SPACE REACTOR SHIELDING FABRICATION

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The fabrication of ground based reactor shielding, steel, concrete, water tankage, etc., is generally simple, based upon well-known engineering data and construction experience. This is not true in the case of the reactor shielding needed for space application. The demand to provide the most efficient shielding materials has forced the nuclear engineer to consider the so-called "exotic" materials.

A new facility has been constructed at the Atomics International Nuclear Field Laboratory, funded by the Atomic Energy Commission, for the fabrication of space reactor neutron shielding by a melting and casting process utilizing one of these "exotic" materials, lithium hydride. This facility is equipped to handle lithium hydride not only under the exacting conditions dictated by the nature of the reactive, moisture sensitive material, but also under the stringent requirements of the nuclear shielding engineer for high purity, maximum density, good structural integrity, etc.

This facility, believed to provide the largest capacity in the world, is capable of producing lithium hydride neutron shields up to 8 feet in diameter weighing 10,000 lbs.

In addition, the facility contains a 1650 cubic feet nitrogen atmosphere, glove-ported room capable of handling these massive shields during a destructive examination to determine the internal characteristics of the shield after thermal and vibrational tests simulating operational conditions.

The first neutron shield fabricated in this new facility was a large, pancake shape 86 inches in diameter, containing about 1700 pounds of lithium hydride. This shield, fabricated by the unique melting and casting process, is the largest lithium hydride shield ever built.

A program of shielding materials and fabrication development has been conducted at Atomics International for about ten years funded by the Atomic Energy Commission. The ultimate goal of the program is the fabrication of a family of neutron and gamma shielding components for the reference ZrH reactor, as illustrated in Fig. 1.

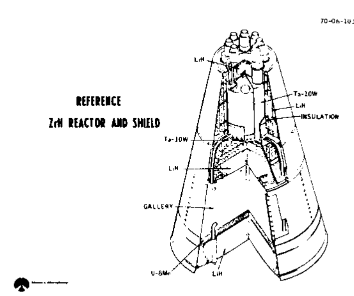

Figure 1.—Reference ZrH Reactor and Shield

This family of shields consists of uranium - 8 weight percent molybdenum and tantalum - 10 weight percent tungsten for the attenuation of gammas, and lithium hydride for the attenuation of fast neutrons.

The development of the technology for the fabrication of lithium hydride shapes as light weight, high efficiency neutron shielding for space reactor application has been the prime effort of the program. The selection of lithium hydride (LiH) as the neutron shielding material was based primarily on its high hydrogen content, stability at high temperatures, and low density.

The high hydrogen content of lithium hydride provides an effective means of shielding men and equipment against the neutrons from the reactor; the high temperature stability permits the material to be used in the high thermal environs of the reactor without melting or decomposition; and the low density (approximately three-fourths that of water) makes it attractive for use in a space system in which weight is critical. Lithium hydride is a brittle, salt-like material which is translucent and a pale-whitish blue in color. It possesses a melting point of 1267°F (686°C) and a dissociation pressure of about 20 torr at the melting point which permits the material to be melted and frozen under a slight pressure of hydrogen without degradation.

Recently a new 3600 square foot facility was completed at the Atomics International Nuclear Field Laboratory, designed specifically for the fabrication of large lithium hydride shields by a melting and casting process. This facility is equipped to handle lithium hydride not only under the exacting conditions dictated by the nature of the reactive, moisture sensitive material, but also under the stringent requirements of the nuclear shielding engineer for high purity, maximum density, and good structural integrity. The facility believed to provide the largest capacity in the world, is capable of producing lithium hydride neutron shields up to eight feet in diameter weighing 10,000 pounds.

In addition, the facility contains a 1650 cubic foot nitrogen atmosphere, glove-ported room capable of handling these massive shields during a destructive examination to determine the internal characteristics of the shield after thermal and vibrational tests simulating operational conditions.

The first neutron shield fabricated in this new facility was a large, pancake shape 86 inches in diameter, containing about 1700 pounds of lithium hydride. Figure 2 shows an artist's interpretation of the shield. Installed in a reactor-shield system, the shape would be inverted from the as-cast view and would be located at the base of the system shown in Figure 1.

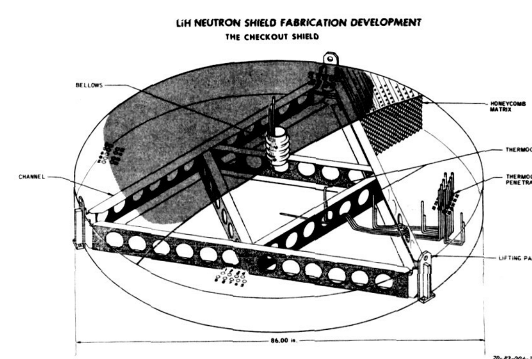

Figure 2.—LiH Neutron Shield Fabrication Development

Figure 3 illustrates the steps in the loading, melting and freezing cycle to fabricate the shield. The empty shield vessel was placed in the shield casting hardware (Figure 4), consisting of a large reservoir, a filler tube-bellows assembly, a supporting structure, and a safety vessel. The latter is necessary in the event of an accidental spill of molten lithium hydride from a ruptured weld, etc. Figure 5 shows the empty shield vessel lifted from the safety vessel. The thermocouples are used to monitor the temperature of the lithium hydride during the cycle.

LiH SHIELD FILLING AND CASTING STEPS

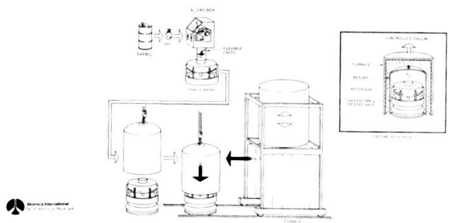

Figure 3.--LiH Shield Filling and Casting Steps

SHIELD ASSEMBLED IN THE CASTING HARDWARE

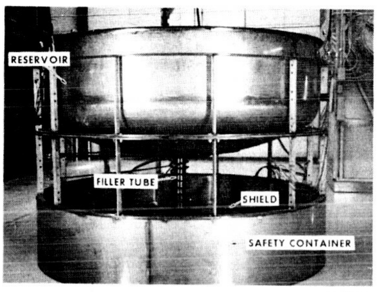

Figure 4.--Shield Assembled in the Casting Hardware

SHIELD VESSEL REMOVED FROM THE SAFETY CONTAINER

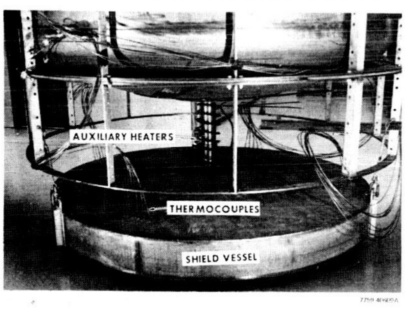

Figure 5.--Shield Vessel Removed from the Safety Container

The casting hardware-shield assembly was placed on a 10,000 pound capacity vibrator platform (Figure 6) and a nitrogen atmosphere dry box was rolled into place over the top of the reservoir. A rubber sleeve was used to connect the top of the reservoir with the bottom of the dry box. The air was purged from the reservoir and shield until the O_2 content was less than 3 percent.

SHIELD-CASTING HARDWARE ASSEMBLY ON THE VIBRATOR TABLE

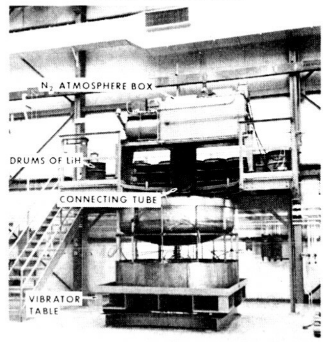

Figure 6.--Shield-Casting Hardware Assembly on Vibrator Table

The bags of LiH were removed from the sealed drums, weighed and loaded into the dry box antechamber (Figure 7). The antechamber was purged to an O_2 content of 3 percent or less and the bags transferred into the dry box where they were slit open and the lithium hydride crystals poured into the reservoir (Figure 8). After the required 1900 pounds was loaded, the reservoir was sealed and the assembly was moved to the retort base. High temperature electrical conductors were connected between the base terminals and the auxiliary heaters located around the filler tube-bellows assembly and on the bottom of the reservoir. These heaters provide the fine control necessary during the final stages of freezing. Thermocouples also were connected to their base terminals. (Figure 9).

LOADING BAGS OF LiH INTO THE DRY BOX ANTECHAMBER

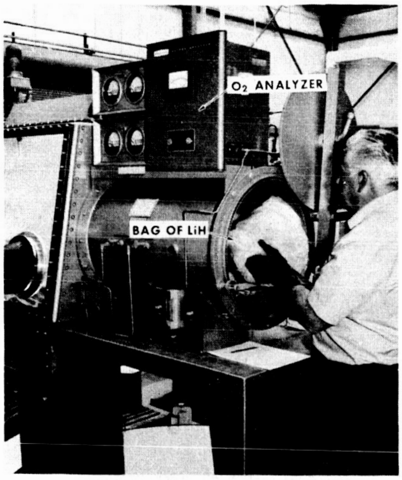

Figure 7.--Loading Bags of LiH into the Dry Box Antechamber

TRANSFERRING THE BAGS OF LiH INTO THE N_2 ATMOSPHERE BOX

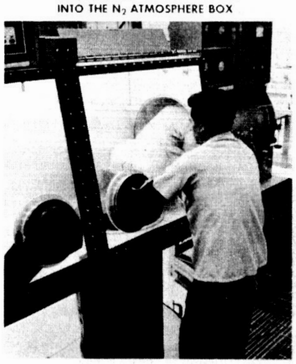

Figure 8.--Transferring the Bags of LiH into the N_2 Atmosphere Box

INSTALLING THE RETORT OVER THE SHIELD-CASTING HARDWARE ASSEMBLY

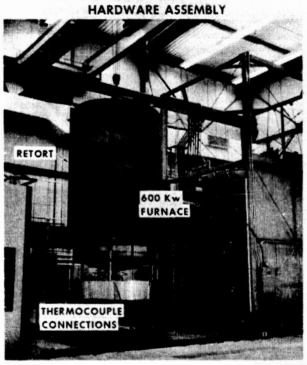

Figure 9.--Installing the Retort over the Shield-Casting Hardware Assembly

The Incoloy retort was lowered over the assembly, the retort sealed, evacuated to about 10 microns pressure, and backfilled with H_2 to 1.6 psig pressure. The furnace was elevated (Figure 10), rolled into place over the retort, and lowered onto the retort (Figure 11).

ELEVATING THE FURNACE

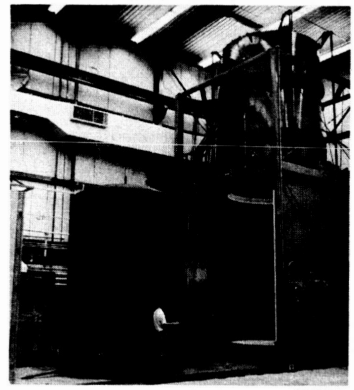

Figure 10.--Elevating the Furnace

MONITORING THE CASTING CYCLE

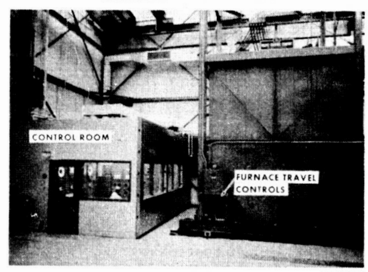

Figure 11.--Monitoring the Casting Cycle

The power to the four temperature control zones of the furnace was turned on and the retort and contents heated to about 1400°F (Figure 12). The temperatures of the shield and casting hardware, the gas flow and pressure, and the O_2 content of the H_2 were monitored throughout the cycle (Figure 13). About 30 hours were required to melt the 1900-pound charge of lithium hydride and raise the melt temperature to about 1400°F.

FURNACE TEMPERATURE CONTROL PANEL

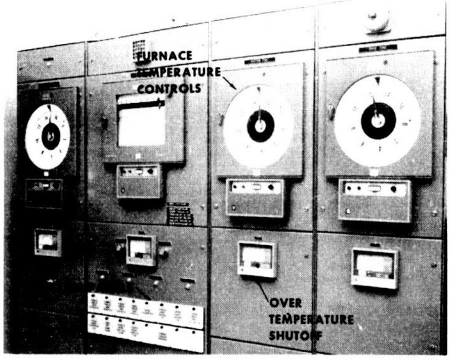

Figure 12.—Furnace Temperature Control Panel

GAS PRESSURE AND FLOW,
AND AUXILIARY HEATER CONTROL PANELS CAST

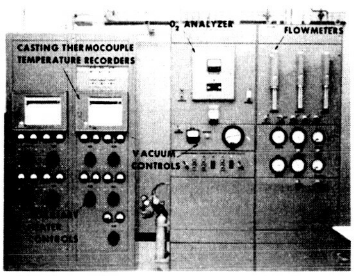

Figure 13.—Gas Pressure and Flow and Auxiliary Heater Control Panels

Cooling was accomplished by raising the furnace upwards stepwise and adjusting the furnace temperature downwards to permit the lithium hydride to freeze radially inwards and axially upwards. The lithium hydride in the reservoir and the filler tube-bellows assembly was kept hotter than the lithium hydride in the shield using the auxiliary heaters. Adjustment of the auxiliary heater power was used to force the freezing front upwards into the filler tube-bellows assembly. Seventy-five hours were required to freeze the lithium hydride in the shield.

When the assembly had cooled to about room ambient, the H_2 was evacuated from the retort, the retort backfilled with argon, and the retort unsealed and removed. The casting hardware-shield assembly was removed from the retort base, and the cast shield was lifted from the safety vessel and photographed in the same position as before the casting cycle (Figure 14). Visually the shield vessel was not found to have been distorted in any significant manner by the heating and cooling cycle.

CAST LiH SHIELD LIFTED FROM THE SAFETY CONTAINER

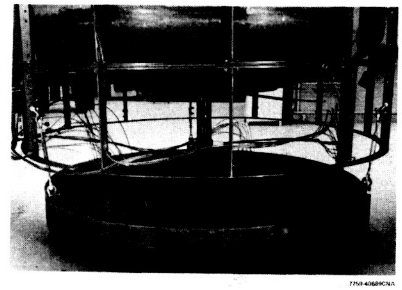

Figure 14.—Cast LiH Shield Lifted from the Safety Container

Twenty-eight radiographic exposures were made covering the entire cross-sectional area of the shield. Evaluation of the radiographs revealed that the shield was the soundest ever produced, exhibiting less than average of the normally occurring small cracks and fissures between the lithium hydride crystals.

The filler tube-bellows assembly was cut from the shield and a temporary closure of the stub made. A series of void volume measurements were made by evacuating the shield, then backfilling it to atmospheric pressure with helium from a tank of known volume and pressure, and calculating the percent void using the Perfect gas law. A void volume of 5 percent was obtained whereas the average void volume for all previous shields is about 6 percent. This measurement confirmed the visual appraisal from the radiographs.

The next steps in the normal development program would be a series of thermal cycles and vibration testing simulating near-use conditions; however, this shield was not a prototype design, but was designed and built specifically to checkout the new facility and equipment, and to investigate the difficulties which might arise in the casting of the thin, large diameter shape. The next planned step, therefore, is a destructive examination in the Shield Examination Room. Figure 15 shows the completed shield readied for installation in the nitrogen-filled room (Figure 16).

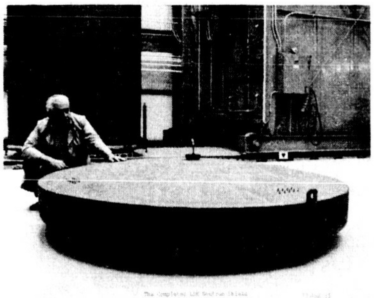

Figure 15.—The Completed LiH Neutron Shield

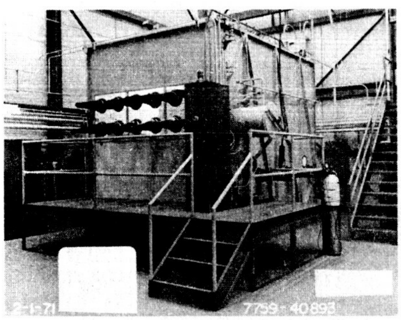

Figure 16.—The N_2-filled Shield Examination Room

Table I compares the capability of the new facility with the older, smaller facility which has been used for many years to cast numerous smaller shields. The envisioned future shield system (Figure 17) required for supplying reactor-produced electrical power for manned application will be fabricated in this large facility, although the smaller facility remains operational for the fabrication of smaller lithium hydride shielding components.

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NEUTRON SHIELD
CASTING CAPABILITIES

	BUILDING 3	BUILDING 42
• RETORT ID (in.)	48	105
• RETORT HEIGHT (in.)	60	125
• SHIELD DIAMETER, MAXIMUM (in.)*	42	96
• SHIELD HEIGHT, MAXIMUM (in.)*	40	80

*MAXIMUM DIAMETER AND MAXIMUM HEIGHT CANNOT BE USED IN THE SAME ASSEMBLY

Atomics International

TABLE I

Table I.—Neutron Shield Casting Capabilities

REACTOR/SHIELD ASSEMBLY

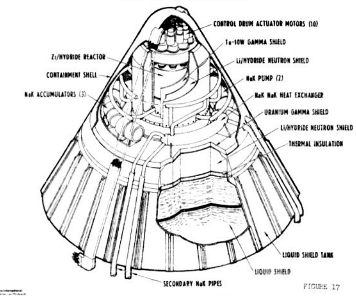

FIGURE 17

Figure 17.—Reactor/Shield Assembly