	1.7956+06	5.4140-02	6.6920+05	2.1760+00	1.4562+06	9.9980-02
1.9330+06	1.1250+00	2.1746+06	4.9390-02	6.5120+05	1.4770+00	9.6182+05	1.3240-01
1.8460+06	1.0220+00	1.8866+06	5.3820-02	6.3390+05	1.6830+00	1.0669+06	1.2820-01
1.7640+06	1.1110+00	1.9598+06	5.3210-02	6.1740+05	1.9130+00	1.1811+06	1.2440-01
1.6880+06	1.2210+00	2.0610+06	5.2120-02	5.9750+05	1.1870+00	7.0923+05	1.4840-01
1.6170+06	1.0730+00	1.7350+06	5.7990-02	5.7500+05	1.7460+00	1.0039+06	1.2760-01
1.5500+06	1.2470+00	1.9328+06	5.5110-02	5.4360+05	1.2920+00	7.0233+05	1.3680-01
1.4870+06	1.2070+00	1.7948+06	5.7790-02	4.8820+05	1.4640+00	7.1472+05	1.4220-01

RUN T4 (2-26-66)

FAST NEUTRON SPECTRUM

EMPTY DEWAR AT 0 DEGREES

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N	ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.3090+07	1.5550+01	2.0355+08	4.8440-02	1.8820+06	1.8270+03	3.4384+09	1.6620-02
1.1640+07	2.5080+01	2.9193+08	4.0220-02	1.7990+06	1.9340+03	3.4793+09	1.6650-02
1.0410+07	3.8890+01	4.0484+08	3.4680-02	1.7210+06	1.9770+03	3.4024+09	1.6900-02
9.3710+06	6.2240+01	5.8325+08	2.9810-02	1.6470+06	2.0150+03	3.3187+09	1.7240-02
8.4790+06	8.8840+01	7.5327+08	2.7360-02	1.5790+06	2.1840+03	3.4485+09	1.7090-02
7.7080+06	1.1540+02	8.8950+08	2.6200-02	1.5140+06	2.3760+03	3.5973+09	1.6800-02
7.0380+06	1.4960+02	1.0529+09	2.5020-02	1.4540+06	2.5810+03	3.7528+09	1.6600-02
6.4520+06	1.7300+02	1.1162+09	2.5030-02	1.3970+06	2.4860+03	3.4729+09	1.7430-02
5.9350+06	2.0980+02	1.2452+09	2.4170-02	1.3430+06	2.6530+03	3.5630+09	1.7490-02
5.4790+06	2.7350+02	1.4985+09	2.2470-02	1.2920+06	2.9110+03	3.7610+09	1.7160-02
5.0730+06	2.9320+02	1.4874+09	2.2840-02	1.2440+06	3.3610+03	4.1811+09	1.6470-02
4.7110+06	3.3600+02	1.5829+09	2.2440-02	1.1990+06	3.3500+03	4.0166+09	1.7130-02
4.3860+06	3.8800+02	1.7018+09	2.1910-02	1.1560+06	3.5080+03	4.0552+09	1.7330-02
4.0940+06	4.4940+02	1.8398+09	2.1220-02	1.1160+06	3.3610+03	3.7509+09	1.8520-02
3.8300+06	5.0030+02	1.9161+09	2.0980-02	1.0770+06	3.8440+03	4.1400+09	1.7830-02
3.5900+06	5.6760+02	2.0377+09	2.0430-02	1.0410+06	3.8050+03	3.9610+09	1.8610-02
3.3730+06	6.5770+02	2.2184+09	1.9620-02	1.0060+06	4.3840+03	4.4103+09	1.7970-02
3.1740+06	7.0940+02	2.2516+09	1.9460-02	9.7320+05	5.1530+03	5.0149+09	1.6950-02
2.9930+06	7.7270+02	2.3127+09	1.9230-02	9.4180+05	4.5620+03	4.2965+09	1.8540-02
2.8270+06	8.3610+02	2.3637+09	1.9070-02	9.1190+05	4.3760+03	3.9905+09	1.9490-02
2.6740+06	9.5880+02	2.5638+09	1.8410-02	8.8340+05	4.9450+03	4.3684+09	1.8910-02
2.5330+06	1.0480+03	2.6546+09	1.8180-02	8.5620+05	4.4920+03	3.8461+09	2.0450-02
2.4030+06	1.1150+03	2.6793+09	1.8130-02	8.3030+05	4.4310+03	3.6791+09	2.1250-02
2.2830+06	1.2510+03	2.8560+09	1.7710-02	8.0550+05	4.2540+03	3.4266+09	2.2380-02
2.1720+06	1.3820+03	3.0017+09	1.7400-02	7.8180+05	4.0190+03	3.1421+09	2.3740-02
2.0680+06	1.4860+03	3.0730+09	1.7320-02	7.5910+05	5.1040+03	3.8744+09	2.1850-02
1.9720+06	1.6790+03	3.3110+09	1.6780-02				

RUN T3 (2-26-66)

FAST NEUTRON SPECTRUM

2.5 IN.LIQUID HYDROGEN AT 0 DEGREES

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.3090+07	1.1480+01	1.5027+08	3.4850-02
1.1640+07	1.9810+01	2.3059+08	2.8040-02
1.0410+07	3.0150+01	3.1386+08	2.4400-02
9.3710+06	4.4020+01	4.1251+08	2.2020-02
8.4790+06	5.9760+01	5.0671+08	2.0730-02
7.7080+06	8.2130+01	6.3306+08	1.9330-02
7.0380+06	1.0210+02	7.1858+08	1.8870-02
6.4520+06	1.2100+02	7.8069+08	1.8680-02
5.9350+06	1.3770+02	8.1725+08	1.8660-02
5.4790+06	1.6250+02	8.9034+08	1.8260-02
5.0730+06	1.8100+02	9.1821+08	1.8240-02
4.7110+06	1.9830+02	9.3419+08	1.8350-02
4.3860+06	2.2100+02	9.6931+08	1.8290-02
4.0940+06	2.5170+02	1.0305+09	1.7880-02
3.8300+06	2.8360+02	1.0862+09	1.7610-02
3.5900+06	3.1710+02	1.1384+09	1.7290-02
3.3730+06	3.4560+02	1.1657+09	1.7150-02
3.1740+06	3.6550+02	1.1601+09	1.7210-02
2.9930+06	4.0880+02	1.2235+09	1.6810-02
2.8270+06	4.0530+02	1.1458+09	1.7450-02
2.6740+06	4.5330+02	1.2121+09	1.7080-02
2.5330+06	5.2100+02	1.3197+09	1.6480-02
2.4030+06	5.4210+02	1.3027+09	1.6660-02
2.2830+06	5.5400+02	1.2648+09	1.7080-02
2.1720+06	6.0940+02	1.3236+09	1.6850-02
2.0680+06	6.2230+02	1.2869+09	1.7230-02

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.9720+06	7.2090+02	1.4216+09	1.6520-02
1.8820+06	7.5380+02	1.4187+09	1.6710-02
1.7990+06	7.5320+02	1.3550+09	1.7260-02
1.7210+06	7.3890+02	1.2716+09	1.7910-02
1.6470+06	7.4750+02	1.2311+09	1.8370-02
1.5790+06	8.2490+02	1.3025+09	1.8060-02
1.5140+06	8.5030+02	1.2874+09	1.8270-02
1.4540+06	9.0170+02	1.3111+09	1.8290-02
1.3970+06	8.1380+02	1.1369+09	1.9860-02
1.3430+06	8.6280+02	1.1587+09	2.0030-02
1.2920+06	9.3410+02	1.2069+09	1.9790-02
1.2440+06	1.0880+03	1.3535+09	1.8930-02
1.1990+06	1.0460+03	1.2542+09	2.0070-02
1.1560+06	1.1020+03	1.2739+09	2.0260-02
1.1160+06	9.8190+02	1.0958+09	2.2440-02
1.0770+06	1.1490+03	1.2375+09	2.1390-02
1.0410+06	1.0960+03	1.1409+09	2.2760-02
1.0060+06	1.2800+03	1.2877+09	2.1840-02
9.7320+05	1.4320+03	1.3936+09	2.1140-02
9.4180+05	1.2820+03	1.2074+09	2.2990-02
9.1190+05	1.2740+03	1.1618+09	2.3770-02
8.8340+05	1.3130+03	1.1599+09	2.4170-02
8.5620+05	1.2950+03	1.1088+09	2.5090-02
8.3030+05	1.1350+03	9.4239+08	2.7680-02
8.0550+05	1.1050+03	8.9008+08	2.8950-02
7.8180+05	1.0880+03	8.5060+08	3.0090-02

RUN T2 (2-26-66)

FAST NEUTRON SPECTRUM

7.0 IN.LIQUID HYDROGEN AT 0 DEGREES

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.3090+07	7.4540+00	9.7573+07	2.5980-02
1.1640+07	1.1460+01	1.3339+08	2.2150-02
1.0410+07	1.8130+01	1.8873+08	1.8930-02
9.3710+06	2.7430+01	2.5705+08	1.6790-02
8.4790+06	3.5060+01	2.9727+08	1.6310-02
7.7080+06	4.6170+01	3.5588+08	1.5550-02
7.0380+06	5.6040+01	3.9441+08	1.5370-02
6.4520+06	6.3350+01	4.0873+08	1.5600-02
5.9350+06	6.8170+01	4.0459+08	1.6050-02
5.4790+06	7.6030+01	4.1657+08	1.6160-02
5.0730+06	8.2420+01	4.1812+08	1.6380-02
4.7110+06	8.7740+01	4.1334+08	1.6720-02
4.3860+06	9.7720+01	4.2860+08	1.6680-02
4.0940+06	1.0140+02	4.1513+08	1.7080-02
3.8300+06	1.0560+02	4.0445+08	1.7510-02
3.5900+06	1.1650+02	4.1823+08	1.7300-02
3.3730+06	1.2330+02	4.1589+08	1.7420-02
3.1740+06	1.2520+02	3.9738+08	1.7830-02
2.9930+06	1.2460+02	3.7293+08	1.8460-02
2.8270+06	1.2810+02	3.6214+08	1.8800-02
2.6740+06	1.4260+02	3.8131+08	1.8450-02
2.5330+06	1.5150+02	3.8375+08	1.8500-02
2.4030+06	1.5090+02	3.6261+08	1.9100-02
2.2830+06	1.5360+02	3.5067+08	1.9600-02
2.1720+06	1.5470+02	3.3601+08	2.0190-02
2.0680+06	1.6060+02	3.3212+08	2.0460-02
1.9720+06	1.6840+02	3.3208+08	2.0600-02
1.8820+06	1.7080+02	3.2145+08	2.1130-02
1.7990+06	1.6860+02	3.0331+08	2.1950-02

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.7210+06	1.6740+02	2.8810+08	2.2590-02
1.6470+06	1.6540+02	2.7241+08	2.3420-02
1.5790+06	1.7320+02	2.7348+08	2.3620-02
1.5140+06	1.6120+02	2.4406+08	2.5120-02
1.4540+06	1.7710+02	2.5750+08	2.4670-02
1.3970+06	1.5020+02	2.0983+08	2.7590-02
1.3430+06	1.5140+02	2.0333+08	2.8500-02
1.2920+06	1.5850+02	2.0478+08	2.8610-02
1.2440+06	1.7990+02	2.2380+08	2.7680-02
1.1990+06	1.6780+02	2.0119+08	2.9750-02
1.1560+06	1.7120+02	1.9791+08	3.0490-02
1.1160+06	1.5420+02	1.7209+08	3.3560-02
1.0770+06	1.6400+02	1.7663+08	3.3510-02
1.0410+06	1.5020+02	1.5636+08	3.6330-02
1.0060+06	1.6740+02	1.6840+08	3.5650-02
9.7320+05	1.7580+02	1.7109+08	3.5560-02
9.4180+05	1.5720+02	1.4805+08	3.8670-02
9.1190+05	1.4510+02	1.3232+08	4.1420-02
8.8340+05	1.5200+02	1.3428+08	4.1710-02
8.5620+05	1.4960+02	1.2809+08	4.3320-02
8.3030+05	1.0950+02	9.0918+07	5.2290-02
8.0550+05	1.1980+02	9.6499+07	5.1520-02
7.8180+05	1.0730+02	8.3887+07	5.6100-02
7.5910+05	1.2460+02	9.4584+07	5.4010-02
7.3740+05	1.2010+02	8.8562+07	5.7280-02
7.1670+05	1.3150+02	9.4246+07	5.6730-02
6.9680+05	1.0430+02	7.2676+07	6.6550-02
6.7770+05	1.2440+02	8.4306+07	6.4580-02

RUN T1 (2-26-66)

FAST NEUTRON SPECTRUM

13.0 IN.LIQUID HYDROGEN AT 0 DEGREES

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.3090+07	4.3510+00	5.6955+07	2.4260-02
1.1640+07	6.8800+00	8.0083+07	2.0390-02
1.0410+07	9.4640+00	9.8520+07	1.8640-02
9.3710+06	1.3850+01	1.2979+08	1.6810-02
8.4790+06	1.6900+01	1.4330+08	1.6680-02
7.7080+06	2.0270+01	1.5624+08	1.6640-02
7.0380+06	2.3100+01	1.6258+08	1.6960-02
6.4520+06	2.5660+01	1.6556+08	1.7330-02
5.9350+06	2.6850+01	1.5935+08	1.8040-02
5.4790+06	2.8710+01	1.5730+08	1.8520-02
5.0730+06	2.8960+01	1.4691+08	1.9420-02
4.7110+06	3.1130+01	1.4665+08	1.9700-02
4.3860+06	3.0540+01	1.3395+08	2.0880-02
4.0940+06	3.1360+01	1.2839+08	2.1480-02
3.8300+06	3.2250+01	1.2352+08	2.2100-02
3.5900+06	3.3510+01	1.2030+08	2.2470-02
3.3730+06	3.3840+01	1.1414+08	2.3120-02
3.1740+06	3.1690+01	1.0058+08	2.4600-02
2.9930+06	3.2810+01	9.8200+07	2.4920-02
2.8270+06	2.9660+01	8.3849+07	2.7040-02
2.6740+06	3.1540+01	8.4338+07	2.7090-02
2.5330+06	2.8480+01	7.2140+07	2.9390-02
2.4030+06	3.0770+01	7.3940+07	2.9100-02
2.2830+06	2.9750+01	6.7919+07	3.0570-02
2.1720+06	2.9380+01	6.3813+07	3.1770-02
2.0680+06	2.8900+01	5.9765+07	3.3010-02
1.9720+06	2.9930+01	5.9022+07	3.3390-02
1.8820+06	2.8380+01	5.3411+07	3.5380-02
1.7990+06	2.6020+01	4.6810+07	3.8070-02

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.7210+06	2.5910+01	4.4591+07	3.9080-02
1.6470+06	2.1920+01	3.6102+07	4.3730-02
1.5790+06	2.3320+01	3.6822+07	4.3730-02
1.5140+06	2.0340+01	3.0795+07	4.7950-02
1.4540+06	2.3820+01	3.4634+07	4.5600-02
1.3970+06	1.8880+01	2.6375+07	5.2710-02
1.3430+06	1.7950+01	2.4107+07	5.6000-02
1.2920+06	1.7600+01	2.2739+07	5.8040-02
1.2440+06	2.0030+01	2.4917+07	5.6090-02
1.1990+06	1.7090+01	2.0491+07	6.3010-02
1.1560+06	1.9480+01	2.2519+07	6.0980-02
1.1160+06	1.6210+01	1.8090+07	6.9860-02
1.0770+06	1.6010+01	1.7243+07	7.2380-02
1.0410+06	1.3090+01	1.3627+07	8.3070-02
1.0060+06	1.3170+01	1.3249+07	8.5780-02
9.7320+05	1.2950+01	1.2603+07	8.8420-02
9.4180+05	1.2110+01	1.1405+07	9.4110-02
9.1190+05	1.1710+01	1.0678+07	9.8570-02
8.8340+05	1.2400+01	1.0954+07	9.8570-02
8.5620+05	1.0370+01	8.8788+06	1.1120-01
8.3030+05	8.2900+00	6.8832+06	1.2920-01
8.0550+05	7.9190+00	6.3788+06	1.3610-01
7.8180+05	8.4000+00	6.5671+06	1.3610-01
7.5370+05	5.5880+00	4.2117+06	1.4440-01
7.2690+05	8.5780+00	6.2353+06	1.4910-01
7.0170+05	6.5150+00	4.5716+06	1.4750-01
6.6850+05	7.2100+00	4.8199+06	1.3490-01
6.2920+05	7.9910+00	5.0279+06	1.3990-01

RUNS R9,R10 (2-20-66)

THERMAL NEUTRON SPECTRUM

2.5 IN.LIQUID HYDROGEN AT 37 DEGREES

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N	ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
7.3470+00	6.6420+05	4.8799+06	5.8020-02	2.0590-02	5.3880+08	1.1094+07	1.5940-02
4.3720+00	1.0070+06	4.4026+06	5.9160-02	1.8320-02	8.6270+08	1.5805+07	1.2280-02
2.8970+00	1.6950+06	4.9104+06	5.0550-02	1.6250-02	1.4620+09	2.3757+07	1.0160-02
2.0590+00	2.1740+06	4.4763+06	5.4650-02	1.4530-02	1.9530+09	2.8377+07	9.5400-03
1.5390+00	3.0720+06	4.7278+06	4.9560-02	1.2950-02	2.5290+09	3.2751+07	8.2940-03
1.1930+00	3.8430+06	4.5847+06	4.7870-02	1.1470-02	2.8230+09	3.2380+07	8.5190-03
9.5210-01	4.6930+06	4.4682+06	4.7510-02	1.0190-02	3.0440+09	3.1018+07	9.0360-03
7.7750-01	5.7360+06	4.4597+06	4.6920-02	9.0770-03	3.3820+09	3.0698+07	9.4370-03
6.4690-01	6.8840+06	4.4533+06	4.4860-02	8.1070-03	3.6640+09	2.9704+07	9.9650-03
5.4660-01	7.8920+06	4.3138+06	4.5810-02	7.2680-03	4.0680+09	2.9566+07	1.0390-02
4.6800-01	9.6290+06	4.5064+06	4.1840-02	6.4890-03	4.8680+09	3.1588+07	9.6230-03
4.0520-01	1.0100+07	4.0925+06	4.6850-02	5.7740-03	5.4390+09	3.1405+07	1.0070-02
3.5420-01	1.0230+07	3.6235+06	4.9030-02	5.1670-03	5.8730+09	3.0346+07	9.8060-03
3.1230-01	1.1310+07	3.5321+06	4.9260-02	4.6160-03	5.2100+09	2.4049+07	9.2840-03
2.7740-01	1.2600+07	3.4952+06	4.9550-02	4.1160-03	5.6840+09	2.3395+07	9.7850-03
2.4800-01	1.3210+07	3.2761+06	5.0460-02	3.6930-03	5.8320+09	2.1538+07	1.0610-02
2.1240-01	1.7770+07	3.7743+06	3.2190-02	3.3110-03	6.2990+09	2.0856+07	1.0560-02
1.7530-01	2.3700+07	4.1546+06	3.0490-02	2.9670-03	6.5750+09	1.9508+07	1.1340-02
1.4710-01	2.6340+07	3.8746+06	3.1520-02	2.6580-03	6.9450+09	1.8460+07	1.1540-02
1.2520-01	2.6390+07	3.5544+06	3.3160-02	2.3830-03	7.3840+09	1.7596+07	1.2310-02
1.0790-01	2.9170+07	3.1474+06	3.5670-02	2.1370-03	7.4590+09	1.5940+07	1.2870-02
9.3890-02	3.0150+07	2.8308+06	3.8690-02	1.9090-03	7.5080+09	1.4333+07	1.3580-02
8.2470-02	2.9990+07	2.4733+06	4.2410-02	1.7070-03	7.5240+09	1.2843+07	1.5010-02
7.5010-02	3.6450+07	2.6612+06	4.0020-02	1.5300-03	7.6630+09	1.1724+07	1.5770-02
6.5090-02	3.6360+07	2.3667+06	4.4710-02	1.3670-03	7.7490+09	1.0593+07	1.6610-02
5.6930-02	4.3270+07	2.4634+06	3.5370-02	1.2250-03	7.7220+09	9.4594+06	1.8330-02
4.8970-02	5.4890+07	2.6880+06	3.4330-02	1.0990-03	7.5920+09	8.3436+06	1.9730-02
4.2570-02	7.0420+07	2.9978+06	3.2420-02	9.8530-04	7.3570+09	7.2489+06	2.1440-02
3.7360-02	9.8910+07	3.6953+06	2.9210-02	8.8250-04	7.0460+09	6.2181+06	2.3490-02
3.3060-02	1.2460+08	4.1193+06	2.8110-02	7.9000-04	6.6580+09	5.2598+06	2.5930-02
2.9520-02	1.6670+08	4.9210+06	2.5970-02	7.0730-04	6.2370+09	4.4114+06	2.8840-02
2.6160-02	2.5570+08	6.6891+06	1.9630-02	6.3330-04	5.7920+09	3.6681+06	3.2210-02
2.3070-02	3.7490+08	8.6489+06	1.7680-02				

RUNS R8,R7 (2-20-66)

THERMAL NEUTRON SPECTRUM

4.5 IN.LIQUID HYDROGEN AT 37 DEGREES

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
4.4270+01	5.9250+04	2.6230+06	1.7400-02
1.4840+01	1.0660+06	1.5819+07	7.8550-02
7.3470+00	4.1480+05	3.0475+06	8.8750-02
4.3720+00	7.4470+05	3.2558+06	7.6830-02
2.8970+00	1.0960+06	3.1751+06	7.5220-02
2.0590+00	1.8890+06	3.8895+06	5.9180-02
1.5390+00	2.4460+06	3.7644+06	5.8720-02
1.1930+00	3.2950+06	3.9309+06	5.4020-02
9.5210-01	3.6520+06	3.4771+06	6.0410-02
7.7750-01	4.7450+06	3.6892+06	5.2290-02
6.4690-01	5.7200+06	3.7003+06	5.3610-02
5.4660-01	6.4370+06	3.5185+06	5.4770-02
4.6800-01	7.1860+06	3.3630+06	5.3600-02
4.0520-01	8.5370+06	3.4592+06	5.1980-02
3.5420-01	8.9670+06	3.1761+06	5.4700-02
3.1230-01	8.8400+06	2.7607+06	6.1640-02
2.7740-01	1.0930+07	3.0320+06	5.4130-02
2.4800-01	1.1210+07	2.7801+06	5.9590-02
2.1240-01	1.4010+07	2.9757+06	3.9160-02
1.7530-01	1.8550+07	3.2518+06	3.7230-02
1.4710-01	2.1920+07	3.2244+06	3.6660-02
1.2520-01	2.1880+07	2.7394+06	4.0750-02
1.0790-01	5.4610+06	5.8924+05	1.1140-01
9.3890-02	2.1180+07	1.9886+06	4.9800-02
8.2470-02	2.6050+07	2.1483+06	4.8360-02
7.3010-02	2.8360+07	2.0706+06	5.0560-02
6.5090-02	2.7730+07	1.8049+06	5.3870-02
5.6930-02	3.5220+07	2.0051+06	4.1780-02
4.8970-02	4.6650+07	2.2845+06	3.8390-02
4.2570-02	5.8070+07	2.4720+06	3.7890-02
3.7360-02	7.5790+07	2.8315+06	3.5850-02
3.3060-02	9.4850+07	3.1357+06	3.4190-02
2.9520-02	1.4040+08	4.1446+06	3.0480-02
2.6160-02	2.2530+08	5.8938+06	2.2090-02

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
2.3070-02	3.3310+08	7.6846+06	1.9900-02
2.0590-02	5.0200+08	1.0336+07	1.7690-02
1.8320-02	8.8810+08	1.6270+07	1.2870-02
1.6250-02	1.6080+09	2.6130+07	1.0310-02
1.4530-02	2.2410+09	3.2562+07	9.4710-03
1.2950-02	3.1650+09	4.0987+07	7.8950-03
1.1470-02	3.4970+09	4.0111+07	8.1540-03
1.0190-02	3.8260+09	3.8987+07	8.5700-03
9.0770-03	4.1720+09	3.7869+07	9.0450-03
8.1070-03	4.4820+09	3.6336+07	9.5850-03
7.2680-03	4.8500+09	3.5250+07	1.0120-02
6.4890-03	5.9110+09	3.8356+07	9.2930-03
5.7740-03	6.5130+09	3.7606+07	9.7870-03
5.1670-03	7.2220+09	3.7316+07	9.4020-03
4.6160-03	6.6250+09	3.0581+07	8.7630-03
4.1160-03	7.0980+09	2.9215+07	9.3230-03
3.6930-03	7.3430+09	2.7118+07	1.0050-02
3.3110-03	7.7660+09	2.5713+07	1.0120-02
2.9670-03	8.3270+09	2.4706+07	1.0730-02
2.6580-03	8.5040+09	2.2604+07	1.1090-02
2.3830-03	8.8240+09	2.1028+07	1.2000-02
2.1370-03	8.9340+09	1.9092+07	1.2520-02
1.9090-03	9.3640+09	1.7876+07	1.2900-02
1.7070-03	9.3790+09	1.6010+07	1.4280-02
1.5300-03	9.1010+09	1.3925+07	1.5360-02
1.3670-03	9.4690+09	1.2944+07	1.5990-02
1.2250-03	9.2870+09	1.1377+07	1.7820-02
1.0990-03	9.0490+09	9.9449+06	1.9280-02
9.8530-04	8.7110+09	8.5829+06	2.1040-02
8.8250-04	8.2680+09	7.2965+06	2.3170-02
7.9000-04	7.7420+09	6.1162+06	2.5720-02
7.0730-04	7.1990+09	5.0919+06	2.8770-02
6.3330-04	6.6070+09	4.1842+06	3.2380-02

RUNS R5,R6 (2-20-66)

THERMAL NEUTRON SPECTRUM

7.0 IN.LIQUID HYDROGEN AT 37 DEGREES

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
7.3470+00	3.2470+05	2.3856+06	1.0590-01
4.3720+00	4.9890+05	2.1812+06	1.0950-01
2.8970+00	7.5080+05	2.1751+06	1.0470-01
2.0590+00	1.2740+06	2.6232+06	8.0760-02
1.5390+00	1.6680+06	2.5671+06	7.8020-02
1.1930+00	1.8340+06	2.1880+06	8.6450-02
9.5210-01	2.5250+06	2.4041+06	7.7700-02
7.7750-01	3.3050+06	2.5696+06	7.0600-02
6.4690-01	3.5560+06	2.3004+06	7.4910-02
5.4660-01	4.1100+06	2.2465+06	7.4800-02
4.6800-01	5.0840+06	2.3793+06	7.0160-02
4.0520-01	5.8350+06	2.3643+06	6.8220-02
3.5420-01	6.4240+06	2.2754+06	6.7010-02
3.1230-01	5.7530+06	1.7967+06	8.4230-02
2.7740-01	6.5890+06	1.8278+06	7.7860-02
2.4800-01	7.6180+06	1.8893+06	7.2920-02
2.1240-01	9.6960+06	2.0594+06	5.0350-02
1.7530-01	1.2880+07	2.2579+06	4.5910-02
1.4710-01	1.5300+07	2.2506+06	4.5370-02
1.2520-01	1.2310+07	1.5412+06	5.9380-02
1.0790-01	1.4470+07	1.5613+06	5.8120-02
9.3890-02	1.4620+07	1.3727+06	6.2260-02
8.2470-02	1.4850+07	1.2247+06	6.9070-02
7.3010-02	1.9150+07	1.3981+06	6.2860-02
6.5090-02	1.9320+07	1.2575+06	6.9570-02
5.6930-02	2.4360+07	1.3868+06	5.2480-02
4.8970-02	2.8470+07	1.3942+06	5.4930-02
4.2570-02	3.4490+07	1.4682+06	5.1420-02
3.7360-02	4.7470+07	1.7735+06	4.6040-02
3.3060-02	6.4010+07	2.1162+06	4.3150-02
2.9520-02	9.7450+07	2.8767+06	3.6850-02
2.6160-02	1.4370+08	3.7592+06	2.8440-02
2.3070-02	2.2260+08	5.1354+06	2.4670-02

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
2.0590-02	3.6040+08	7.4206+06	2.0960-02
1.8320-02	6.5660+08	1.2029+07	1.5100-02
1.6250-02	1.3170+09	2.1401+07	1.1470-02
1.4530-02	2.0720+09	3.0106+07	9.9020-03
1.2950-02	2.9570+09	3.8293+07	8.2050-03
1.1470-02	3.3790+09	3.8757+07	8.3330-03
1.0190-02	3.6720+09	3.7418+07	8.8090-03
9.0770-03	3.9490+09	3.5845+07	9.3470-03
8.1070-03	4.1500+09	3.3644+07	1.0010-02
7.2680-03	4.4650+09	3.2452+07	1.0610-02
6.4890-03	5.5520+09	3.6027+07	9.6400-03
5.7740-03	5.9440+09	3.4321+07	1.0300-02
5.1670-03	6.7040+09	3.4640+07	9.8000-03
4.6160-03	6.2700+09	2.8942+07	9.0560-03
4.1160-03	6.8330+09	2.8125+07	9.5500-03
3.6930-03	7.1000+09	2.6220+07	1.0290-02
3.3110-03	7.3870+09	2.4458+07	1.0430-02
2.9670-03	7.7600+09	2.3024+07	1.1190-02
2.6580-03	7.9140+09	2.1035+07	1.1540-02
2.3830-03	8.2470+09	1.9653+07	1.2470-02
2.1370-03	8.4560+09	1.8070+07	1.2940-02
1.9090-03	8.3000+09	1.5845+07	1.3830-02
1.7070-03	8.5720+09	1.4632+07	1.4970-02
1.5300-03	8.3210+09	1.2731+07	1.6150-02
1.3670-03	8.3180+09	1.1371+07	1.7160-02
1.2250-03	8.1650+09	1.0002+07	1.9090-02
1.0990-03	7.9360+09	8.7217+06	2.0670-02
9.8530-04	7.6140+09	7.5021+06	2.2590-02
8.8250-04	7.2000+09	6.3540+06	2.4910-02
7.9000-04	6.7080+09	5.2993+06	2.7700-02
7.0730-04	6.2150+09	4.3959+06	3.1000-02
6.3330-04	5.6830+09	3.5990+06	3.4900-02

RUNS R4,R3 (2-20-66)

THERMAL NEUTRON SPECTRUM

10.5 IN.LIQUID HYDROGEN AT 37 DEGREES

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
2.9550+01	4.7970+05	1.4175+07	1.5090-01
5.8600+00	1.6790+05	9.8389+05	1.3990-01
2.8970+00	3.4410+05	9.9686+05	1.6340-01
2.0590+00	4.2890+05	8.8311+05	1.7450-01
1.5390+00	7.1480+05	1.1001+06	1.3170-01
1.1930+00	8.3770+05	9.9938+05	1.3700-01
9.5210-01	1.2660+06	1.2054+06	1.0780-01
7.7750-01	1.6840+06	1.3093+06	9.6800-02
6.4690-01	1.7690+06	1.1444+06	1.0740-01
5.4660-01	2.1840+06	1.1938+06	9.7760-02
4.6800-01	2.3280+06	1.0895+06	1.0350-01
4.0520-01	2.3320+06	9.4493+05	1.1340-01
3.5420-01	2.6220+06	9.2871+05	1.1390-01
3.1230-01	3.5010+06	1.0934+06	9.1560-02
2.7740-01	2.9500+06	8.1633+05	1.1690-01
2.4800-01	3.8990+06	9.6695+05	1.0360-01
2.1240-01	4.0890+06	8.6850+05	7.3170-02
1.7530-01	5.9250+06	1.0387+06	6.4350-02
1.4710-01	6.6610+06	9.7983+05	6.6740-02
1.2520-01	7.7110+06	9.6542+05	6.7760-02
1.0790-01	9.4730+06	1.0221+06	6.0810-02
9.3890-02	7.1990+06	6.7591+05	8.0230-02
8.2470-02	8.5720+06	7.0693+05	7.6560-02
7.3010-02	1.0370+07	7.5711+05	7.4800-02
6.5090-02	9.0460+06	5.8880+05	9.4510-02
5.6930-02	1.1390+07	6.4843+05	7.0950-02
4.8970-02	1.5090+07	7.3896+05	6.2010-02
4.2570-02	1.7870+07	7.6073+05	6.3410-02
3.7360-02	2.4440+07	9.1308+05	5.5130-02
3.3060-02	3.2670+07	1.0801+06	5.1960-02
2.9520-02	4.7290+07	1.3960+06	4.3780-02
2.6160-02	6.5520+07	1.7140+06	3.4910-02
2.3070-02	9.8570+07	2.2740+06	3.0640-02

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
2.0590-02	1.5940+08	3.2820+06	2.5740-02
1.8320-02	3.1520+08	5.7745+06	1.7710-02
1.6250-02	6.7260+08	1.0930+07	1.2940-02
1.4530-02	1.1240+09	1.6332+07	1.0820-02
1.2950-02	1.8210+09	2.3582+07	8.4180-03
1.1470-02	2.1760+09	2.4959+07	8.3480-03
1.0190-02	2.3430+09	2.3875+07	6.8500-03
9.0770-03	2.5380+09	2.3037+07	9.3770-03
8.1070-03	2.6170+09	2.1216+07	1.0130-02
7.2660-03	2.8280+09	2.0554+07	1.0720-02
6.4890-03	3.5280+09	2.2893+07	9.7370-03
5.7740-03	3.8780+09	2.2392+07	1.0260-02
5.1670-03	4.1770+09	2.1583+07	9.9690-03
4.6160-03	4.0710+09	1.8792+07	9.0350-03
4.1160-03	4.3930+09	1.8082+07	9.5850-03
3.6930-03	4.5190+09	1.6689+07	1.0360-02
3.3110-03	4.7160+09	1.5615+07	1.0510-02
2.9670-03	4.9160+09	1.4586+07	1.1290-02
2.6580-03	5.1170+09	1.3601+07	1.1560-02
2.3830-03	5.2320+09	1.2468+07	1.2610-02
2.1370-03	5.2850+09	1.1294+07	1.3170-02
1.9090-03	5.2830+09	1.0085+07	1.3950-02
1.7070-03	5.3470+09	9.1273+06	1.5350-02
1.5300-03	5.0680+09	7.7540+06	1.6750-02
1.3670-03	4.8190+09	6.5876+06	1.8160-02
1.2250-03	4.6970+09	5.7538+06	2.0190-02
1.0990-03	4.4830+09	4.9268+06	2.2040-02
9.8530-04	4.2170+09	4.1550+06	2.4300-02
8.8250-04	3.9070+09	3.4479+06	2.7030-02
7.9000-04	3.5620+09	2.8140+06	3.0320-02
7.0730-04	3.2250+09	2.2810+06	3.4200-02
6.3330-04	2.8930+09	1.8321+06	3.8660-02

RUNS R1,R2 (2-20-66)

THERMAL NEUTRON SPECTRUM

13.0 IN.LIQUID HYDROGEN AT 37 DEGREES

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N	ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
4.3720+00	2.0830+05	9.1069+05	1.6790-01	1.8320-02	2.0930+08	3.8344+06	1.8580-02
2.4780+00	2.3840+05	5.9076+05	1.7440-01	1.6250-02	4.6270+08	7.5189+06	1.3290-02
1.5390+00	4.4370+05	6.8285+05	1.9060-01	1.4530-02	8.0250+08	1.1660+07	1.0850-02
1.1930+00	6.4220+05	7.6614+05	1.5750-01	1.2950-02	1.3160+09	1.7042+07	8.3350-03
9.5210-01	9.2640+05	8.8203+05	1.3000-01	1.1470-02	1.6370+09	1.8776+07	8.1280-03
7.7750-01	8.4550+05	6.5738+05	1.6890-01	1.0190-02	1.7400+09	1.7731+07	8.6710-03
6.4690-01	1.0480+06	6.7795+05	1.4890-01	9.0770-03	1.8450+09	1.6747+07	9.2760-03
5.4660-01	1.1870+06	6.4881+05	1.5680-01	8.1070-03	1.9860+09	1.6101+07	9.8320-03
4.6800-01	1.0760+06	5.0357+05	1.9320-01	7.2680-03	2.1030+09	1.5285+07	1.0490-02
4.0520-01	1.4480+06	5.8673+05	1.5430-01	6.4890-03	2.5600+09	1.6612+07	9.6500-03
3.5420-01	2.1970+06	7.7818+05	1.2010-01	5.7740-03	2.8470+09	1.6439+07	1.0080-02
3.1230-01	2.2270+06	6.9549+05	1.2220-01	5.1670-03	3.0990+09	1.6013+07	9.7920-03
2.7740-01	2.5160+06	6.9794+05	1.1710-01	4.6160-03	3.0210+09	1.3945+07	8.8400-03
2.4800-01	2.0020+06	4.9650+05	1.6030-01	4.1160-03	3.2120+09	1.3221+07	9.4770-03
2.1240-01	3.4380+06	7.3023+05	7.6620-02	3.6930-03	3.3200+09	1.2261+07	1.0230-02
1.7530-01	4.0680+06	7.1312+05	7.6070-02	3.3110-03	3.4470+09	1.1413+07	1.0360-02
1.4710-01	3.7100+06	5.4574+05	9.5820-02	2.9670-03	3.4970+09	1.0376+07	1.1330-02
1.2520-01	4.1870+06	5.2421+05	1.0240-01	2.6580-03	3.6400+09	9.6751+06	1.1600-02
1.0790-01	5.5350+06	5.9723+05	8.0730-02	2.3830-03	3.7210+09	8.8671+06	1.2650-02
9.3890-02	6.0250+06	5.6569+05	8.1720-02	2.1370-03	3.8000+09	8.1206+06	1.3140-02
8.2470-02	5.8950+06	4.8616+05	9.8000-02	1.9090-03	3.8200+09	7.2924+06	1.3860-02
7.3010-02	5.9950+06	4.3769+05	1.0630-01	1.7070-03	3.7270+09	6.3620+06	1.5680-02
6.5090-02	6.5800+06	4.2829+05	1.0700-01	1.5300-03	3.6680+09	5.6120+06	1.6750-02
5.6930-02	8.9380+06	5.0884+05	7.7900-02	1.3670-03	3.4550+09	4.7230+06	1.8060-02
4.8970-02	1.1110+07	5.4406+05	6.7010-02	1.2250-03	3.3780+09	4.1380+06	1.9910-02
4.2570-02	1.5090+07	6.4238+05	5.7040-02	1.0990-03	3.2010+09	3.5179+06	2.1770-02
3.7360-02	1.9850+07	7.4160+05	5.3460-02	9.8530-04	2.9930+09	2.9490+06	2.3990-02
3.3060-02	2.0660+07	6.8302+05	5.7650-02	8.8250-04	2.7490+09	2.4260+06	2.6670-02
2.9520-02	3.6720+07	1.0840+06	4.3420-02	7.9000-04	2.4960+09	1.9718+06	2.9760-02
2.6160-02	4.2080+07	1.1008+06	3.8300-02	7.0730-04	2.2360+09	1.5815+06	3.3370-02
2.3070-02	7.1570+07	1.6511+06	3.0830-02	6.3330-04	1.9920+09	1.2615+06	3.7190-02
2.0590-02	1.0180+08	2.0961+06	2.8040-02				

RUNS T9,T10 (2-22-66)

THERMAL NEUTRON SPECTRUM

2.5 IN.LIQUID HYDROGEN AT 78 DEGREES

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N	ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.2710+02	6.0840+04	7.7328+06	1.6050-01	4.4380-02	9.0090+07	3.9982+06	5.3260-02
3.1810+01	2.3330+05	7.4213+06	1.3090-01	3.9630-02	9.8330+07	3.8968+06	4.9880-02
1.4360+01	3.6830+05	5.2888+06	1.5130-01	3.5320-02	1.2950+08	4.5739+06	4.5280-02
9.1560+00	6.4870+05	5.9395+06	1.7630-01	3.1470-02	1.6760+08	5.2744+06	4.0470-02
7.1800+00	8.2680+05	5.9364+06	1.6770-01	2.8080-02	2.1760+08	6.1102+06	3.8370-02
5.7810+00	1.2430+06	7.1858+06	1.3260-01	2.5130-02	2.8380+08	7.1319+06	3.4170-02
4.7550+00	1.1570+06	5.5015+06	1.7370-01	2.2440-02	4.1850+08	9.3911+06	2.8840-02
3.9800+00	1.4290+06	5.6874+06	1.6310-01	2.0030-02	6.4350+08	1.2889+07	2.3770-02
3.3790+00	1.4090+06	4.7610+06	1.9140-01	1.7940-02	1.0600+09	1.9016+07	1.9840-02
2.9050+00	2.4270+06	7.0504+06	1.2300-01	1.6120-02	1.7660+09	2.8468+07	1.5760-02
2.5240+00	2.6550+06	6.7012+06	1.2360-01	1.4470-02	2.5000+09	3.6175+07	1.3760-02
2.2140+00	4.4810+06	9.9209+06	6.5800-02	1.2950-02	3.4460+09	4.4626+07	1.2180-02
1.9570+00	3.0470+06	5.9630+06	1.3580-01	1.1600-02	3.7660+09	4.3686+07	1.2550-02
1.7430+00	4.2900+06	7.4775+06	1.0570-01	1.0410-02	3.9670+09	4.1296+07	1.3350-02
1.4850+00	4.4960+06	6.6766+06	8.0920-02	9.3260-03	4.2550+09	3.9682+07	1.3630-02
1.2180+00	6.1010+06	7.4310+06	6.8250-02	8.3450-03	4.6210+09	3.8562+07	1.4390-02
1.0170+00	5.4230+06	5.5152+06	8.9320-02	7.4920-03	4.8940+09	3.6666+07	1.5280-02
8.6190-01	6.7060+06	5.7799+06	8.4090-02	6.7310-03	6.1390+09	4.1322+07	1.4510-02
7.4000-01	7.1400+06	5.2836+06	8.8060-02	6.0360-03	6.5610+09	3.9602+07	1.4750-02
6.4220-01	9.1840+06	5.8980+06	7.8320-02	5.4030-03	7.4410+09	4.0204+07	1.4670-02
5.6260-01	8.0020+06	4.5019+06	9.8950-02	4.8490-03	7.0370+09	3.4122+07	1.3790-02
4.9690-01	1.1300+07	5.6150+06	7.5000-02	4.3610-03	7.1130+09	3.1020+07	1.4180-02
4.4210-01	1.4180+07	6.2690+06	6.6160-02	3.9220-03	7.4810+09	2.9340+07	1.4780-02
3.9590-01	9.4840+06	3.7547+06	1.0880-01	3.5270-03	8.1260+09	2.8660+07	1.5140-02
3.4790-01	1.5480+07	5.3855+06	5.9780-02	3.1660-03	8.3600+09	2.6468+07	1.5670-02
3.0070-01	1.3130+07	3.9482+06	8.2020-02	2.8370-03	8.7950+09	2.4951+07	1.6460-02
2.6260-01	2.1200+07	5.5671+06	5.1290-02	2.5460-03	9.2620+09	2.3581+07	1.7320-02
2.3120-01	1.8260+07	4.2217+06	6.9470-02	2.2880-03	9.1570+09	2.0951+07	1.8730-02
2.0520-01	2.2390+07	4.5944+06	6.8030-02	2.0560-03	9.6310+09	1.9801+07	1.9300-02
1.8330-01	2.5500+07	4.6741+06	6.6560-02	1.8460-03	9.6080+09	1.7736+07	2.0960-02
1.6200-01	2.9150+07	4.7223+06	5.4560-02	1.6590-03	1.0010+10	1.6607+07	2.1730-02
1.4180-01	3.2600+07	4.6227+06	5.7000-02	1.4910-03	9.6410+09	1.4375+07	2.3950-02
1.2520-01	3.1350+07	3.9250+06	6.2920-02	1.3410-03	8.9670+09	1.2025+07	2.6640-02
1.1130-01	3.8900+07	4.3296+06	5.7010-02	1.2050-03	9.3760+09	1.1298+07	2.8130-02
9.9630-02	3.9190+07	3.9045+06	6.3280-02	1.0830-03	8.4480+09	9.1492+06	3.2080-02
8.8590-02	3.8550+07	3.4151+06	6.1580-02	9.7330-04	7.7760+09	7.5684+06	3.6400-02
7.8310-02	4.1330+07	3.2366+06	6.4740-02	8.7500-04	7.5330+09	6.5914+06	3.9270-02
6.9730-02	4.3160+07	3.0095+06	6.8170-02	7.8710-04	6.2270+09	4.9013+06	4.7840-02
6.2480-02	5.5080+07	3.4414+06	6.0960-02	7.0780-04	6.5410+09	4.6297+06	4.9450-02
5.5760-02	5.9540+07	3.3200+06	5.5160-02	6.3640-04	5.6160+09	3.5740+06	6.0810-02

RUNS T8,T7 (2-22-66)

THERMAL NEUTRON SPECTRUM

4.5 IN.LIQUID HYDROGEN AT 78 DEGREES

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N	ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
7.9460+01	5.8910+04	4.6810+06	1.9200-01	3.1950-02	1.3460+08	4.3005+06	4.3720-02
1.6650+01	3.5270+05	5.8725+06	1.7740-01	2.8460-02	1.9490+08	5.5469+06	3.8920-02
1.2070+01	5.0920+05	6.1460+06	1.6010-01	2.5440-02	2.5280+08	6.4312+06	3.4290-02
8.1680+00	5.9020+05	4.8208+06	1.4260-01	2.2700-02	3.7900+08	8.6033+06	2.8880-02
5.2680+00	9.4660+05	4.9867+06	1.2560-01	2.0240-02	5.3920+08	1.0913+07	2.5090-02
3.6790+00	1.2220+06	4.4957+06	1.3360-01	1.8110-02	9.5890+08	1.7366+07	2.0290-02
2.7150+00	1.4830+06	4.0265+06	1.3630-01	1.6270-02	1.5890+09	2.5853+07	1.6130-02
2.0850+00	2.1110+06	4.4014+06	1.2010-01	1.4590-02	2.3600+09	3.4432+07	1.3750-02
1.6520+00	1.8870+06	3.1173+06	1.5730-01	1.3060-02	3.2720+09	4.2732+07	1.2180-02
1.3410+00	3.3860+06	4.5406+06	1.0720-01	1.1690-02	3.7510+09	4.3849+07	1.2230-02
1.1100+00	3.8260+06	4.2469+06	1.0840-01	1.0490-02	4.0270+09	4.2243+07	1.2850-02
9.3460-01	5.1590+06	4.8216+06	9.2800-02	9.3960-03	4.3720+09	4.1079+07	1.3090-02
7.9750-01	4.7340+06	3.7754+06	1.1120-01	8.4060-03	4.6230+09	3.8861+07	1.3960-02
6.8850-01	6.7730+06	4.6632+06	9.1050-02	7.5460-03	4.9720+09	3.7519+07	1.4700-02
6.0040-01	7.2640+06	4.3613+06	9.3330-02	6.7770-03	6.0760+09	4.1177+07	1.4160-02
5.2820-01	7.8390+06	4.1406+06	9.6470-02	6.0750-03	6.5200+09	3.9609+07	1.4360-02
4.6830-01	9.8370+06	4.6067+06	8.2400-02	5.4370-03	7.3200+09	3.9799+07	1.4430-02
4.1800-01	9.5270+06	3.9823+06	9.2190-02	4.8770-03	7.4270+09	3.6221+07	1.3190-02
3.6610-01	1.0460+07	3.8294+06	7.7790-02	4.3860-03	7.2800+09	3.1930+07	1.3630-02
3.1530-01	1.1870+07	3.7420+06	7.6450-02	3.9430-03	7.8610+09	3.0996+07	1.4000-02
2.7440-01	1.3170+07	3.6138+06	7.6290-02	3.5450-03	8.0840+09	2.8658+07	1.4750-02
2.4100-01	1.4180+07	3.4174+06	8.2980-02	3.1880-03	8.7090+09	2.7764+07	1.5180-02
2.1340-01	1.8990+07	4.0525+06	6.6050-02	2.8630-03	8.8310+09	2.5283+07	1.5840-02
1.9020-01	1.9320+07	3.6747+06	7.2400-02	2.5680-03	9.2090+09	2.3649+07	1.6710-02
1.6770-01	2.5650+07	4.3015+06	5.7550-02	2.3070-03	9.6240+09	2.2203+07	1.7660-02
1.4650-01	2.5100+07	3.6771+06	6.3730-02	2.0720-03	9.7600+09	2.0223+07	1.8560-02
1.2910-01	2.8690+07	3.7039+06	6.2020-02	1.8600-03	9.8240+09	1.8273+07	2.0020-02
1.1460-01	3.1930+07	3.6592+06	6.3190-02	1.6700-03	1.0010+10	1.6717+07	2.1130-02
1.0240-01	3.3140+07	3.3935+06	6.4970-02	1.5010-03	1.0010+10	1.5025+07	2.2940-02
9.0890-02	3.4270+07	3.1148+06	6.1920-02	1.3490-03	9.4160+09	1.2702+07	2.5410-02
8.0220-02	3.7400+07	3.0002+06	6.4130-02	1.2120-03	8.8450+09	1.0720+07	2.8080-02
7.1330-02	3.7790+07	2.6956+06	6.5780-02	1.0890-03	8.6090+09	9.3752+06	3.0740-02
6.3840-02	3.9980+07	2.5523+06	7.1600-02	9.7850-04	7.8950+09	7.7253+06	3.4660-02
5.6900-02	5.3710+07	3.0561+06	5.7020-02	8.7950-04	7.2440+09	6.3711+06	3.9780-02
5.0540-02	5.8950+07	2.9793+06	5.8910-02	7.9090-04	6.6420+09	5.2532+06	4.4340-02
4.5190-02	6.6080+07	2.9862+06	6.0080-02	7.1100-04	6.2420+09	4.4381+06	4.9860-02
4.0310-02	8.2040+07	3.3070+06	5.2220-02	6.3910-04	6.2250+09	3.9784+06	5.5810-02
3.5890-02	1.0660+08	3.8259+06	4.8370-02				

RUNS T5,T6 (2-22-66)

THERMAL NEUTRON SPECTRUM

7.0 IN.LIQUID HYDROGEN AT 78 DEGREES

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N	ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
9.7800+01	4.5930+04	4.4920+06	1.6960-01	3.1950-02	6.6250+07	2.1167+06	4.8800-02
2.0530+01	1.4270+05	2.9296+06	1.9400-01	2.8460-02	9.1640+07	2.6081+06	4.5330-02
1.0610+01	2.7140+05	2.8796+06	1.7740-01	2.5440-02	1.1670+08	2.9688+06	4.0620-02
6.4810+00	4.3510+05	2.8199+06	1.6620-01	2.2700-02	1.8150+08	4.1200+06	3.2780-02
4.3670+00	5.8790+05	2.5674+06	1.7580-01	2.0240-02	2.7160+08	5.4972+06	2.7700-02
2.9360+00	7.6720+05	2.2525+06	1.5320-01	1.8110-02	4.4920+08	8.1350+06	2.3190-02
2.0850+00	1.1710+06	2.4415+06	1.5690-01	1.6270-02	8.0460+08	1.3094+07	1.7680-02
1.7430+00	1.5560+06	2.7121+06	1.8350-01	1.4590-02	1.2770+09	1.8631+07	1.4590-02
1.4850+00	1.7160+06	2.5483+06	1.5890-01	1.3060-02	1.7790+09	2.3234+07	1.2850-02
1.2180+00	1.4950+06	1.8209+06	1.8270-01	1.1690-02	2.0930+09	2.4467+07	1.2740-02
1.0170+00	3.1830+06	3.2371+06	1.0050-01	1.0490-02	2.2510+09	2.3613+07	1.3400-02
8.6190-01	2.5180+06	2.1703+06	1.4260-01	9.3960-03	2.5190+09	2.3669+07	1.3400-02
7.1470-01	2.5370+06	1.8132+06	1.3590-01	8.4060-03	2.6530+09	2.2301+07	1.4360-02
6.0040-01	3.2910+06	1.9759+06	1.4190-01	7.5460-03	2.8870+09	2.1785+07	1.5090-02
5.2820-01	4.5730+06	2.4155+06	1.1160-01	6.7770-03	3.4230+09	2.3198+07	1.4690-02
4.6830-01	4.4670+06	2.0919+06	1.2400-01	6.0750-03	3.8860+09	2.3620+07	1.4490-02
4.1800-01	5.8520+06	2.4461+06	1.0520-01	5.4370-03	4.3880+09	2.3858+07	1.4500-02
3.6610-01	4.3460+06	1.5911+06	1.2630-01	4.8770-03	4.2900+09	2.0922+07	1.3500-02
3.1530-01	5.8000+06	1.8287+06	1.0770-01	4.3800-03	4.4230+09	1.9399+07	1.3590-02
2.7440-01	6.9420+06	1.9049+06	9.7090-02	3.9430-03	4.6730+09	1.8426+07	1.4170-02
2.4100-01	7.4080+06	1.7853+06	1.0550-01	3.5450-03	4.8550+09	1.7211+07	1.4810-02
2.1340-01	8.7950+06	1.8769+06	9.1490-02	3.1880-03	5.0850+09	1.6211+07	1.5500-02
1.9020-01	9.0500+06	1.7213+06	1.0340-01	2.8650-03	5.2010+09	1.4890+07	1.6140-02
1.6770-01	1.0180+07	1.7072+06	8.9000-02	2.5680-03	5.6530+09	1.4517+07	1.6580-02
1.4650-01	1.2330+07	1.8063+06	8.3760-02	2.3070-03	5.7910+09	1.3360+07	1.7770-02
1.2910-01	1.5340+07	1.9804+06	7.6300-02	2.0720-03	5.7240+09	1.1860+07	1.8920-02
1.1460-01	1.5020+07	1.7213+06	8.2160-02	1.8600-03	5.5830+09	1.0384+07	2.0770-02
1.0240-01	1.4780+07	1.5135+06	8.7560-02	1.6700-03	5.8290+09	9.7344+06	2.1770-02
9.0890-02	1.5680+07	1.4252+06	8.4390-02	1.5010-03	5.8390+09	8.7643+06	2.3360-02
8.0220-02	2.2030+07	1.7672+06	6.7700-02	1.3490-03	5.6820+09	7.6650+06	2.5540-02
7.1330-02	1.7050+07	1.2162+06	8.8470-02	1.2120-03	5.3530+09	6.4878+06	2.8330-02
6.3840-02	2.3060+07	1.4722+06	7.6670-02	1.0890-03	5.1510+09	5.6094+06	3.1390-02
5.6900-02	2.5200+07	1.4339+06	6.8050-02	9.7850-04	4.6250+09	4.5256+06	3.6030-02
5.0540-02	3.2430+07	1.6390+06	6.5050-02	8.7950-04	4.1930+09	3.6877+06	4.1220-02
4.5190-02	3.4160+07	1.5437+06	7.1970-02	7.9090-04	3.8440+09	3.0402+06	4.7290-02
4.0310-02	4.2390+07	1.7087+06	6.1390-02	7.1100-04	3.3360+09	2.3719+06	5.6060-02
3.5890-02	5.1230+07	1.8386+06	5.8290-02	6.3910-04	3.3910+09	2.1672+06	6.1690-02

RUNS T4,T3 (2-22-66)

THERMAL NEUTRON SPECTRUM

10.5 IN.LIQUID HYDROGEN AT 78 DEGREES

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N	ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
3.3080+01	9.7300+04	3.2187+06	1.7440-01	2.1940-02	1.0520+08	2.3081+06	4.0470-02
6.7180+00	2.9610+05	1.9892+06	1.7710-01	1.9620-02	1.6060+08	3.1510+06	3.2600-02
3.0000+00	4.9810+05	1.4943+06	1.7530-01	1.7520-02	2.9650+08	5.1947+06	2.4440-02
1.6670+00	8.7440+05	1.4576+06	1.7590-01	1.5700-02	5.1260+08	8.0478+06	2.0040-02
1.1170+00	1.2690+06	1.4175+06	1.6000-01	1.4110-02	7.6600+08	1.0808+07	1.6940-02
8.6190-01	1.9530+06	1.6833+06	1.6980-01	1.2640-02	1.0760+09	1.3601+07	1.4760-02
7.4000-01	2.0470+06	1.5148+06	1.8130-01	1.1330-02	1.2600+09	1.4276+07	1.4750-02
6.4220-01	2.1080+06	1.3538+06	1.9910-01	1.0170-02	1.3680+09	1.3913+07	1.5420-02
5.6260-01	2.5100+06	1.4121+06	1.7710-01	9.1190-03	1.4420+09	1.3150+07	1.6000-02
4.8280-01	2.6800+06	1.2939+06	1.5310-01	8.1650-03	1.5900+09	1.2982+07	1.6590-02
3.9670-01	2.3110+06	9.1677+05	1.8450-01	7.3110-03	1.7640+09	1.2897+07	1.6810-02
3.3100-01	3.5240+06	1.1664+06	1.5030-01	6.5530-03	2.1770+09	1.4266+07	1.6600-02
2.8710-01	3.5630+06	1.0229+06	1.6980-01	5.8820-03	2.3720+09	1.3952+07	1.6800-02
2.5150-01	3.5750+06	8.9911+05	1.8000-01	5.2720-03	2.7140+09	1.4308+07	1.6000-02
2.2200-01	4.4540+06	9.8879+05	1.5650-01	4.7230-03	2.6510+09	1.2521+07	1.4600-02
1.9750-01	5.0660+06	1.1190+06	1.3330-01	4.2300-03	2.8250+09	1.1950+07	1.4980-02
1.7680-01	4.6700+06	8.2566+05	1.8620-01	3.7900-03	2.8180+09	1.0680+07	1.6100-02
1.5660-01	7.6990+06	1.2057+06	1.0750-01	3.3970-03	3.0860+09	1.0483+07	1.6550-02
1.3740-01	8.6420+06	1.1874+06	1.0320-01	3.0480-03	3.2460+09	9.8999+06	1.7220-02
1.2150-01	6.2440+06	7.5865+05	1.6710-01	2.7370-03	3.3930+09	9.2866+06	1.8220-02
1.0820-01	9.9020+06	1.0714+06	1.0450-01	2.4610-03	3.4170+09	8.4092+06	1.9540-02
9.7000-02	8.9540+06	8.6854+05	1.2770-01	2.2110-03	3.6130+09	7.9883+06	2.0150-02
8.6380-02	1.0140+07	8.7589+05	1.1600-01	1.9860-03	3.6200+09	7.1893+06	2.1660-02
7.6470-02	1.2720+07	9.7270+05	9.8880-02	1.7840-03	3.6550+09	6.5205+06	2.3100-02
6.8180-02	1.2580+07	8.5770+05	1.1150-01	1.6020-03	3.6010+09	5.7688+06	2.5350-02
6.0550-02	1.3530+07	8.1924+05	9.5720-02	1.4400-03	3.4110+09	4.9118+06	2.7830-02
5.3580-02	1.6790+07	8.9961+05	9.2330-02	1.2940-03	3.4410+09	4.4527+06	3.0050-02
4.7750-02	1.9180+07	9.1584+05	8.7910-02	1.1620-03	3.2700+09	3.7997+06	3.3610-02
4.2830-02	2.1650+07	9.2727+05	8.4470-02	1.0430-03	2.9620+09	3.0894+06	3.8810-02
3.8320-02	2.7420+07	1.0507+06	8.0290-02	9.3680-04	2.5270+09	2.3673+06	4.8040-02
3.4220-02	3.6080+07	1.2347+06	6.7750-02	8.4170-04	2.7160+09	2.2861+06	4.7290-02
3.0560-02	3.6470+07	1.1145+06	7.1670-02	7.5690-04	2.4710+09	1.8703+06	5.5830-02
2.7330-02	6.0320+07	1.6485+06	5.1290-02	6.8040-04	2.0930+09	1.4241+06	7.0670-02
2.4510-02	7.7340+07	1.8956+06	4.7280-02	6.1170-04	1.9500+09	1.1928+06	8.5730-02

RUNS T1,T2 (2-22-66)

THERMAL NEUTRON SPECTRUM

13.0 IN.LIQUID HYDROGEN AT 78 DEGREES

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
3.7340+01	1.1740+05	4.3837+06	1.8700-01
3.0000+00	4.3700+05	1.3110+06	1.9440-01
1.3920+00	6.6680+05	9.2819+05	1.9650-01
7.7360-01	1.3760+06	1.0645+06	1.7820-01
5.4780-01	1.7710+06	9.7015+05	1.7180-01
4.1900-01	2.1520+06	9.0169+05	1.8850-01
3.3960-01	2.5830+06	8.7719+05	1.8300-01
2.8090-01	2.7310+06	7.6714+05	1.9380-01
2.4100-01	3.7100+06	8.9411+05	1.7290-01
2.0180-01	3.3470+06	6.7542+05	1.6820-01
1.6770-01	6.1540+06	1.0320+06	1.1380-01
1.4650-01	5.3470+06	7.8334+05	1.4950-01
1.2910-01	7.5640+06	9.7651+05	1.1270-01
1.1460-01	7.4370+06	8.5228+05	1.3590-01
1.0240-01	8.2640+06	8.4623+05	1.3330-01
9.0890-02	6.3310+06	5.7542+05	1.6710-01
8.0220-02	8.3770+06	6.7200+05	1.3760-01
7.1330-02	9.1840+06	6.5509+05	1.3530-01
6.3840-02	1.1500+07	7.3416+05	1.2120-01
5.6900-02	1.1380+07	6.4752+05	1.2420-01
5.0540-02	1.3520+07	6.8330+05	1.1540-01
4.5190-02	1.5730+07	7.1084+05	1.0360-01
4.0310-02	2.0690+07	8.3401+05	7.9740-02
3.5890-02	2.3480+07	8.4270+05	7.8700-02
3.1950-02	2.7870+07	8.9045+05	7.4050-02
2.8460-02	3.6120+07	1.0280+06	6.3540-02
2.5440-02	5.1090+07	1.2997+06	5.0080-02
2.2700-02	6.3090+07	1.4321+06	5.0260-02
2.0240-02	9.6300+07	1.9491+06	3.8110-02
1.8110-02	1.6970+08	3.0733+06	2.9210-02
1.6270-02	2.8070+08	4.5670+06	2.2980-02

ENERGY (EV)	N(E)	E*N(E)	DELTA(N)/N
1.4590-02	4.2900+08	6.2591+06	1.9350-02
1.3060-02	6.4760+08	8.4577+06	1.6280-02
1.1690-02	7.9280+08	9.2678+06	1.5670-02
1.0490-02	8.9550+08	9.3938+06	1.5950-02
9.3960-03	1.0110+09	9.4994+06	1.6030-02
8.4060-03	1.0890+09	9.1541+06	1.6980-02
7.5460-03	1.1800+09	8.9043+06	1.7860-02
6.7770-03	1.4220+09	9.6369+06	1.7290-02
6.0750-03	1.6420+09	9.9751+06	1.7010-02
5.4370-03	1.8600+09	1.0113+07	1.6820-02
4.8770-03	1.7780+09	8.6713+06	1.5940-02
4.3860-03	1.8310+09	8.0308+06	1.6000-02
3.9430-03	1.9770+09	7.7953+06	1.6430-02
3.5450-03	2.0360+09	7.2176+06	1.7300-02
3.1880-03	2.1970+09	7.0040+06	1.7790-02
2.8630-03	2.2740+09	6.5105+06	1.8760-02
2.5680-03	2.3560+09	6.0502+06	1.9900-02
2.3070-03	2.5120+09	5.7952+06	2.0400-02
2.0720-03	2.5380+09	5.2587+06	2.1580-02
1.8600-03	2.5710+09	4.7821+06	2.3710-02
1.6700-03	2.4630+09	4.1132+06	2.5830-02
1.5010-03	2.3480+09	3.5243+06	3.0130-02
1.3490-03	2.4300+09	3.2781+06	3.0380-02
1.2120-03	2.2940+09	2.7803+06	3.4920-02
1.0890-03	2.2000+09	2.3958+06	3.9610-02
9.7850-04	2.1280+09	2.0822+06	4.3940-02
8.7950-04	1.9080+09	1.6781+06	5.0900-02
7.9090-04	1.6680+09	1.3192+06	6.4920-02
7.1100-04	1.4300+09	1.0167+06	7.6120-02
6.3910-04	1.0740+09	6.8639+05	1.2830-01

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REFERENCES

1. G. D. Trimble, G. K. Houghton, and J. H. Audas, "Measurement of Neutron Spectra in Liquid Hydrogen, " NASA Report NASA CR-54230 (GA-5750), General Atomic Division, General Dynamics Corporation (1964).

2. A. E. Profio, "Verification of Analytical Techniques (GAPLSN - Transport Theory and O5R - Monte Carlo Theory) by Utilization of Measured Fast Neutron Spectra in Infinite Paraffin and Spherical Paraffin Shields, " Air Force Weapons Laboratory Report AFWL-TR-65-193, General Atomic Division, General Dynamics Corporation, March 1966.

3. A. E. Profio, J. Kirkbride, "Measurement of Fast Neutron Spectra in an Infinite Medium of CH_2, " Air Force Weapons Laboratory Report AFWL-TR-64-180, General Atomic Division, General Dynamics Corporation, April 1965.

4. V. V. Verbinski, J. C. Courtney, W. R. Burns, and T. A. Love, "The Response of Some Organic Scintillators to Fast Neutrons, " in ANS-SD-2, Proceedings of the Special Session on Fast Neutron Spectroscopy, 1964 Winter Meeting, American Nuclear Society.

5. D. L. Horrocks, Nucl. Instr. Methods, 30, 157-110 (1964).

6. Private Communication to G. D. Trimble, July 1965.

7. K. F. Flynn, L. E. Glendenin, E. P. Steinberg, and P. M. Wright, Nucl. Instr. Methods, 27, 13-17 (1964).

8. Private Communication to G. D. Trimble, July 1966.

9. J. H. Alexander, G. W. Hinman and J. R. Triplett, "GAPLSN, A Modified DSN Program for the Solution of the One-Dimensional Anisotropic Transport Equation, " General Atomic Report GA-4972, March 1964.

10. G. D. Joanou and J. S. Dudek, "GAM-II - A B_3 Code for the Calculation of Fast Neutron Spectra and Associated Multigroup Constants, " General Atomic Report GA-4265, September 1963.

11. Y. D. Naliboff, "LHK - An IBM 7044 Code to Calculate Cross Sections and Kernels for Liquid Para- and Ortho-Hydrogen," NASA Report NASA-CR-54227, General Atomic Division, General Dynamics Corporation, July 1964.

12. H. A. Vieweg, G. D. Joanou and C. V. Smith, "GATHER-II - An IBM 7090 FORTRAN-II Program for the Computation of Thermal Neutron Spectra and Associated Multigroup Cross Sections," General Atomic Report GA-4132, July 1963.

13. R. W. Vance and W. M. Duke, Applied Cryogenic Engineering, John Wiley and Sons, Inc., New York, 1962, p-38.

14. J. R. Beyster, et al., "Integral Neutron Thermalization Annual Summary Report, Oct. 1, 1961 through Sept. 31, 1962," USAEC Report GA-3542, General Atomic Division, General Dynamics Corporation (1962).