HISTORIC AMERICAN ENGINEERING RECORD

WATERTOWN ARSENAL, Building No. 100
(Horace Hardy Lester Reactor)

HAER NO. MA-20-R

Location:	Wooley Avenue, Watertown, Middlesex County, Massachusetts. UTM: 19.321520.4692080 USGS QUAD: Newton, Massachusetts
Engineer/Architect:	Army Materials Research Agency (conceptual design); Bendix Aviation Corporation (engineering design); Giffels and Vallet: Rosetti, Detroit (architects-engineers); Vara Construction Co., Boston (general contractors).
Date of Construction:	1960; shut down spring 1970.
Present Owner:	U.S. Army Materials Technology Laboratories (AMTL) Arsenal Street Watertown, Massachusetts 02172
Present Use:	The nuclear reactor is inoperative. The reactor containment building is used for neutron radiography work on the ground level.
Significance:	Building No. 100, the Horace Hardy Lester Reactor, was the first nuclear reactor designed to meet the needs of U.S. Army materials research programs. It continued a long history of nondestructive materials testing at Watertown Arsenal, including the Emery Testing Machine of 1879 and a 280,000-volt x-ray machine for materials radiography in 1922, and reflected Watertown Arsenal's emphasis on materials testing after World War II. At the time of construction, its "segregational" design, which allowed several discrete experiments to be conducted simultaneously, was unique.
Project Information:	This documentation was undertaken in accordance with Section 106 of the National Historic Preservation Act of 1966, as amended, prior to base realignment and closure.

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I. ARCHITECTURAL DESCRIPTION AND MODIFICATIONS

Building No. 100, the Horaca Hardy Lester Raactor, is located naar the southwast cornar of tha prasent-day AMTL property surroundad by Wooley Avanue (north), Craig Street (east), North Beacon Straat (south), and buildings adjacent to Walch Avenue (wast). It sits in a grassed area, surrounded by late-ninataanth-century and aarly-twantieth-cantury brick industrial buildings. Tha reactor is accassad through two support buildings (Building No. 97, HAER No. MA-20-S, and Building No. 292, HAER No. MA-20-T) located to tha west. Originally constructad in 1920, they wara refurbished and connactad to the raactor in 1959/1960.

Complatad in 1960 at an approximata cost of $1,300,000, Building No. 100 is a completely enclosad, cylindrical, tank-type reactor containmant shall with an elliptical domed top. Its design was basad, with modifications, on that of an axisting Bulk Shielding Facility at Oak Ridga National Laboratory, Illinois. The gas-tight, prassure-vassel structura measuras 80 ft. in diameter and is approximataly 69 ft. high, with a basa foundation extanding 18 ft. 7-1/2 in. below ground. It has a 2-ft-thick concreta wall lining and walded-steal-plata axtarior with 1/2-in-thick staal plata abova ground and 1/4-in-thick plata balow ground. It rests on a highly compactad gravel basa and a 1-ft.-thick concreta mud mat.

The reactor shall is antarad and axitad via two double door airlocks, one consisting of a short connector corridor to Building No. 97 to the wast, and one to the outsida on the south sida. The lattar has a brick wall vastibula dasigned to be dismantled and rabuilt whan moving larga equipment in and out of tha reactor shall. When tha raactor was operativa, air prassura was maintainad at 2psi, and the doors wara permitted to be usad only ona at a tima.

On tha intarior, tha cantral, high-density and normal-dansity concrata reactor tank ("swimming-pool" typa) and biological shield is an octagonal structura. It is an opan-top, tank-typa, tharmal, heterogeneous, water-cooled and modaratad nautron raactor for conducting farrous-based materials resaarch. The raactor has a 21-ft outside dismater snd 10-1/2-ft insida diameter, laid on a 5-ft slab. It is 30 ft. daap, with an 40,0000 gallon capacity. Whan activa, fual waa storad in an annular well caat Into tha uppar parlmetar wall sactions, and tha cora was immarsed In 22-ft of watar. Tha combinatlon of concrete walls and water providad protaction against tha escaping of harmful radiations from tha cora. No fual alemants or watar remain today.

Tha raactor core fual alemants consistad of a thin layar of aluminum uranium 235 alloy sandwiched betwaan aluminum platas, 3 in. wida, 24 in. tall, and 0.060 in. thick. Tha reactor dasign called for 18 platas per elements and betwaan 20 (minimum loading) and 35 (maximum loading) fuel alamants for powering at ona megawatt. Light (deminaralized) wster was usad as the coolant. Accass to tha core wes from tha raactor top whara removabla metal platas coverad tha pool. The rata of raaction was regulated by control rods (three shim-safety boron carbide rods and ona stainless steal regulating rod) drivan by a motor at tha top of tha raactor. Tha reactor initially operated at ona magawatt of powar, but was subsaquantly incraasad to fiva megawatts in 1968.

Segragatad intarnal resaarch facilitias include a serias of aluminum-lined nautron baam tubas that axtand from tha core araa to tha axterior of tha raactor: 16 horizontal tubes (6 in. diametar) located on two lavals; six slant baam 6-in tubes; and one through baam 6-in tuba running adjacant to the cora. In addition, thara ara two pnaumatic "rabbit" tubas (2 in. diameter) which allowad small samples to be passad through tha core whan the reactor was operating.

The interior arrangement of working space consists of an open ground floor (operating or experiment floor) level around the reactor core and two platform levels in the south portion of building. The first platform was used for experiments, and the second, narrower, top, platform contains the reactor control room situated against the south perimeter wall of the containment shell. Access to the revolving crane and the reactor top is from this level. Beam tube ports are located on the ground level and first platform level. A Shepard-Niles 10-ton overhead, pendant-type, polar bridge crane operates on a circular track around the perimeter of the dome with a radius of 40 ft.

A gamma ray facility in the basement extends some 9 ft. below foundation level and is located on the north side of the reactor, east of the door connecting to Building No. 97. When active, it was filled with water and accessed via a hatch in the ground floor level. Pumps, heat exchangers and other ancillary equipment were also located in the lower basement level.

Associated external equipment include pumping equipment and transformers (west), an approximately 150-ft tall cooling tower (north, installed in 1965 and dismantled in 1984), a 30,000-gallon, low-level, radioactive waste storage tank for reactor pool water during maintenance (southwest, Structure No. 242), and overflow tanks under Building No. 97. All liquids and air leaving the reactor were monitored for radioactivity under the requirements of the Atomic Energy Commission.

The principles governing the function of the Horace Hardy Lester Reactor were similar to those in the more common reactor plants of the period which were designed to harness the heat produced for power generation. At Watertown, however, the nuclear radiations themselves were the important product for their research applications, specifically what they revealed about materials as they passed through samples and how they affected or changed materials. The nuclear fission chain reaction took place in the submerged fuel in the reactor core. In addition to its shielding properties, the water served to slow the neutrons making the reaction more efficient. Water was also pumped through the core at the rate of 1100 gallons per minute to carry away the tremendous heat. Initially, the heat exchanger and coolant system was located in the basement level. Subsequent power increases required the supplementary construction of a cooling tower. The entire operations were conducted by remote control from the control room on the upper platform level. The control rods, which absorbed neutrons and were inserted and withdrawn from the core to control the speed of the reaction, were driven by motors atop the pool. Outside the control room was a board with a plan of the core; operators kept track by hand of the location of each fuel plate. Overall, the simplicity of operations was such that as few as two highly qualified operators were required to run the reactor.

The experiment stations were located on the experimental, or ground, floor and the first platform level. Beam tubes, both horizontal and slanted as described above, led from the core to ports with shielded chambers at the stations. Samples to be irradiated were placed in the sealed chambers. The pneumatic tubes carried small samples directly into the core from remote stations. The arrangement allowed different experiments to be conducted simultaneously at each station, a unique capability at the time of construction.

Modifications to the nuclear reactor during its 10-year use life were a function of two basic factors: a low number of operational problems that were encountered and increased utilization requiring expanded capabilities. In the latter case, future enhancement had been considered during planning and design of the reactor in many instances.[1]

During the first four years of operations, problems were encountered with water leakage through the concrete biological shield, particularly in the cavities in the annulus created by humps of concrete over the slant tubes. Initial efforts to rectify the problem met with limited auccess. In 1961 and 1962, a chemical liquid grout with a preset jelling time (AM-9) wae pumped into drilled holes end wall-to-floor joints in the main pool and the joint around each beam was sealed with pressure-eensitive tape, all but eliminating the leekege. Corrosion of the heat exchanger of the reactor coolant system resulted in replacement of the eluminum tube bundle with stainleee eteel and installation of a recirculeting water cooling tower to provide secondary coolant in 1965. Additional chenges in this pariod included improvements to monitoring and alarm systems for the various componente end modification of three beem tube extensiona to permit flooding from the pool top for use as water shutters for installed experimenta.

At the preaent time, ell fuel elements and water have been removed, following shutdown of the reector in 1970. The interior reactor experimental facilities, including the concrete shield structure, the control room, and the crane have been left intact. The asbestos lining of the dome ceiling has been removed. A portable neutron radiogrephy machine hes been instelled on the ground level, southwest side, end e protective unmortared concrete block well constructed around it.

II. HISTORICAL INFORMATION AND SIGNIFICANCE

Wetertown Areenal wae esteblished in 1816 for the storage, repair, and issue of smell erme, ordnence, and supplies for the U.S. Army, and, seconderily, for the menufecture of emall arms cartridgea. The original construction consisted of a regularly arranged quadrangle of aimilar brick buildings located eaat of the present-day AMTL property. By the 1840e, the construction of wooden field, aiege, end aeacoest gun cerriages and their limbere and caiesone, along with work in metallurgy and the development of cast iron guns, had begun. In the aecond half of the nineteenth century, perticularly after 1890, land to the west was developed as a mejor fecility for gun carriage manufecturing. In addition to its industriel growth, Watertown Arsenal sustained a long history of materials teeting and metals reeearch. Construction of the Horace Hardy Lester Reactor in 1960 represents the laat major phese of research development et Watertown Arsenal.

Watertown Arsenel'a contributions to metellurgy began in the nineteenth century, perticulerly with the developmant of the Rodman cast-iron cannon in 1849 and installation of the Emery Testing Machina, which teatad the strength of metale, in 1879. Technological developments at Wetertown Arsenel in the twentieth century continued to teke place not only in industrial production proceasea, but in laboratory reseerch geared towards improving both products and processes. Mejor accomplishments occurred in the 1920e end 1930a: cold-working, or autofrettege, of eteel gune (1921); use of radiogrephy (x-ray) aa a method for the identificetion end eliminetion of caating defects in steel foundry control and for welding control (1922); centrifugal casting of steel gun tubes (1925); eucceaaful introduction of the ell welded gun carriage (1929); development of molybdenum high speed tool steele to replace stretegic tungsten tool steels (1930); uee of spectrogrephic enalyses of the chemical componenta of foundry metals (1934); development of cast armor plate for vehicles and other lerge applicationa (1935); along with development of impect teeting for high velocity ruptures of metel and mecroetching for inspection of forginga and of centrifugally cast guna. During this period, Watertown Arsenal's commitment to integreted research with private industrial and university laboratories wes reflected in the formation of the Ferroue Metallurgical Advisory Boerd.[2]

The uee of nondestructive meteriele tests, of which the x-ray was the most advenced, marked an importent routa of experimentation at the Watertown Arsenal leading to construction of the nuclear reactor. The reactor was dedicated as the Horace Hardy Lester Reactor for Materials Research, May 17, 1960. Dr. Horace Hardy Lester (1883-1955) belongs to the roster of prominent scientists working at the Watertown Arsenal. Employed at the Arsenal from 1922 to 1953, Dr. Lester pioneered in the field of industrial radiography, resulting in improved steel castings and welded structures. He received national recognition for his research and publications on nondestructive testing. The research project under his direction which motivated construction of the reactor was subsequently administered by another notable metals scientist, Dr. Laurence S. Foster.[3]

The design of the reactor was derived from a study conducted in the early 1950s jointly by the Army Ordnance Corps, Watertown Arsenal staff, and Nuclear Development Associates.[4] Their goal was to define the technical needs of the Watertown Arsenal, as well as those of academic scientists and industries in the Boston metropolitan area and to determine the best, safest, and most cost-effective type of reactor to meet those requirements. The study concluded in 1952 that the most appropriate design was a hybrid between the Oak Ridge Bulk Shielding Facility (swimming pool) and the Low Intensity Training Reactor (LITR). The proposed reactor specifications addressed identified needs for reliability, ease of operation and maintenance, experimental flexibility, future capabilities for higher power (neutron flux) levels with minimal modifications, safety, and the academic community's need for an unclassified facility. In outlining the program for Watertown Arsenal, the report recognized the basic materials research undertaken at the Arsenal, as well as its longstanding interest in cooperation with private scientists and industry, stating that "Watertown's interests appear to lie mainly in research in physical metallurgy and solid state physics. Other interests include activation analyses, production of very short-lived isotopes, training of personnel and daily contact with recognized experts who would be attracted to work at the proposed reactor". [5] The report also reflected the fact that this was intended to be a research facility and was to be located in a populated metropolitan area.[6]

Upon its completion, the Horace Hardy Lester Reactor was the only facility of its type operated by the U.S. Army. Overseen by the U.S. Army Materials and Research Agency (AMRA), established in 1962, and licensed by the Atomic Energy Commission, the reactor opened up new areas of nondestructive materials testing and laboratory research for all Army programs. In addition to generating neutrons that were extracted as beams for neutron radiography, the reactor also enabled the use of neutron activation analysis for the study of crystalline structures of solids and research in radiation exposure as a means of changing, for example strengthening, the properties of materials. Research conducted at the Watertown Arsenal was basic to the work at all other Army testing locations and arsenals, including Natick Laboratories, Picatinny Arsenal, Detroit Arsenal, and the Army Electronics Research and Development Laboratory, at Fort Monmouth.

The first operations summary report, covering the period 1960 to 1964, concluded that the succession of solid state physics tests carried out at the reactor had demonstrated that the experiments acheived rapid results and had two important fundamental applications. Use of short reactor irradiations and gamma-ray spectroscopy provided qualitetitive determinations of the major constituents of practically any sample, and nondestructive neutron activation analysis demonstrated that many materials reputed to be homogeneous and void of any impurities actually contained several unexpected elements. These experiments included general examination of different materials, such as metals, water, and human hair, as well as specific applications such as analysis of oil samples for a Detroit Arsenal wear studies program.[7]

Reactor use grew as its capabilities were more widely understood and scientists realigned their research programs to take advantage of the capabilities offered for a wide range of sophisticated experiments in materials reseerch and development. The reactor served es one of e number of laboretories compriaing the Nondestructive Testing Facility et the Army Meterials and Mechanics Reaeerch CenterIn 1965, the high level of reseerch program ectivity warranted an epplicetion to the U.S. Atomic Energy Commiasion to permit an increese in power level to triple the flux of neutrons. Thla power increese, from one megewatt to five megawatts, waa accomplished in 1968.

In 1967, the historic Watertown Arsenel wea closed, and in 1968, the eastern half of the Arsenal was sold to the Watertown Redevelopment Authority. The reactor continued to operate under the Army Materials and Mechenics Research Center for a ahort time. By the end of the 1960s, however, the reactor technology was conaidered outmoded, and the reector was ahut down in 1970. The capability for neutron activation anelysis at the Army Meterials Technology Laboratory ia now meintained by e portable neutron rediography mechine loceted within the reactor containment building.

III. ENDNOTES

1. Modificetions, operations, end research programs during the firat four years of operetiona are outlined in the Operations Report.

2. These echievements ere discussed in more detail in Burns and Bahr, 148-154, and in Leater.

3. Dobbe, 61-62.

4. Nucleer Development Associates, Inc.

5. Nuclear Development Aasocietes, Inc., 8.

6. Nuclear Development Asaociatea, Inc., 8. In discussing future power increases, the report notea that as experience with reactors growa, safety levels for location in metropoliten areaa mey be revised upwerda. For exemple, the Oak Ridge LITR, installed in 1948, "has grown from a purely mechanical gedget into a rather powerful reaearch tool, the operating level of which is now around 1500 kw.", 11.

7. Operations Report.

IV. BIBLIOGRAPHY

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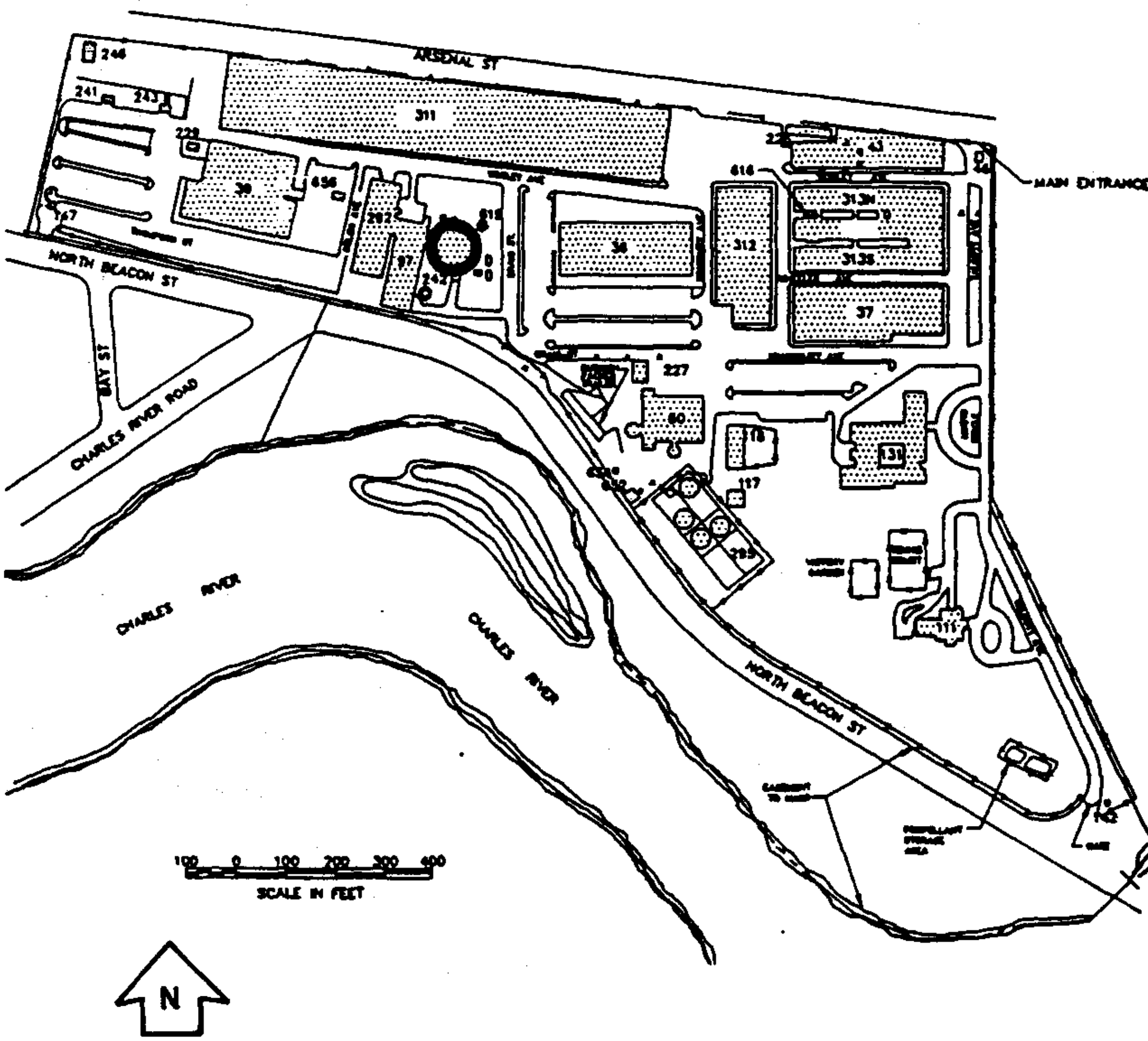
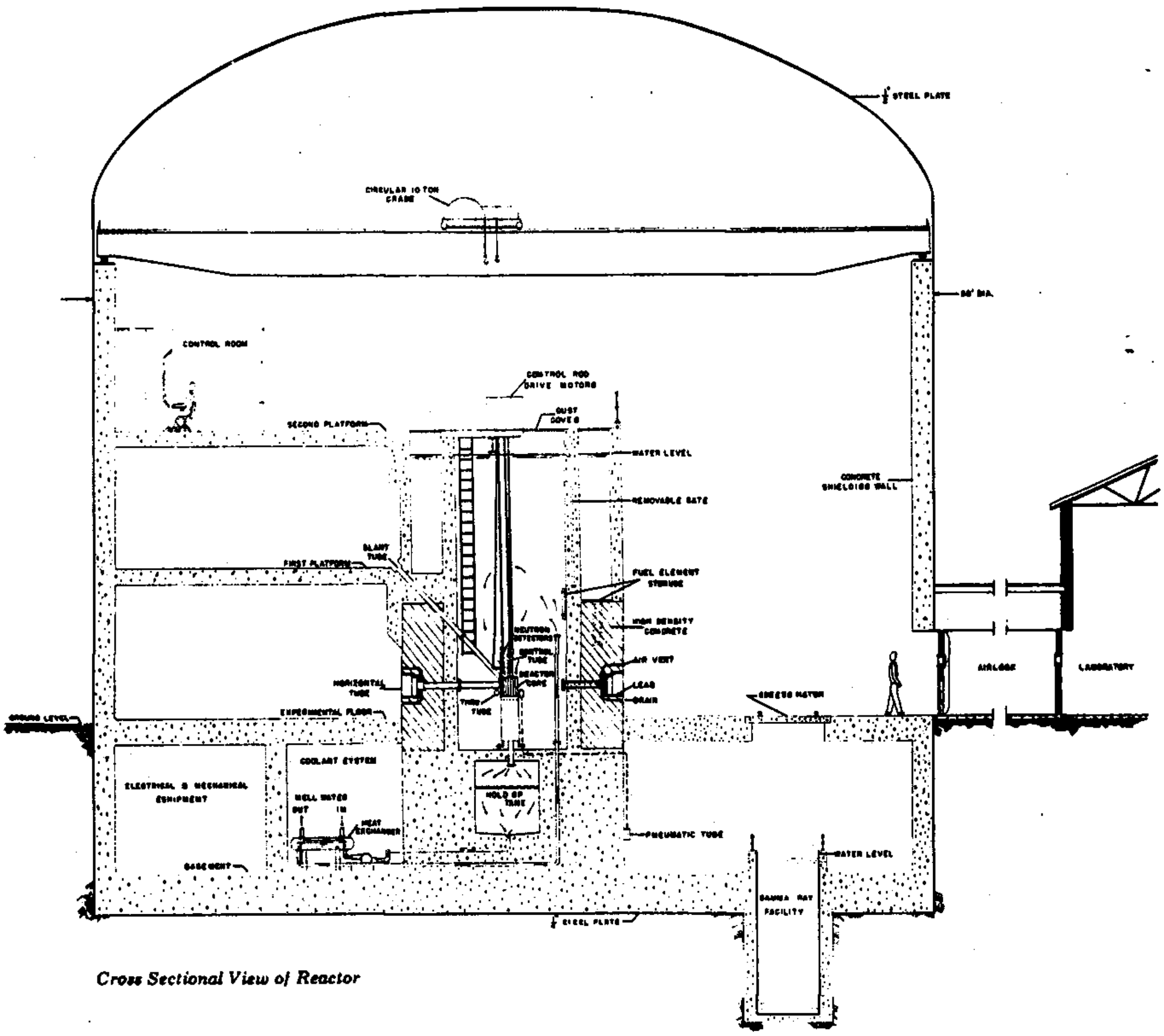
For further aources, conault Burns and Bahr, 1982, previously submittad to tha Library of Congrass as HABS/HAER documantation for Watertown Arsenal, HAER No. MA-20.

LOCATION MAP WITHIN WATERTOWN ARSENAL



Source: E. G. & G., USATHAMA report, 1988.

HORACE HARDY LESTER REACTOR, SECTION DRAWING

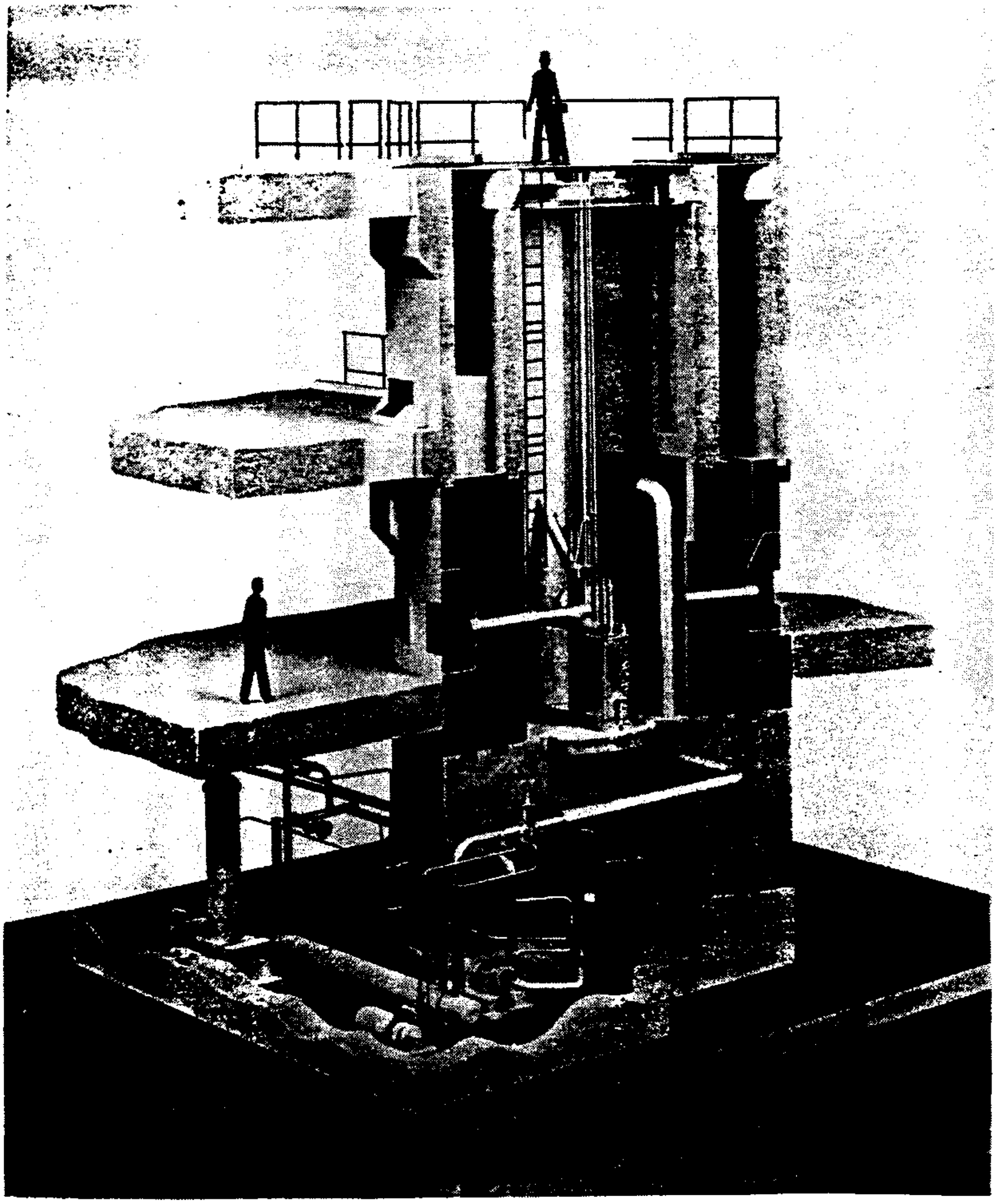


Cross Sectional View of Reactor

Source: Undated pamphlet, "AMRA", AMTL, Watertown, [1965?].

REACTOR MODEL, 1959

AMRA Operations Report, [1965], p. 3. Model now located in lobby of Building No. 292 at AMTL, Watertown, Massachusetts.



Historic Photograph, November 20, 1959. Interior, view southwest of reactor core and shield structure.
U.S. Army Photograph: Corps of Engineers, New England Division. File No. 438. (Copy located at U.S. Army Corps of Engineers, New England Division, Waltham, Massachusetts).