ARGONAUT

Argonne's Nuclear Assembly for University Training

ENGINEERING CONSTRUCTION AND COSTS

By R. H. Armstrong, W. L. Kolb and D. H. Lennox

Reactor Engineering Division

ARGONNE NATIONAL LABORATORY

OPERATED BY THE UNIVERSITY OF CHICAGO

For the Atomic Energy Commission
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ENGINEERING, CONSTRUCTION AND COST OF THE ARGONAUT REACTOR

by

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Including work done by: C. N. Kelber, Andrew Selep and B. I. Spinrad

Reactor Engineering Division

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This report is a compilation of information derived through the process of engineering, construction and costs of designing and building the Argonaut Reactor. The following personnel contributed at various times to this project:

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At this time we would like to express our many thanks to the various service groups of the Laboratory for their excellent support in this project. Special credit is mentioned for the work performed by the Central Shops and Purchasing Department personnel whose participation accelerated the completion and operation of the Argonaut Reactor.
The Argonaut Reactor

The expansion of the nuclear field at Argonne National Laboratory has clearly indicated our need for a low level supplementary reactor facility. In designing a reactor to fill these requirements, we considered the probability that such a reactor might also be of interest to universities engaged in a program in the nuclear sciences. Recognizing the importance of the cost aspects of such a program, we have designed to a cost goal which we feel is compatible with safety and flexibility of use. This reactor is hereinafter referred to as the Argonaut, and is now in the test stage.

The reactor is a thermal heterogeneous type, with an annular core, with internal and external reflectors, and with water moderation. The maximum flux is about $5 \times 10^{11}$ neutrons per cm per sec at a power level of 10 kw. The critical loading is about 4 kg of $^{235}$U.

The Argonaut lattice is basically a cube of graphite 5 ft by 5 ft by 4 ft high, containing a centrally located water annulus 2 ft I.D. by 3 ft O.D. by 4 ft high formed by two concentric aluminum tanks. A 2 ft diameter internal graphite reflector is thus formed and contains a center hole plus four additional holes around the periphery. These ports may be used as a loci for Pile Oscillator Measurements and Danger Coefficient Experiments. This internal reflector plug is removable and may be replaced by a portion of a lattice assembly for internal experimental purposes. The top of the reactor must be accessible for loading of fuel assemblies, for insertion of experiments in the center reflector, and for the possible placement of an external exponential assembly. Therefore, this area is kept free of control mechanisms. Against one face of the graphite lattice is a graphite thermal column 5 ft wide by 5 ft long by 4 ft high, containing 15 horizontal experimental ports. Opposite to this face on the other side of the lattice is a mobile flat bed truck to which is assembled a demountable water tank 4 ft wide by 6 ft long by 3-1/2 ft high.

This tank may be used for shielding studies using aqueous media, or, by removing this tank, solid materials may be stacked on the bed of the truck for testing. Concrete blocks are stacked against the remaining two lattice faces, each of which contains an additional experimental port. The Argonaut reactor, therefore, contains a total of 22 experimental ports, five of which are vertical and 17 of which are horizontal.

The area directly over the lattice is shielded by a 5 ft square by 1 ft high steel box containing a removable plug located directly over the internal graphite reflector. Adjacent to this plug are additional removable plugs which provide apertures for the insertion of fuel assemblies. This entire steel box, including the plugs, is filled with heavy concrete. For experiments at higher power, additional ordinary concrete bricks will be used to supplement the heavy concrete shield. A jib crane of 3-ton capacity with a boom arc of 15 ft is provided for the removal of these shielding components. The upper shielding over the lattice and shield test facility is supported by a structural assembly formed by bolting together 6-in. wide flange aluminum beams. In addition, a five foot square by 1/2 in. thick aluminum plate is bolted over the lattice, and 6 in. by 6 in. wooden beams are mounted over the water shielding test tank. This forms an adequate structure which may be assembled with the simplest of tools, yet one which may be dismantled with ease if, at some later date, it is necessary to move the reactor. The column loading at the four inside columns is 10,000 pounds per column, and at the two outer columns is 4700 pounds per column. The maximum bending stress on the horizontal beams is 7000 psi. The floor loading aside from the column loads is 1500 psi.

The moderating water is contained in an annulus. There are approximately 190 fuel plates arranged in 12 clusters which are separated by graphite segments. This graphite is waterproofed by spraying with Krylon Aluminum Paint. The fuel plates are 2-5/32 in. wide by 24 in. long, by 0.04 in. thick, and are made of 99.9% pure U-235. U-238 is enriched in an aluminum matrix. The source is an antimony plug inserted in a beryllium cube, and is moved into the fuel zone by an electric drive. The source is capable of 10^6 neutrons per second.

At an allowable short term power level of 10 kw, the heat generation is about 50 watts or 170 BTU per hour per plate. Heat removal is accomplished by circulating water between the fuel plates. At the maximum power level the circulation rate is about 6.5 gpm. The water system contains a 1/4-H.P., stainless steel centrifugal pump (capable of 20 gpm against a 14-ft head), a 34,000-BTU single-pass shell and tube stainless steel heat exchanger (containing 4.3 square feet of surface), a 3-kw heater for moderator temperature control, suitable solenoid valves, strainers, check valves, 1-in. aluminum line piping, and finally a 275-gallon dump and makeup water tank. A 5-gpm laboratory ion exchanger is supplied to provide water of adequate purity. A utility tong is located under the reactor tank contains the dump line, cooling water line, gas line and electric lines. This trench terminates in a 7 ft wide x 11 ft long x 4 ft deep covered utility pit. Thus, all the above elements are easily accessible for servicing. The pit cover may be locked to prevent access to this area by unauthorized persons.

The dump line is a 6-in. aluminum pipe located directly under the main reactor tank and terminates in the utility pit. The terminal end of the dump line is connected to a 6-in. rubber-lined, electrically operated, butterfly valve which is held closed by a magnetic clutch. A weighted lever arm opens the valve when the clutch is de-energized, emptying the water into the dump tank. Loss of moderator effects positive shutdown.

Control is obtained by conventional absorbing materials located next to the core in the outer reflector. There are now four types of control devices under test. They are:
1. Gravity-actuated rods replacing the graphite reflector with a cadmium-plastic absorber. This is operated by a winch type of mechanism.

2. Same rod as No. 1, except the actuator is a magnetic jack.

3. Cadmium plates riveted to a clock spring. This is operated from a drum mechanism similar to a window shade.

4. Void control, using a vacuum pump to move D₂O into the control zone.

A supplementary safety system is provided by effecting a rapid decrease in moderator bulk density by introducing bubbles. This is done by injecting nitrogen gas through a quick-opening valve simultaneously with the operation of the 6-in. dump system. This gas line is made to fail safe by using the nitrogen pressure to close a normally open mercoid switch in the interlock system. Thus, two completely independent systems effect the shutdown.

The reactor is contained in a prefabricated metal building 40 ft by 60 ft with 21 ft head room from the floor to inside the ridge. The utility requirements are water at 2 gpm at a temperature of 75°F., and 40 kw of 110-v. A.C. single phase electricity.

The design as described has been developed on the "do-it-yourself" philosophy, using a minimum of skilled help for the erection and tryout. Exclusive of fuel charges and erection cost, this reactor may be built for $100,000.
The figures in this book are intended to supplement the general description of Argonaut given in ANL-5647, ANL-5552 and in Nucleonics 15 (3), 62 (1957). A complete description is in preparation as ANL-5705. This material is published now for the information of those who may have an interest in constructing Argonaut reactors, or supplying components for them.

Descriptive Drawings

FIGURE 1 (RE-1-17500-D) ARGONAUT REACTOR AND BUILDING This key drawing shows the locations of the reactor, work area, pit, trenches, and control console area in the building. The positions of the lattice and shielding are indicated for clarity.

FIGURE 2 (RE-1-20605) HORIZONTAL SECTION A-A This figure is taken through the reactor at the top of the first level of shielding blocks, locating shielding, graphite reflector and thermal columns, structural assembly and the irradiation facility.

FIGURE 3 (RE-1-17598-E) STRUCTURAL ASSEMBLY This shows the supporting beams, cover plate and shielding over the irradiation facility; methods of construction and materials are indicated.

FIGURE 4 (RE-1-20634-C) IRRADIATION FACILITY ASSEMBLY This figure indicates components and working clearances within the assembly for conducting experiments.

FIGURE 5 (RE-1-20606-E) HORIZONTAL SECTION B-B This figure is taken through the reactor at the top of the second level of shielding blocks. This section locates the liners for the horizontal beam holes and can serve as a general plan of the reactor core and reflectors.

FIGURE 6 (RE-1-17507-D) REFLECTOR GRAPHITE ASSEMBLY This drawing indicates the configuration of the 4 in. square graphite that was used to construct the Argonaut reflector. It should be noted on this and the following drawing that larger sizes of graphite block are under consideration as being preferable.

FIGURE 7 (RE-1-17617-D) THERMAL COLUMN ASSEMBLY This assembly shows the location and construction of the fifteen (15) stringers and the thermal column assembly. It should be noted on this drawing that larger sizes of graphite block are under consideration as being preferable.

FIGURE 8 (RE-1-17631-C) HORIZONTAL PLUG AND FOIL HOLDER This figure indicates plugs for beam holes extending to the reactor tank.

FIGURE 9 (RE-1-17771-C) INTERNAL THERMAL COLUMN This drawing indicates central thimble with interlock and the four (4) rectangular stringers. See description of Figure 6 concerning graphite module.

FIGURE 10 (RE-1-17774-F) FUEL, ANNULAR REFLECTOR AND GAS SPARGER ASSEMBLY This drawing indicates the fuel and graphite arrangement in the annulus. The gas sparger heads and piping for the spargers are shown.

FIGURE 11 (RE-1-17751-C) FUEL ASSEMBLY This is the Mark I Fuel Assembly now in use. This and the following figure are subject to revision according to the method of handling adopted.

FIGURE 12 (RE-1-17753-B) ARGONAUT FUEL PLATE - MARK I This figure shows plate as reworked for the Mark I assembly.

FIGURE 13 (RE-1-20571-D) DRUM TYPE CONTROL ROD MECHANISM The drawing shows the major components of the control mechanism.

FIGURE 14 (RE-1-20588-C) CONTROL ROD The actual size of cadmium and method of attachment for the drum control rod is shown on the drawing.

FIGURE 15 (RE-1-20607-D) NORTH-SOUTH ELEVATION "C-C" This figure is an elevation taken through the pit, trench, and reactor, showing the piping and the fuel transfer tools in place on the top Shield Box Assembly.

FIGURE 16 (RE-1-17686-D) ARGONAUT PIPING ASSEMBLY This is an isometric drawing of the piping and its location in the reactor. A description of the various units is included.

FIGURE 17 (RE-1-20608-D) EAST-WEST ELEVATION "D-D" This figure through the vertical centerline of the reactor locates the top shield box assembly (RE-1-17761-F) and source drive unit (RE-1-17643-D).
FIGURE 18 (RE-1-17643-D) SOURCE DRIVE This shows the major components and the space requirements of the source assembly.

FIGURE 19 (RE-1-17761-F) TOP SHIELD BOX ASSEMBLY This drawing indicates the removable center plug section which can be positioned as required for fuel removal.

FIGURE 20 (RE-1-20609-C) CONCRETE BLOCK SHIELDING ASSEMBLY This figure is a key for the detailed shielding drawings.

FIGURE 21 (RE-1-17610-E) LAYER #1 SHIELDING BLOCKS This drawing shows the configuration of shielding in relation to the major reactor components which is carried out through the other layers.

FIGURE 22 (RE-2-20633-C) ARGONAUT ELECTRICAL EQUIPMENT LOCATIONS This drawing is a master key to all the electrical units that are used in the reactor operation and control.

FIGURE 23 (RE-2-20570-F) ARGONAUT CONTROL CONSOLE ASSEMBLY This figure represents the control console desk, sequence panel and instrumentation rack cabinets. The operation and control of reactor is conducted from this area.

FIGURE 24 (RE-2-17796-F) ARGONAUT MASTER CONTROL PANEL WIRING This figure indicates the wiring from the control console to the various units within the reactor and pit.

FIGURE 25 (RE-2-20536-F) ARGONAUT CONTROL CIRCUIT - PART I Schematic drawings showing complete electrical operations of the reactor.

FIGURE 26 (RE-2-20537-F) ARGONAUT CONTROL CIRCUIT - PART II Schematic drawings showing complete electrical operations of the reactor.

COST INFORMATION

FIGURE 27 (RE-1-17500-Supplement, Sheet 1) ARGONAUT REACTOR COST SUMMATION

FIGURE 28 (RE-1-17500-Supplement, Sheet 2) ARGONAUT REACTOR COST SUMMATION

FIGURE 29 (RE-1-17500-Supplement, Sheet 3) ARGONAUT REACTOR COST SUMMATION

These Figures 27, 28 and 29 show all the units required for construction and a breakdown on their cost. Labor and material are shown in separate columns when the unit was fabricated in ANL Central Shops, and is indicated by the prefix S. O. xxxx. Purchased parts are noted in the P. O. column.

FIGURE 30 FOOTNOTES OF THE ARGONAUT REACTOR COST SUMMATION

MISCELLANEOUS

FIGURE 31 (RE-8-20646-C) FLOW DIAGRAM

FIGURE 32 (RE-2-20651-C) PICTORIAL DIAGRAM OF ARGONAUT INSTRUMENTATION

FIGURE 33 (RE-6-20640) ALTERNATE SHIELDING ARRANGEMENT NO. 2 This method uses standard solid concrete building blocks.

FIGURE 34 (RE-6-20641) ALTERNATE SHIELDING ARRANGEMENT NO. 3 This is a monolithic concrete construction.
NOTE:
INTERNAL WORKING CLEARANCES
LENGTH: 57 3/4
WIDTH: 44 3/8
DEPTH: 8 1/8

1/4 STL PLT - SHELF FOR ONE COURSE SOLID CONCRETE BLOCK ON END

1/2 STL PLT MASONITE HOLDER BOTH SIDES

1/4 STL BOX

1 3/8 TOTAL THICKNESS MASONITE COVER

3 3/8 STRUCT. CHANNEL ALL AROUND - 2 PLACES

57 3/4

CONCRETE FILL FLAT BED USE WELDED REINFORCING RODS

4
45
45
41 3/4

1/2 CLEARANCE

ALL WELDED CONSTRUCTION

NOTE: PAINT ALL METAL PARTS WITH RED LEAD PAINT COLOR TO SUIT
VERTICAL FILLERS TO BE SAW CUT

FIGURE 6
NOTE
THIS DWG IS FOR REWORKING OF PRESENT PLATE.
FOR ORIGINAL DWG SEE RE-1-17576-A

FIGURE 12

.375 D MAX DRILL THRU

PRESS FILLER IN FLUSH WITH PLATE
**FIGURE 13**

**NOTES:**

1. Item 62 (type A): Thickness to be determined at assembly to permit axial clearance of .005 for clutch bracket in item 19.

2. Assemble item 69 (full pin) thru gear in item 14 & shaft, down -.005/.001 to produce clearance shown with gear hub 3/4" against bearing.

3. Adjust part item 68, in assembly for end pin end play between nut & clutch plate in item 14.

4. Adjust eccentricity - RE-1-2057-0 & RE-1-2057-9 in assembly to center spring in sheath, RE-1-2057-0.

*DELETE FOR SAFETY AND SLIP ROD ASSEMBLIES. USE ONLY ON CONTROL ROD ASSEMBLY*
22

20° BEFORE BENDING

DIMENSION TO BE DETERMINED AT ASSEMBLY (1/2 APPRX)

SCALE, THICKNESS 4X1

1/2 IN. DIAMETER HOLES

C SINK TAPER SIDE & GRIND FLUSH AFTER PEENING - 1 PER

3/32 IN. HOLES END OF ROD WITH 2 HOLES

22 (1/2) DIA. DRILL, TWO (1/2) DIA. TAPPER

DIETHYL (PLATED IR) 2 HOLES PER 1/2 

CADMIUM 0.032 THICK

希望对你有帮助！
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<td>LAYERS 1766</td>
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<tr>
<td>TOTAL SHIELING</td>
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<td>SPECIAL CONCRETE BLOCKS</td>
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<th>DESCRIPTION</th>
<th>QTY</th>
<th>UNIT COST</th>
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<td>RE-1-20604</td>
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<td>CONTROL BOX ASSY</td>
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<tr>
<td>RE-1-20511</td>
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<td>RE-1</td>
<td>CARDIOCAM CONTROL ROD</td>
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<td>RE-2</td>
<td>SLING CHAIN 1000 LB ROD CART</td>
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<td>RE-1</td>
<td>UTILITY HAND CART</td>
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<td>95.00</td>
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**TOTAL REACTOR COST**

FIGURE 29

*Note: The table above represents the bill of material for the Argonaut Reactor, with detailed parts and their quantities. The costs are listed in dollars.*
1. Structure Assy. RE-L-17598-E, Req. #350136, $855.61
   BIDGERS
   Schein Brothers
   Chicago Boiler Company
   Sherman Reynolds Company
   Oakley Company
   Chicago Metal Manufacturing Company
   Allis Chalmers Company

2. Reactor Tanks Outer and Inner RE-L-17606-E & RE-L-17621-E, Req. #359517, $832.54
   BIDGERS
   Cherry Durrell Company
   S. Blickman, Incorporated
   Schein Brothers
   Process Equipment Company
   Aluminum Company of America (NO BID)
   Stacy Manufacturing Company (NO BID)

3. 6th Dump Valve (less operator) RE-L-17655 -
   P.O. 198587 - Price $157.00.
   6th Dump Valve Assy. RE-L-17655, Req. #360062, $606.00
   BIDGERS
   Boyar Schultz Company (less valve)
   Laystron Mfg. Company (less valve)
   General Mills Company (time and material only)

   NO BIDS OR BIDS OFFERING SUBSTITUTES ON DUMP VALVE
   FROM FOLLOWING:
   American Bosch, Arma Division
   Kempeith Machine Company
   Northwestern Tool & Eng. Company
   Acme Industrial Company
   Cook Electric Company
   Lenz Machine & Tool Works
   Johnson Corporation
   R. W. Lawrence Company
   Associated Valve & Eng. Company
   S. Morgan Smith Company
   Everlasting Valve Company
   W. P. Nevins Company
   Allis Chalmers Company
   Ruggles Lingen & Mfg. Company
   Davis Regulator Company
   McKea Corporation
   Metters & Controls
   Automatic Valve Company
   Hammel-Dahl Valve Company
   Automatic Switch Company

4. Dump Tank Assy. RE-L-20531-B, Req. #35L195, $399.43
   BIDGERS
   Schein Brothers
   Chicago Boiler Company
   Aluminum Company

5. Water Shield Tank RE-L-20631-C (Cart and Tank Only) Req. #W-3501177, $410.00
   BIDGERS
   Brett Machine Company
   Montgomery Equipment Company
   Howe Hand Trucks
   Mercury Manufacturing Company
   Midwest Handling Company
   Materials Trans. Company
   Elmar Engineering Company

6. Winch-type Control Mechanism RE-L-20614-D, Req. #360063, $772.76 (Six Units Basis)
   BIDGERS
   General Mills Mech. Division
   A.F.C. Tool & Machine Company
   American Manufacturing Company
   Columbus Tool, Die & Machine Co. (NO BID)
   Economy Machine Products (NO BID)
   American Machine & Foundry (NO BID)
   United Shoe Machinery Company (NO BID)
   Ford Instrument Company (NO BID)

7. Solid Shield Blocks, Req. #366702 - 150 lbs/ft³
   Density - Actual Size 7-5/8 x 7-5/8 x 15-5/8
   $0.35 ea.
   BIDGERS
   Werden Buck Company
   Joliet Concrete Products Company
   Materials Service Corporation

8. Graphite - BIDGERS $22,300.00
   National Carbon Company
   United Carbon Products Company
   Great Lakes Carbon Company
   Stewpake Carbon Company (NO BID)
   International Graphite Company (NO BID)
   U. S. Graphite (NO BID)

FIGURE 30
Note 1: Nominal size 8" x 8" x 16". Actual 7 3/4" x 7 3/4" x 15 3/8"

Note 2: Nominal size 8" x 8" x 8". Actual 7 3/4" x 7 3/4" x 7 3/8"

Concrete density to be 150 lbs per ft³.

Figure 33

Layer East Side

Layer West Side

<table>
<thead>
<tr>
<th>Layer</th>
<th>Full Size</th>
<th>Half Size</th>
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<tbody>
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<tr>
<td>2</td>
<td>101</td>
<td>8</td>
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<tr>
<td>3</td>
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<tr>
<td>4</td>
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<tr>
<td>5</td>
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<td>18</td>
</tr>
<tr>
<td>14</td>
<td>55</td>
<td>10</td>
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</tbody>
</table>

Material: Solid brick

Source Ports

One full size solid brick = 908.45 ft³, 0.5267 ft³, or 79 lbs.

One half size solid brick = 443.32 ft³, 0.2665 ft³, or 38.5 lbs.

Total volume = 1998.93 ft³, 1083.38 lbs.

Microfilm Stamp:

ARGONNE NATIONAL LABORATORY

Tolerances unless otherwise noted:
Fractional ± 1/16, Decimal ± 0.005, Angle ± 1°

Remove all burrs

Refer above

Scale: 1/8 = 1 ft.

Drawing No.: RE-6-20640-B

AUTHORIZATION:

REPRESENTATIVE: [Signature]

DRAWN BY: [Signature]

CHECKED: [Signature]

DATE: [Date]

NEXT ASSEMBLY: [Date]

NO. REQUIRED:

ARGONNE NATIONAL LABORATORY
ORDINARY CONCRETE 150 LB/FT³ DENSITY 8 THICK X 72" WIDE X 32" LONG REINF. CONCRETE SLAB OVER THERMAL COLUMN & WATER SHIELD TANK.

8 THICK X 48" HIGH X 206" LONG REINF. CONCRETE BEARING WALLS - 2 REQ.

TOTAL AMOUNT OF MONOLITHIC CONCRETE IS 1736 FT³.

192 BRICKS 8"X8"X5" REQUIRED OVER CENTER PLUG

90 BRICKS 8"X8"X1½" 30 BRICKS 8"X8"X7½" REQUIRED OVER SOURCE PORT

FIGURE 34