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UPGRADE AND MODERNIZATION OF THE NBSR

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INTRODUCTION

The NBSR, a 20-MW research reactor operated by the National Institute of Standards and Technology, has become the leading US laboratory in neutron research. About 1000 scientists from 200 industries, government and foreign laboratories, and universities conducted experiments at the NBSR in 1993[1]. Since 1990, when the first instruments in the Cold Neutron Research Facility (CNRF) became available, the number of research participants has doubled. A major program of modernization and facility upgrade was initiated in order to meet this growing demand, and to assure safe and reliable reactor operations for 30 additional years.

A scheduled shutdown, begun in late May 1994, is nearing completion at this writing (May 1995). To upgrade the CNRF, the D_2O cold neutron source has been replaced with a liquid hydrogen cold source, and the remaining four neutron guides are being installed. In addition, the primary and secondary cooling systems have been modernized with the installation of plate heat exchangers, and the refueling system has been completely refurbished. Periodic maintenance is also being done. The entire D_2O primary coolant inventory is about to be replaced, and new shim arms have been installed.

COLD NEUTRON RESEARCH FACILITY

The liquid hydrogen cold source, and the CNRF, was described in the IGORR-3 Proceedings, and elsewhere,[2,3] so only a brief review will be given here. Figure 1 shows the main components of the LH_2 source. A naturally circulating thermosiphon will provide the moderator chamber a steady supply of liquid hydrogen through the center-most of four concentric tubes. A two-phase mixture of vapor and liquid will rise through the adjacent tube to the condenser, located two meters above the chamber, on the reactor face. A new 3.5-kW refrigerator provides helium at 14 K to the condenser. The anticipated heat load, however, is only 1000 W, so about 2 grams of liquid hydrogen will circulate in the thermosiphon. Thermal hydraulic tests[4] conducted at NIST-Boulder on a full scale glass mockup of the moderator chamber, demonstrated that at least 2200 W can be removed via steady, two-phase flow, with a vapor fraction of less than 20%. A 2-m^3 ballast tank is open to the chamber, so in the event of a refrigerator failure, the hydrogen will expand into the tank, where it is stored at 400-500 kPa when the system is shutdown. All components are surrounded by helium containment jackets, providing at least two barriers between hydrogen and oxygen. The location of the cryostat assembly in the reactor is shown in Figure 2.

The cryostat assembly, the hydrogen condenser, and the ballast tank have been installed, subject to rigorous quality control and testing to assure reliability and safety. The LH_2 source will increase the yield of cold neutrons ($E \leq 5$ meV, $\lambda \geq 0.4$ nm) by at least a factor of four. Coupled with the return to full power (the reactor has been operating at 15 MW for two years), and guide improvements, the flux in the guide hall will be six times higher in 1995 than it was before the shutdown.

Installation of four additional guides, will enable the completion of the remaining cold neutron instruments, bringing the CNRF total to 15 instruments on 8 guides. New in-pile pieces for CTE and CT (see Figure 2) will have ^{58}Ni walls, and supermirrors for their top and bottom surfaces. A curved guide on CTW will be used inside the reactor building.

PRIMARY HEAT EXCHANGERS

Three new plate heat exchangers have replaced the two shell-and-tube exchangers, in service since 1975. NBSR is the first application of this size and type of heat exchanger for a nuclear reactor primary system. They have been operated reliably in other applications for tens of millions of hours. Because the reactor primary is D_2O, several extraordinary quality control measures were taken during fabrication. Each plate is one-third thicker than usual, and subject to nuclear quality assurance. Type 316 stainless steel was used to fabricate the plates, all of which were subject to dye-penetration testing. Pairs of plates were laser-welded into cassettes rather than relying on gaskets to seal D_2O volumes. Mass spectroscopy He leak tests of each cassette demonstrated that there were no leaks at the limit of 10^{-9} stp cc/sec.

Installation of the new heat exchangers necessitated major changes in both the primary and secondary piping. The presence of smaller flow channels requires that the secondary must be kept free of foreign material introduced in the cooling towers (bugs), so new filters and backwash capabilities were added. The new heat exchangers are much smaller (and less expensive) and more efficient than the old ones. Each is rated at 12 MW in normal operation; only two are needed at full power. The rebuilt system is expected to meet the cooling requirements of the NBSR for another 30 years.

REFUELING SYSTEM

After the core was off-loaded in June, operations began maintenance of the refueling tools. They discovered that the boral layer attached to the bottom of the refueling plug was interfering with the tools. Inspection of the plug, using a borescope, revealed swelling and sagging of the boral. It was decided to lift the 10-ton plug from the top of the reactor vessel, remove the boral, and completely refurbish the fuel handling tools penetrating the plug. NBSR fuel is handled remotely to keep the D_2O primary isolated. The plug had been in place since its installation prior to the first criticality in 1967. Galvanic corrosion between Graphitar bearings on the tool shafts and the aluminum in the boral was the cause of the corrosion.

CONCLUSION

By July 1995, the NBSR should again be operating at 20 MW, with greatly enhanced experimental capabilities for the CNRF. Future projects include modernizing the thermal neutron instruments, and relicensing the NBSR to 2024, in order to meet the needs of the scientific community for decades to come.

REFERENCES

1. Technical Activities 1993, Reactor Radiation Division of the Materials Science and Engineering Laboratory, NISTIR 5317 (April 1994).

2. Prask, H. J., Rowe, J. M., Rush, J. J., and Schröder, I. G., "The NIST Cold Neutron Research Facility," J. Res. Nat. Inst. Stand. Technol., 98, 1 (1993).

3. Williams, R. E., Blau, M., and Rowe, J. M., "Cold Neutron Gain Calculations for the NBSR Using MCNP," Trans. Am. Nucl. Soc. 69, 401 (1993).

4. Siegwarth, J. D., Olson, D. A., Lewis, M. A., Rowe, J. M., Williams, R. E., and Kopetka, P. H., "Thermal Hydraulic Tests of a Liquid Hydrogen Cold Neutron Source", NIST Internal Document, NISTIR 5026 (July 1994).

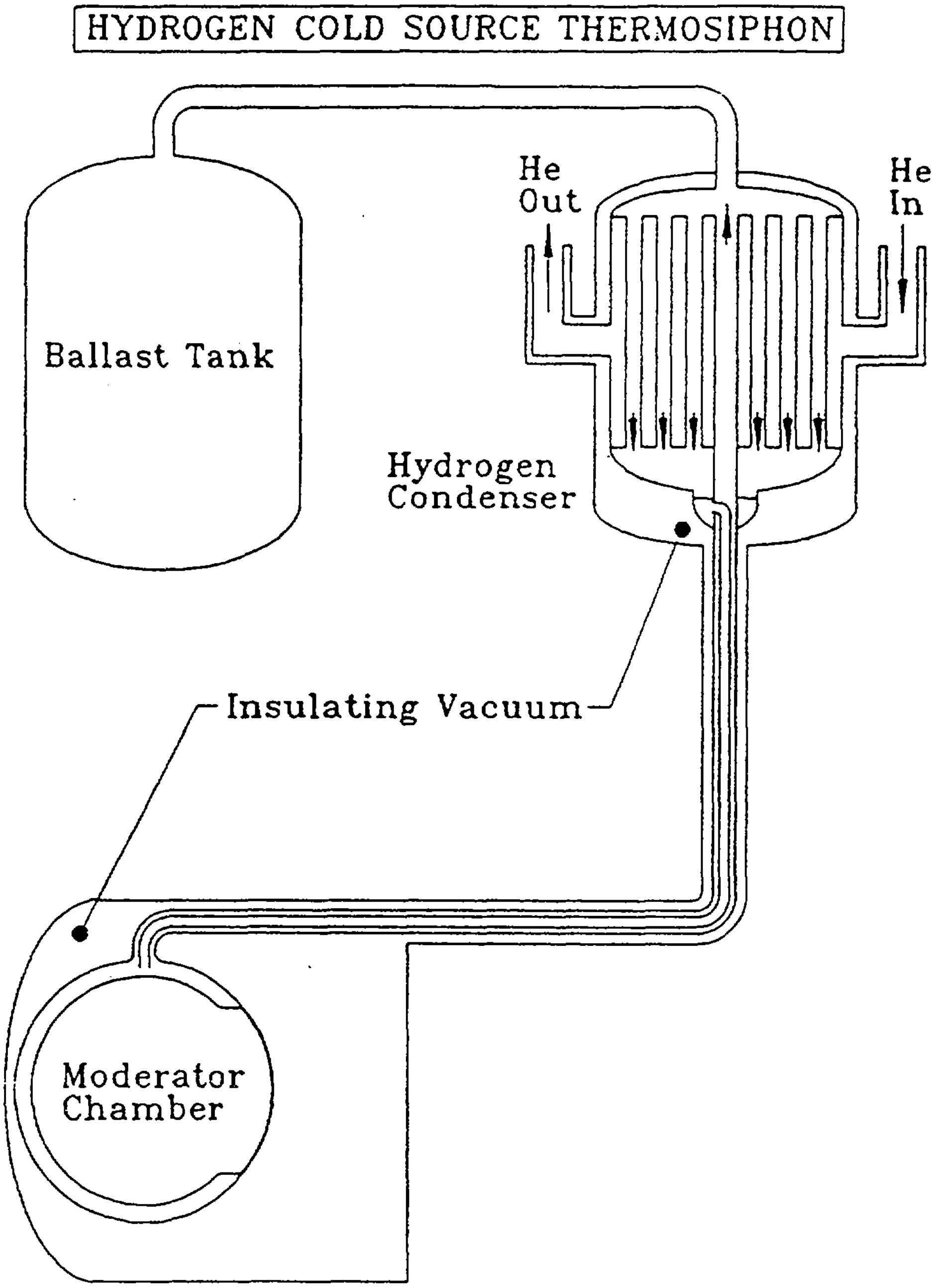

Fig. 1. Schematic of the liquid hydrogen cold neutron source. Each component is completely surrounded by a helium containment, not shown.

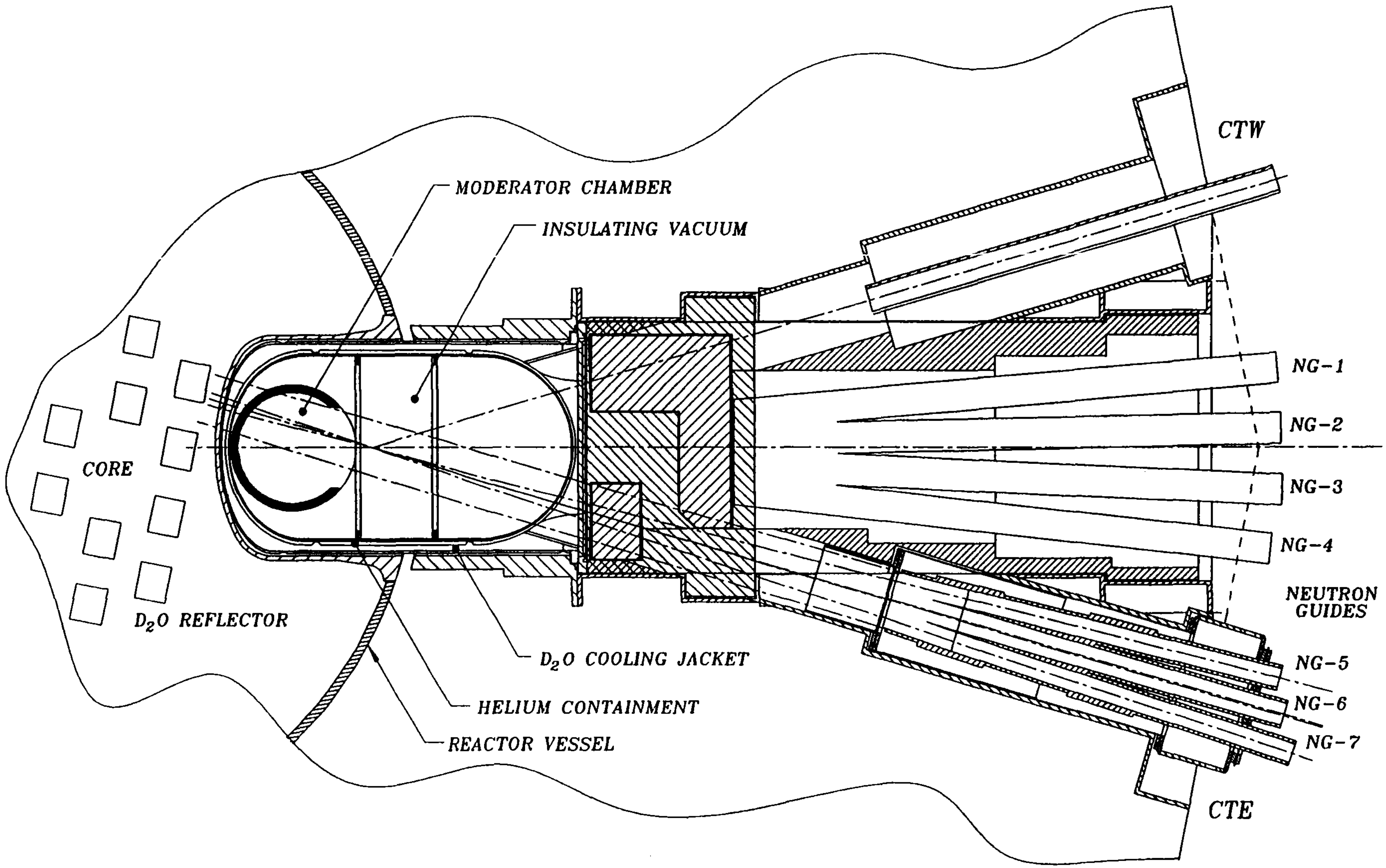

Fig. 2. Plan view of the hydrogen cold source in the cryogenic beam port of the NBSR.

NBSR

National Institute of Standards & Technology

Gaithersburg, Maryland USA

Licensed Power: 20 MW

HEU Fuel, D_2O Moderator

Peak Flux: 4×10^{14} $n/cm^2/sec$

Fuel Cycle: 35 Days

11 Thermal Neutron Beams

8 Cold Neutron Guides

Irradiation Facilities

NBSR History

1967	Critical December 7
1969	10 MW
1985	20 MW
1987	D_2O Cold Neutron Source
1990	Guide Hall Instruments NG-5,6,7
1993	10 Cold Neutron Instruments on NG-3,5,6,7 and CTW
1994	Shutdown May 26 for LH_2 CNS and Modernization
1995	Restart
2004	Relicense for 20 Years

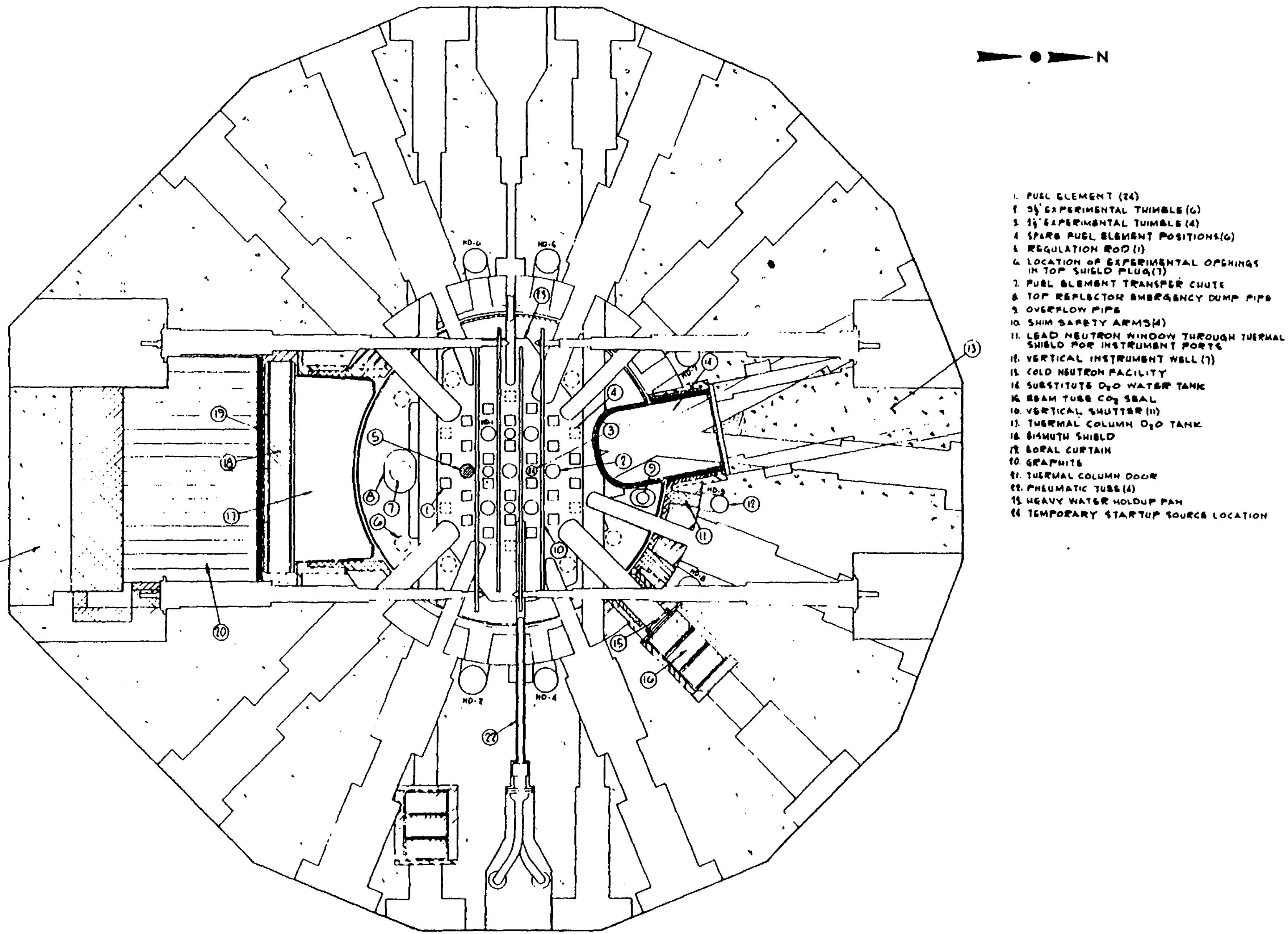

Figure 4.2 Reactor plan view.

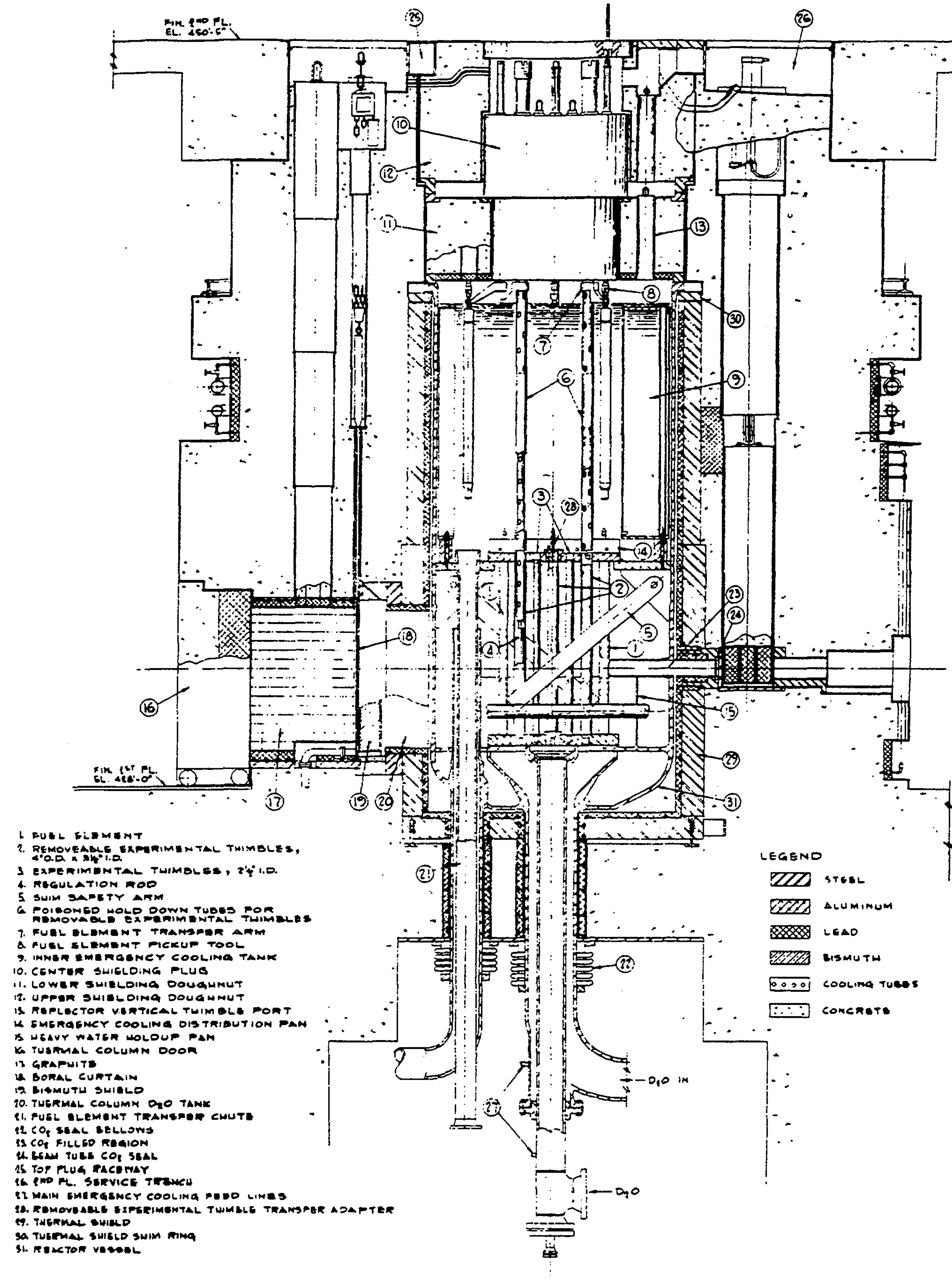

Figure 4.1 Reactor elevation.

Major Shutdown Activities

1. Primary Heat Exchangers, Piping
2. Refurbish Refueling System
3. Replace D_2O Cold Source with LH_2
4. Install 4 Additional Neutron Guides
5. Replace D_2O Coolant Inventory
6. Install New Shim Arms
7. Rad Waste Disposal
8. Lots of Other Stuff

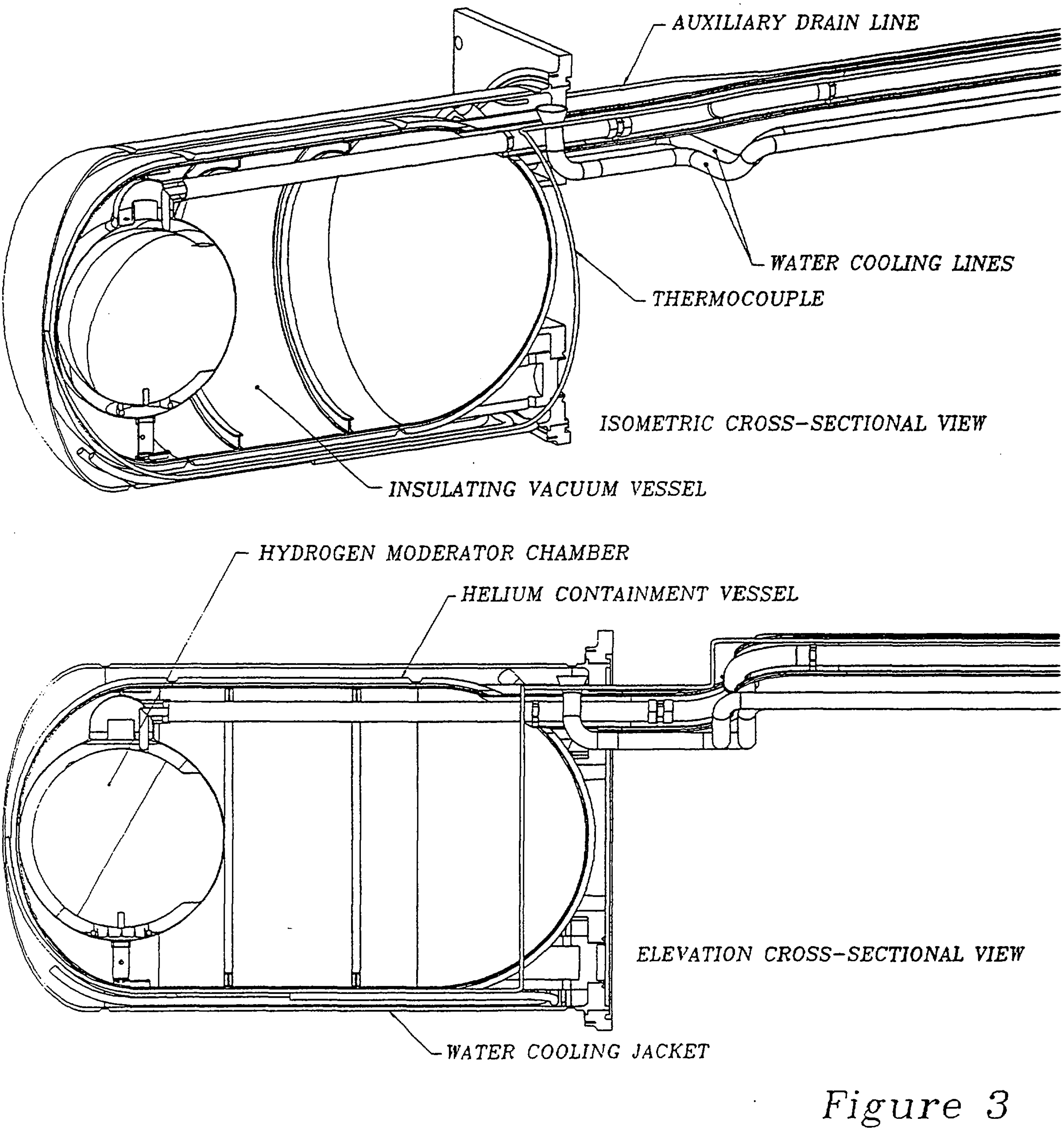
AUXILIARY DRAIN LINE
WATER COOLING LINES
THERMOCOUPLE
ISOMETRIC CROSS-SECTIONAL VIEW
INSULATING VACUUM VESSEL
HYDROGEN MODERATOR CHAMBER
HELIUM CONTAINMENT VESSEL
ELEVATION CROSS-SECTIONAL VIEW
WATER COOLING JACKET

Figure 3

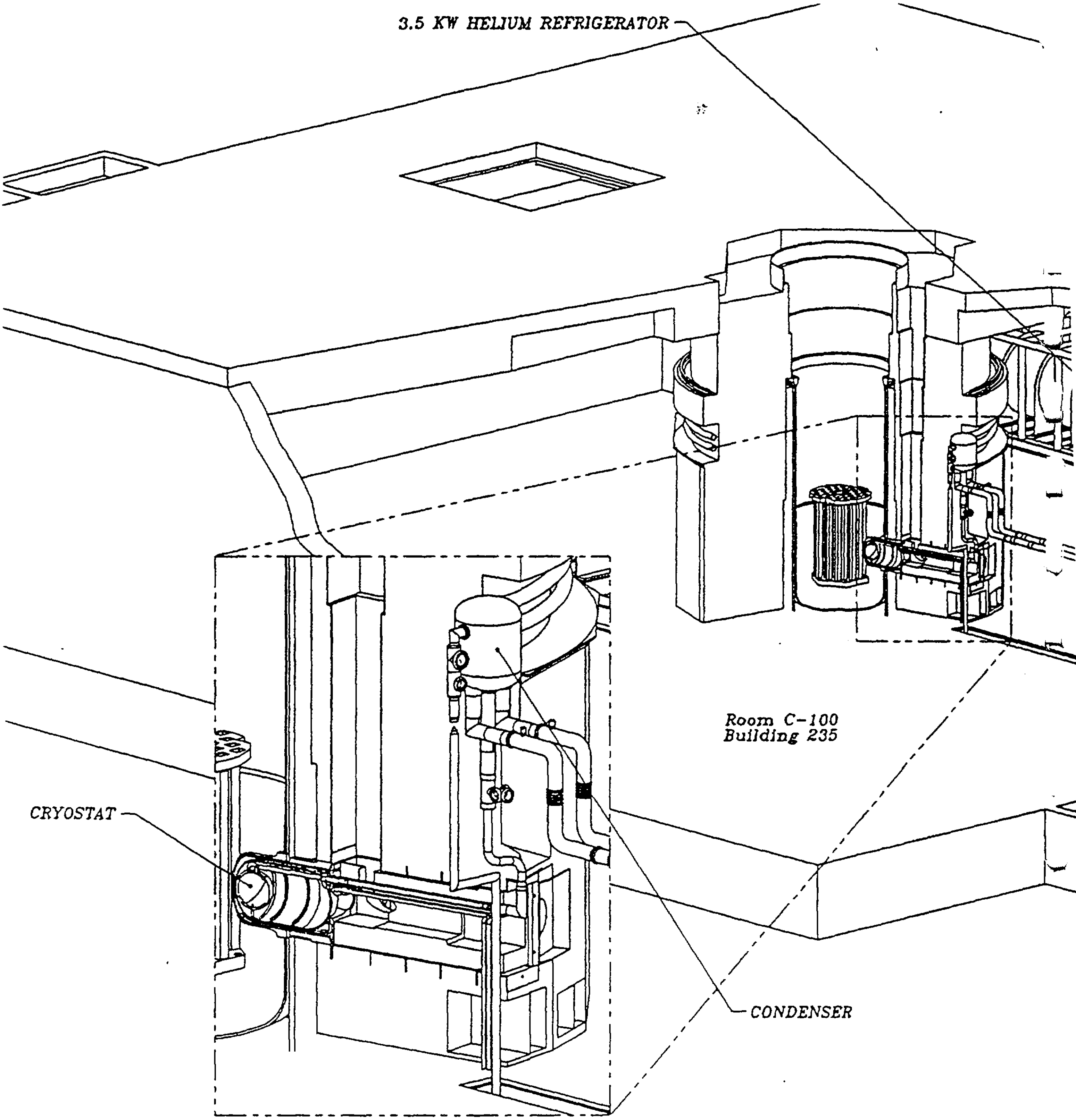
3.5 KW HELIUM REFRIGERATOR
CRYOSTAT
Room C-100
Building 235
CONDENSER

Figure 2

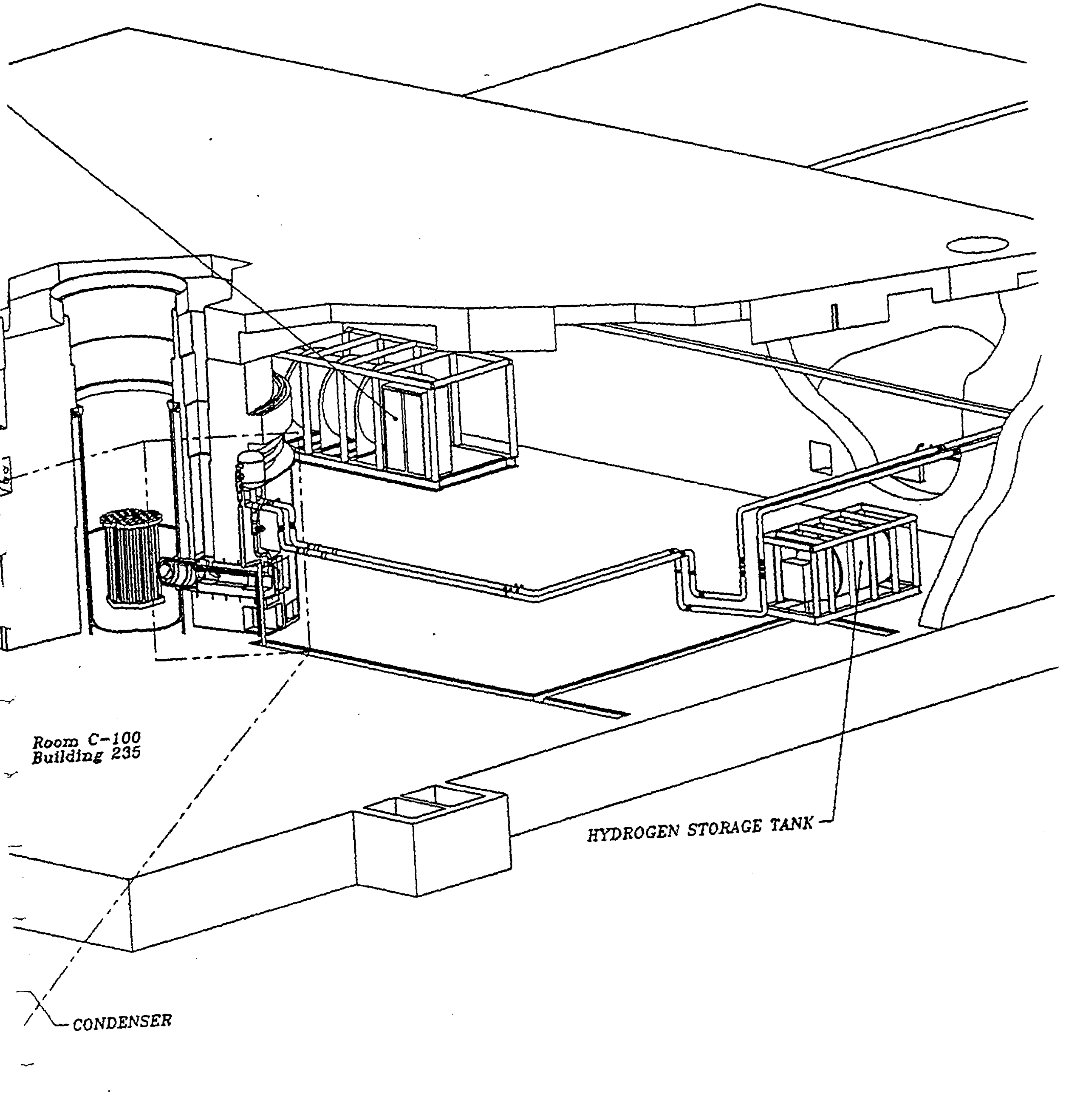

Figure 2