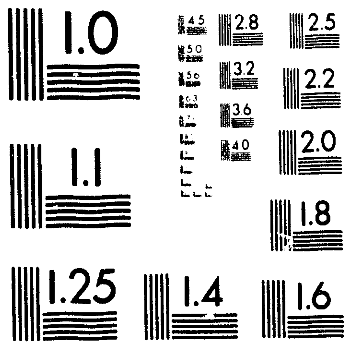
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THE ADVANCED NEUTRON SOURCE (ANS) PROJECT
A WORLD-CLASS RESEARCH REACTOR FACILITY

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Paper to be presented at
the 1993 Annual Meeting of the American Nuclear Society
San Diego, California
June 20-24, 1993

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Prepared by the Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831; managed by Martin Marietta Energy Systems, Inc., for the Department of Energy under Contract No. DE-AC05-84OR21400.

1. Project Purpose

The Advanced Neutron Source (ANS) is a new research facility being designed at the Oak Ridge National Laboratory (ORNL) in Tennessee. This world-class laboratory will meet the national need for an intense, steady-state, broad-spectrum source of neutrons for research. The ANS will provide the scientific community with crucial tools for neutron beam research in physics, chemistry, biotechnology, pharmacology, medicine and energy-related materials and structures. In addition, it will provide needed facilities for isotope production (including transuranic isotopes), materials irradiation testing, and analytical chemistry. The project provides the means for the United States to regain the world leadership that it previously held in this field.

The facility is based on a 330 MW_f heavy-water cooled and reflected reactor as the neutron source, with a thermal neutron flux of about 7.5×10^{19} $m^{-2}.sec^{-1}$. Within the reflector region will be one hot source which will serve 2 hot neutron beam tubes, two cryogenic cold sources serving fourteen cold neutron beam tubes, two very cold beam tubes, and seven thermal neutron beam tubes. In addition there will be ten positions for materials irradiation experiments, five of them instrumented.

Isotope production goals are 1.5 g/year of ^{252}Cf and 40 μg/year of ^{254}Es. A number of rabbit tubes will be provided, with hot cells and other servicing facilities.

2. Project Status

Preliminary feasibility studies began in 1984, followed by preconceptual design in 1986 and conceptual design in 1990-1992. Oak Ridge National Laboratory is the lead laboratory assisted by 4 other federal laboratories, 13 universities and 16 industrial companies. As the Department of Energy's (DOE) Maintenance and Operating contractor for ORNL, Martin Marietta Energy Systems, Inc. is responsible for the overall success of this project, and its eventual operation and maintenance.

A conceptual design report was issued in June, 1992. It contained approximately 12 thousand single-spaced pages of text plus 390 E-size (34"x 48") drawings. This report has been reviewed by the scientific community and the DOE. Extensive reviews by outside experts and panels have also occurred; nearly 50 reviews and workshops in the last four years, including four major DOE programmatic reviews.

The employment of an Architect-Engineering company (Gilbert/Commonwealth, Inc.) experienced in the design of commercial nuclear facilities to support preparation of the conceptual design provided valuable input to assure that the facility would meet the appropriate nuclear industry criteria and could be designed and built as a "licensable" facility. Assisting Gilbert/Commonwealth, Inc. during the conceptual design was Atomic Energy of Canada, Limited (AECL) doing business in the United States as AECL Technologies, Air Products and Chemicals, DRS Architects and Planners, The University of Tennessee and The Pennsylvania State University. AECL performed the conceptual designs of the heavy-water systems, including a heavy

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water upgrading and detritiation facility. Air Products and Chemicals was responsible for the cryogenics for the cold sources, DRS created the architectural features of the facility, stressing the user-friendly requirements and the necessity for a campus atmosphere for the research staff, and the universities performed special studies.

The project is now in advanced conceptual design, and planning for a fiscal year 1994 design and construction Congressional Line Item start. The schedule includes completion of sufficient engineering and design, safety analysis and reviews to support actual physical construction beginning in fiscal year 1996. Construction completion and commissioning will be in fiscal year 2002.

3. Safety

The ANS is to be designed, built, and operated as a DOE facility. However, DOE Orders require its reactors to meet the comparable standards, codes and guides that are applied to comparable Nuclear Regulatory Commission (NRC) licensed facilities. Accordingly, the ANS design criteria are chosen to ensure that applicable safety requirements are incorporated into the design. The ANS risk limitation goals are based on the current licensing practices of the NRC. The ANS team has followed a proactive policy of building safety into the design. Safety analyses have concentrated to date in three areas: probabilistic risk assessments and evaluations, transient thermal-hydraulic analyses to support and define the cooling and shutdown systems for the high power-density core, and containment response to severe accident conditions.

4. Cost Estimates and Schedule

The Conceptual Design Report was revised in April 1993, to reflect the results of Value Engineering and other studies, and it is the basis for the project's cost estimate. The costs were estimated in fiscal year 1992 dollars, and escalated based on the project schedule using DOE escalation rates. Costs are accounted for under 3 categories of funding: Line Item costs, Operating Expenses, and Capital Equipment. The Line Item category refers to those costs associated with the Congressional Line Item and includes all design, procurement and construction costs. The Operating Expense funding category covers the costs associated with the complementary research and development (R&D) program and the initial buildup of facility operations staff as well as certain operating materials and supplies. Capital equipment costs cover the procurement of equipment used in the R&D portion of the project. Certain development activities are ongoing and many more are planned, including corrosion tests, core stability tests, fuel plate irradiation, flow and thermal-hydraulic testing.

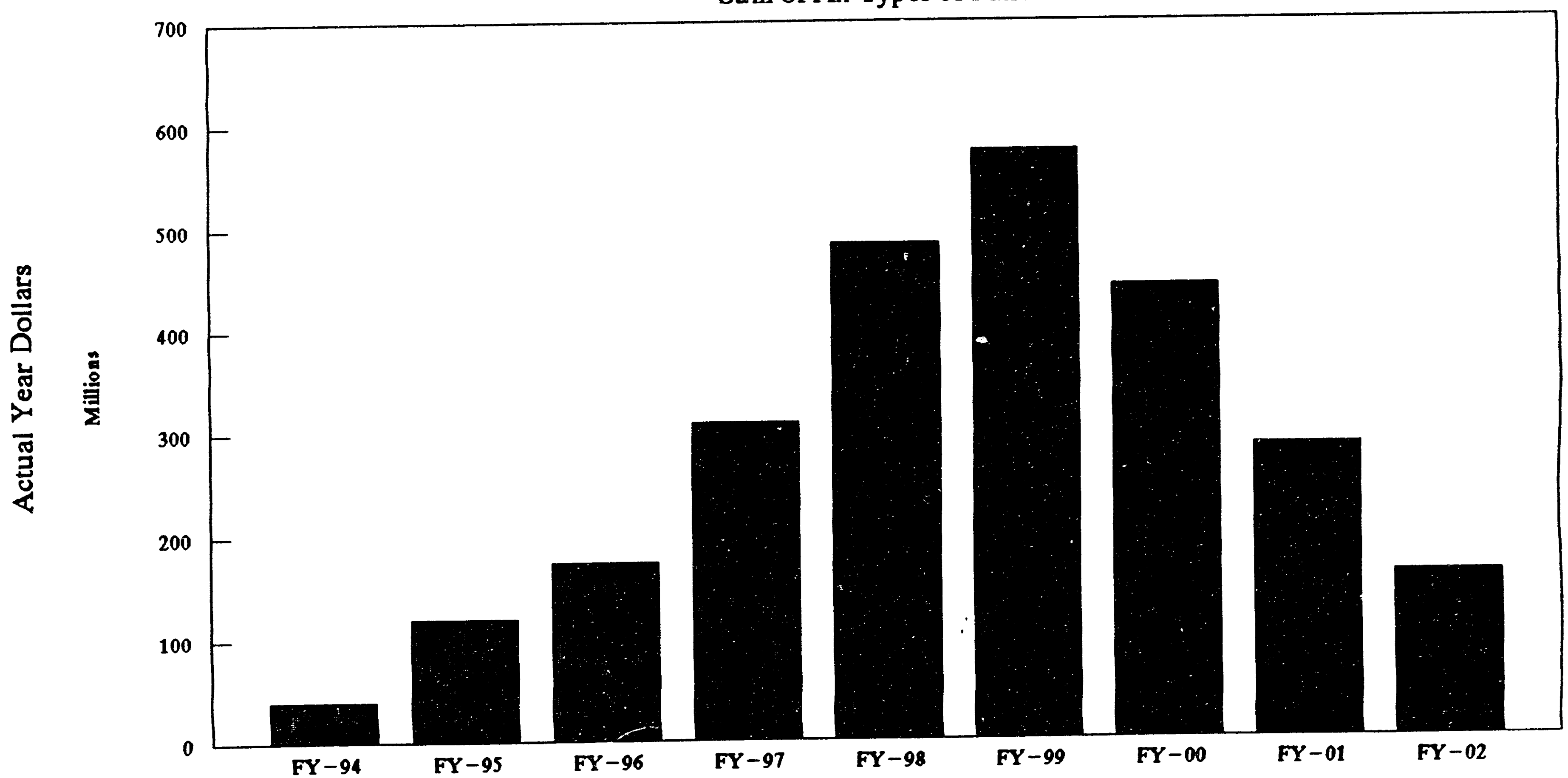
ANS Project Cost Estimates

FUNDING CATEGORY	FY 1992, $M	Actual Year $M
Line Item	1642	2024
Operating Expense	427	539
Capital Equipment	18	21
Totals	2087	2584

The figure on the facing page illustrates the year-by-year profile of expenditures.

ADVANCED NEUTRON SOURCE

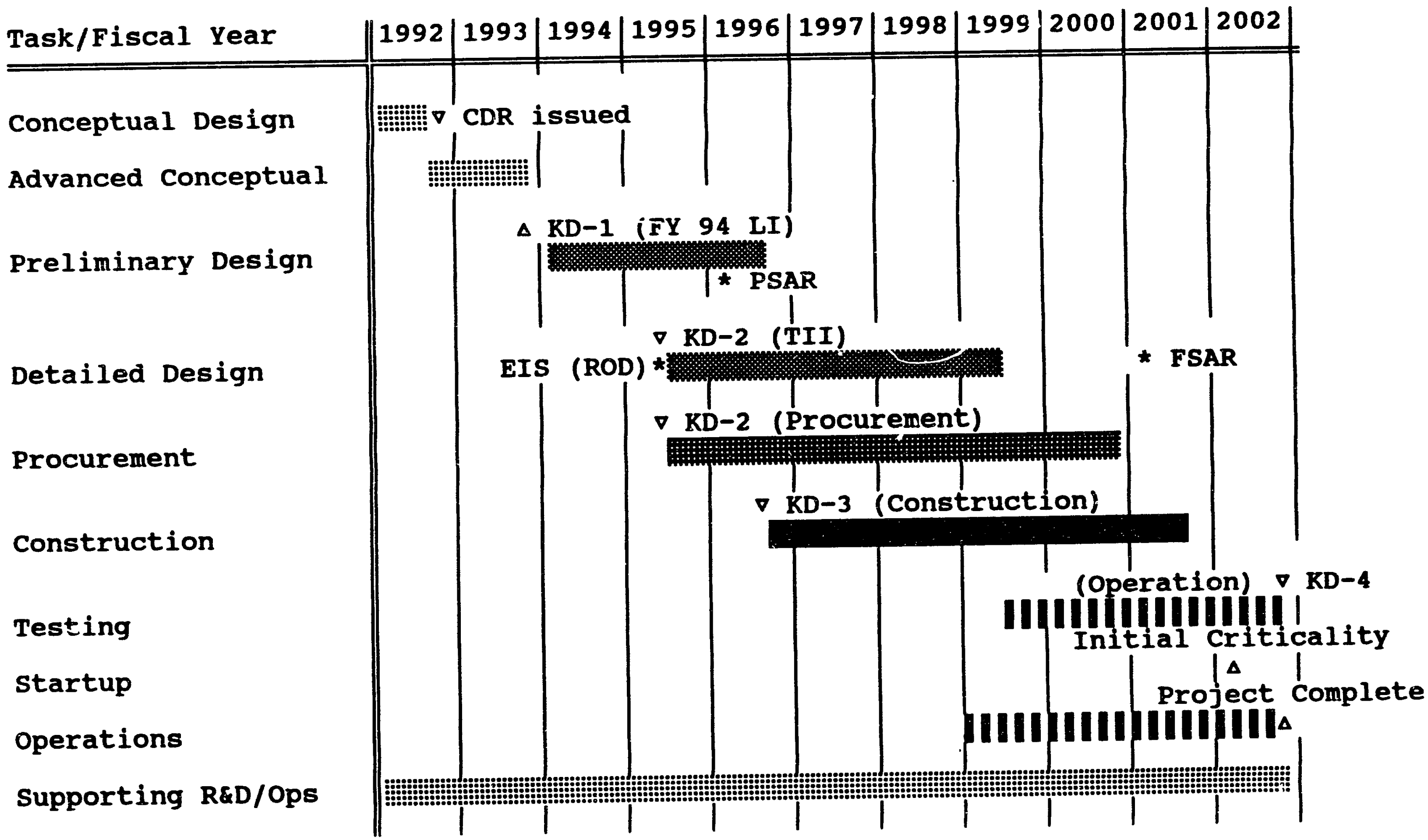
Sum of All Types of Funds



The schedule for this project was also developed during the conceptual design stage and revised in April 1993. An activity schedule addressing design, procurement, certification and permitting, research, construction, startup and turnover was developed, and consists of approximately 15,000 activities. The schedule begins with the start of preliminary design (Title I) in fiscal year 1994, construction start is in fiscal year 1996, and completion in September of 2002. The schedule includes the preparation and review of a Preliminary Safety Analysis Report (PSAR) and a Final Safety Analysis Report (FSAR), prepared in accordance with Regulatory Guide 1.70. A bar schedule illustrating the major project activities and timing is shown on the facing page.

The critical path for the project is similar to the typical power reactor critical path, with certain variations. It begins with the site characterization, which establishes the seismic and severe environmental phenomena. It then proceeds through the design and analysis of the reactor mockup and interior concrete structures in the reactor building, the construction of the interior concrete structures, the testing of the reactor mockup, the final design and fabrication of the reactor, installation of the reactor assembly components, testing of plant systems, DOE readiness reviews, and initial power testing.

Advanced Neutron Source (ANS) Project Schedule



The KD code is related to Key Decisions within the DOE management and approval process

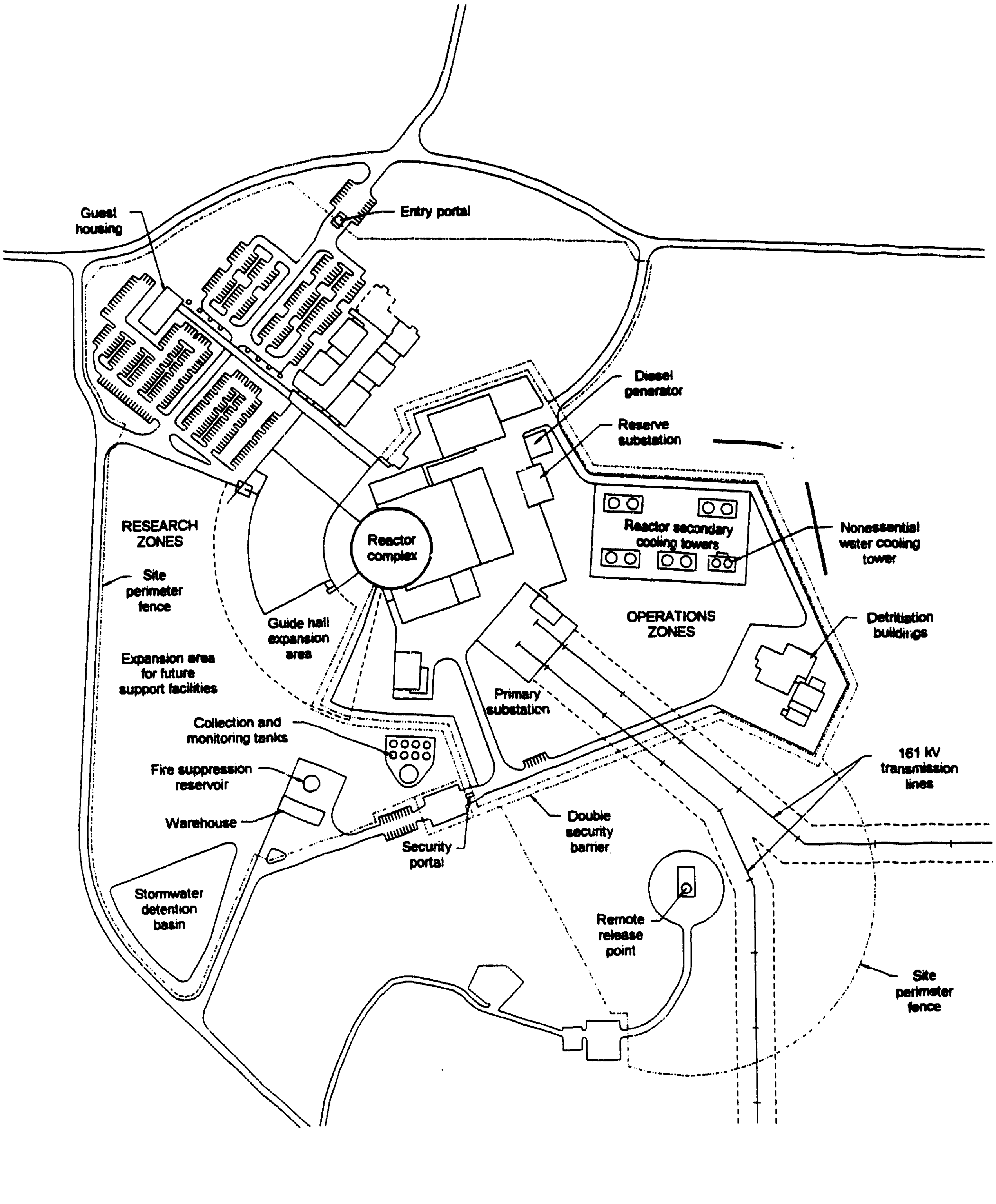
5. ANS Site Description

The preferred site for the ANS is located on the DOE's Oak Ridge Reservation in eastern Tennessee. Final selection of a site is dependent upon the Environmental Impact Statement activity currently underway. The Record of Decision from that process is a schedule constraint on initiation of final detailed design for the project. The figure on the facing page is a plan of the complex as it would be arranged on the preferred site. The domed reactor containment building is located in the center, with an adjacent fan-shaped guide hall housing cold neutron experiments. Research support facilities, including laboratories and shops, are also located in a manner facilitating activities planned for the guide hall. An office building to house the research staff and visiting scientists and researchers is located in close proximity to the research laboratory area. This is also the central reception and entry/exit portal for all personnel. On the side of the reactor building essentially opposite from the research facilities is the reactor support building that houses the reactor control room, safety-related power systems, instrumentation, cooling equipment, demineralizers and filters. Also located in proximity to the reactor support building is an operations support building that houses the operating staff, shops, training facilities including a simulator, parts storage areas and similar facilities.

The site is divided into a user friendly accessible research zone and a much more restricted access operations zone. These zones are not mixed, ensuring that the scientific community and the operating and maintenance communities are separate. This separation is achieved by careful arrangement of the buildings and areas, with barriers to prevent accidental or intentional mingling of the communities. The research zone includes the first floor of the reactor building where the experiment and production stations using hot and thermal neutrons are located, the guide hall housing the cold neutron experiments, the research support area and the office building. The operations zone is essentially all other parts of the facility.

Power would be supplied to the preferred site by two 161 kv transmission lines from the Tennessee Valley Authority. In addition, a 13.8 kv line is also provided, and will be used both as a source of construction power and as an emergency backup. In addition, Class 1E diesel generators are also provided. Cooling towers are used to dissipate the reactor heat energy, and are located east of the reactor complex. A heavy water upgrade and detritiation facility is provided to maintain the cleanliness and purity of the heavy water coolant and reflector.

A double security barrier is provided around the operations portion of the facility. A separate portal for personnel entry and equipment deliveries not related to operations is also provided in the facility complex. Provision for future expansion of the guide hall is another feature included in the design.



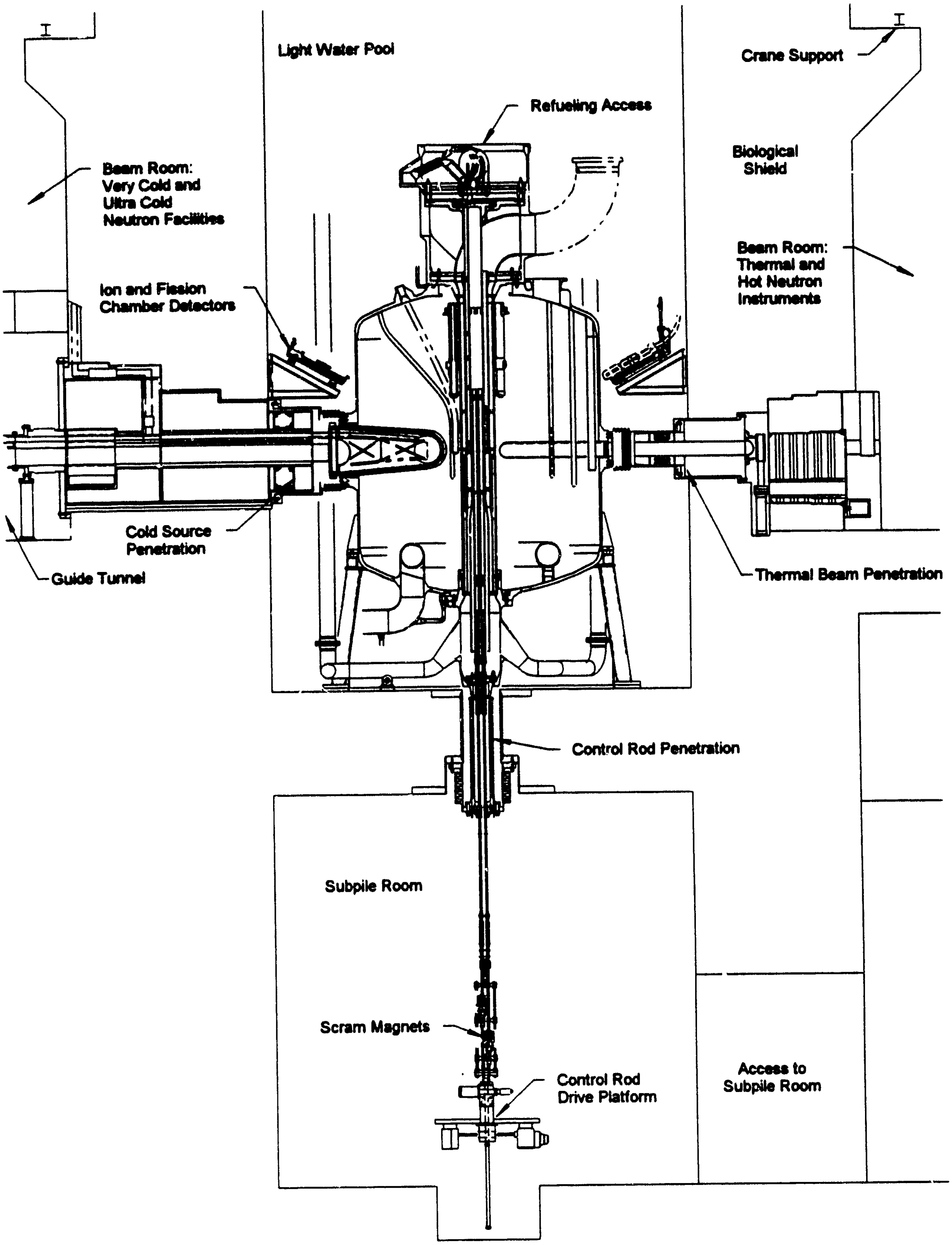
Site arrangement for the candidate site.

6. The Reactor

The reactor assembly is illustrated on the facing page. It consists of a 330 MW fission heavy-water cooled and reflected reactor. In order to meet the flux performance goals, the reactor core must produce many neutrons in a small volume. The required high thermal neutron flux must be produced in a region that is accessible to the beam tubes and of sufficient volume to accommodate the large number of beam tubes and irradiation facilities. The reactor design is also to be based on known technology to reduce the technical risk and reduce the amount of R&D required to verify the design concept. The core kinetics must be stable, the reactivity coefficients for power, voiding and other incidents must be negative, and the design is to meet the standards used by comparable licensed facilities, including safety margins. For these reasons, the ANS core design incorporates proven technology that has been used at two existing high flux reactors - the High Flux Isotope Reactor (HFIR) at ORNL and the Institut Laue-Langevin (ILL) at Grenoble, France.

The core is a compact arrangement with two annular fuel elements. The compact design results in a high heat flux, so the rate of heat exchange to the coolant is high. The fuel is highly enriched U_3Si_2 mixed with aluminum powder, clad with aluminum and rolled into curved plates. Aluminum has a high thermal conductivity and low neutron absorption cross section, so it is well suited as a material for low temperature reactors designed to produce thermal neutrons. The coolant, moderator and reflector are heavy water meeting the requirements for an effective moderator, a low absorption rate, and a long diffusion length. These qualities result in a thermal flux peak in an accessible region of the reflector tank a short distance away from the core fuel elements.

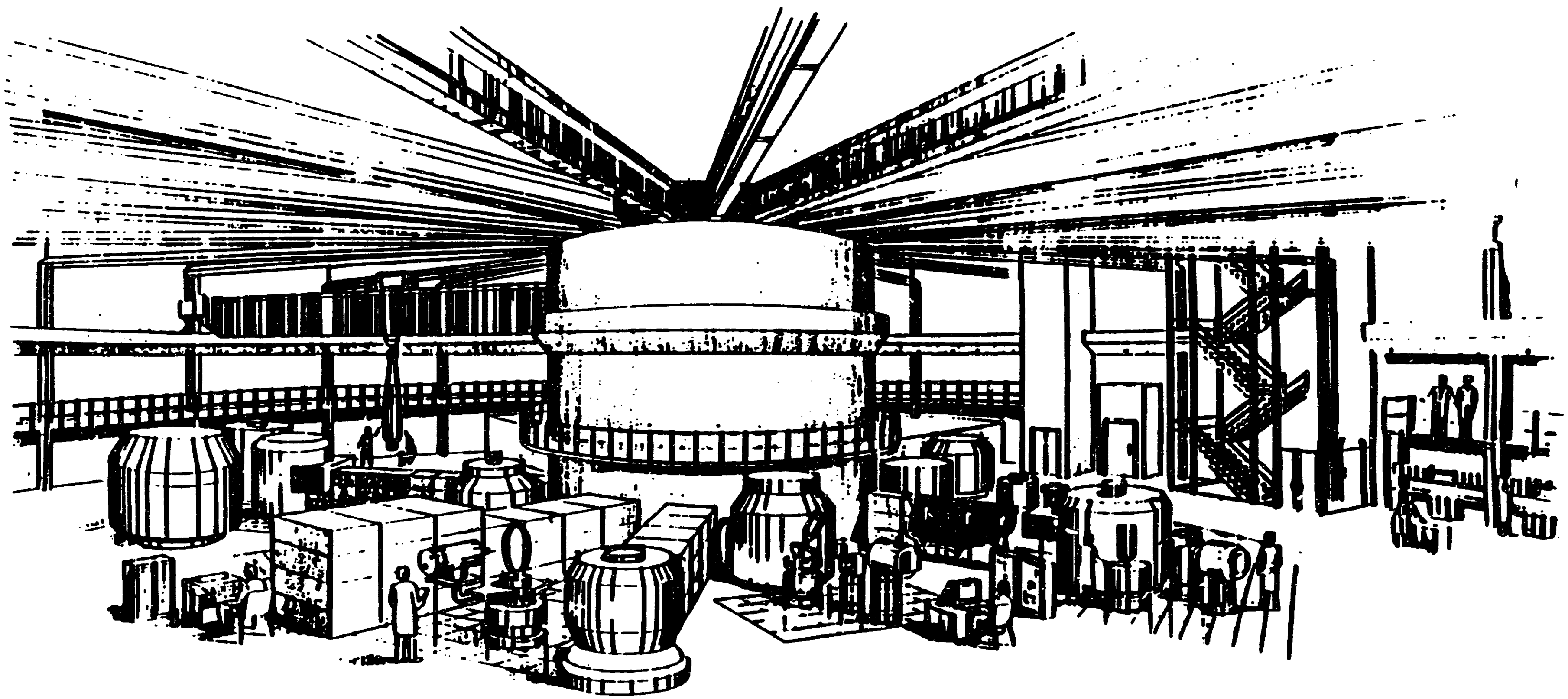
The reflector tank and the entire reactor coolant system are submerged in a light water pool, which provides both shielding and a source of coolant in the event of a primary coolant pipe break. The primary coolant pressure boundary is a tube slightly larger than the core fuel element's diameter, so the reflector tank operates at ambient pressure. Four reactor coolant loops are provided, which exchange heat with a light water cooling loop, rejecting the heat to cooling towers.



Reactor assembly, shield, and building interfaces.

The illustration on the facing page is an artist's impression of the first floor of the reactor building, housing the thermal neutron experiments. This view does not show the shielding that would normally surround each beam tube and experiment station. The biological shield around the reactor is visible in the center, surrounded by the various beams. The beams carrying the cold neutrons to the guide hall exit the building on the far side of the biological shield, and are submerged in a pool. These cold neutrons are conditioned by passing thermal neutrons through containers of liquefied deuterium. The ANS has two cold sources, serviced by a helium refrigeration system which maintains the deuterium at the appropriate conditions. The cold neutrons are transported to the guide hall using reflective, evacuated rectangular beam guides.

This area of the reactor building is a part of the research zone, and as such is designed for occupancy when the reactor is at power. A large personnel lock is provided to evacuate the personnel when necessary, and this area also includes a large equipment hatch for spectrometers and other experimental apparatus, and serviced by a crane that operates on a circular track.



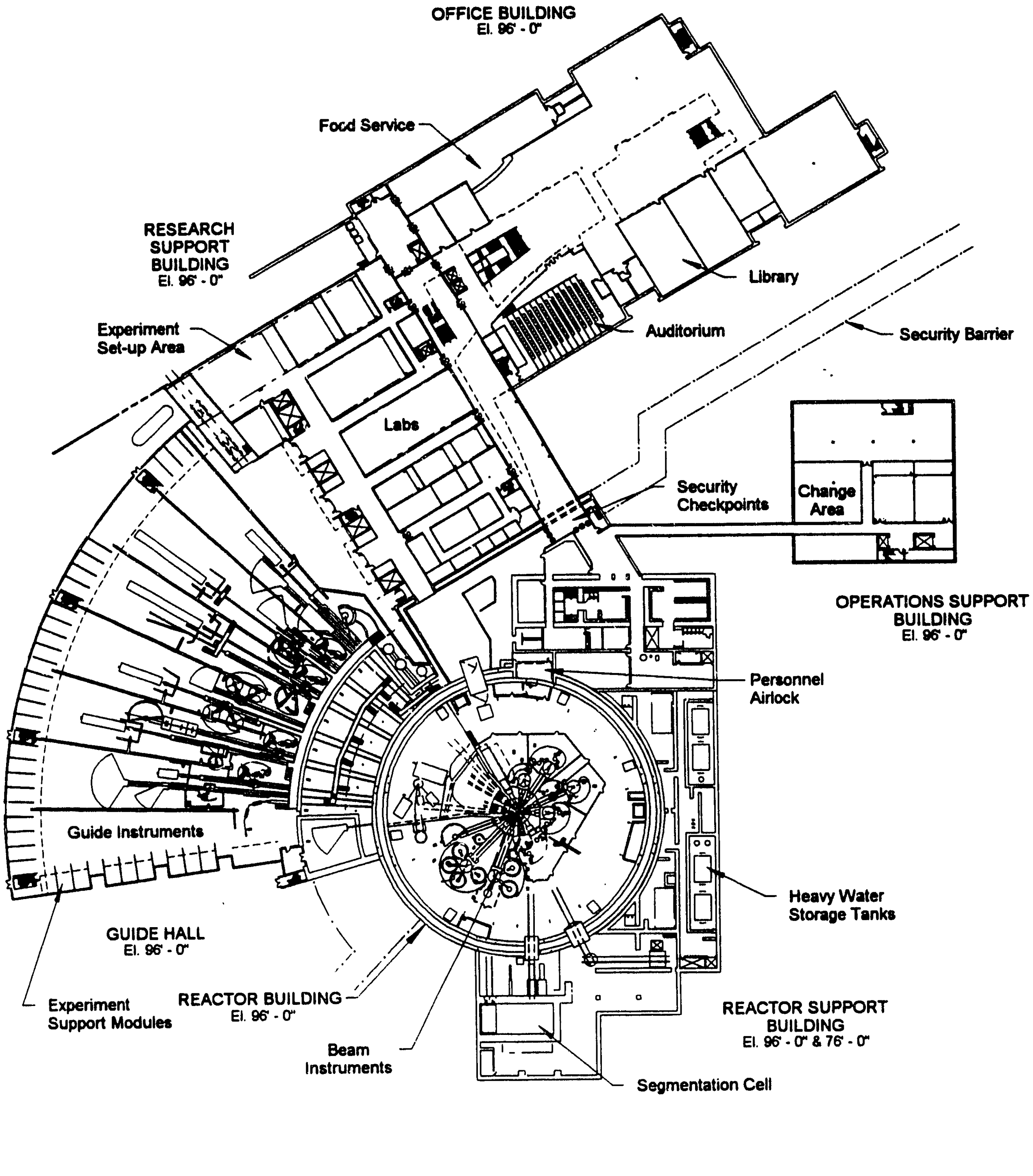
Artist's Impression of the ANS Beam Room

7. Facility Arrangements

The illustration on the facing page is a plan view of the reactor building, reactor support building, operations support building, guide hall, research support building, and office building. Elevations are referenced to the centerline of the core, arbitrarily defined as elevation 100'0" for the conceptual design. Conversion of facility dimensions to self-consistent SI units is planned for the advanced conceptual design phase. This floor of the reactor building is the same as that illustrated overleaf.

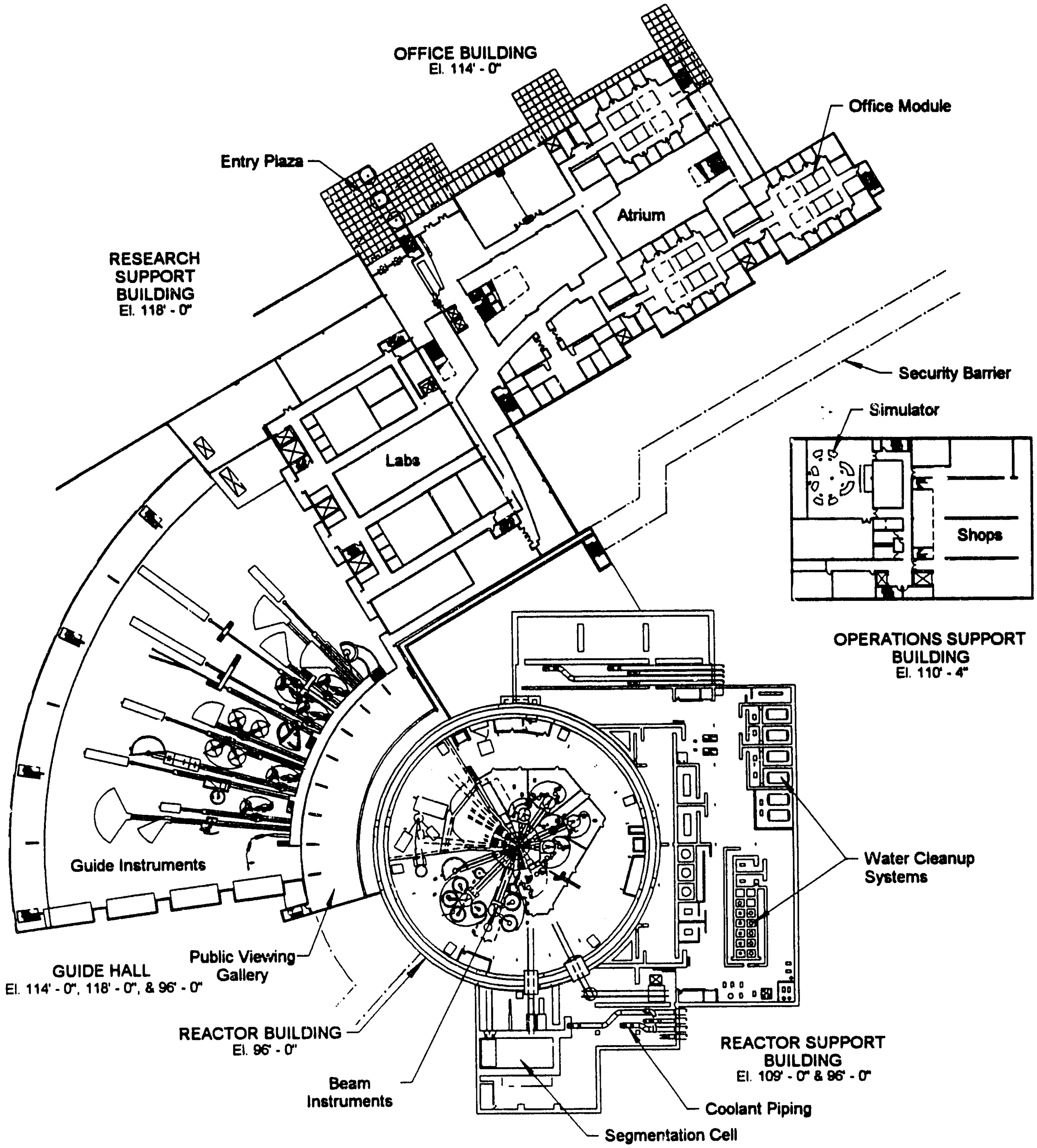
The reactor building is a 60 meter (200 feet) diameter steel pressure containment within a concrete shield building and incorporates a filtered annulus area. There are three floors in the reactor building and four floors in the reactor support building. The large size of this building, more than a typical power reactor, is dictated by the requirements of the experiments located within the building. It is designed for a post-accident design pressure of about 70 kPa (10 psig).

At this level in the reactor support building are filters and demineralizers and waste collection and treatment systems.



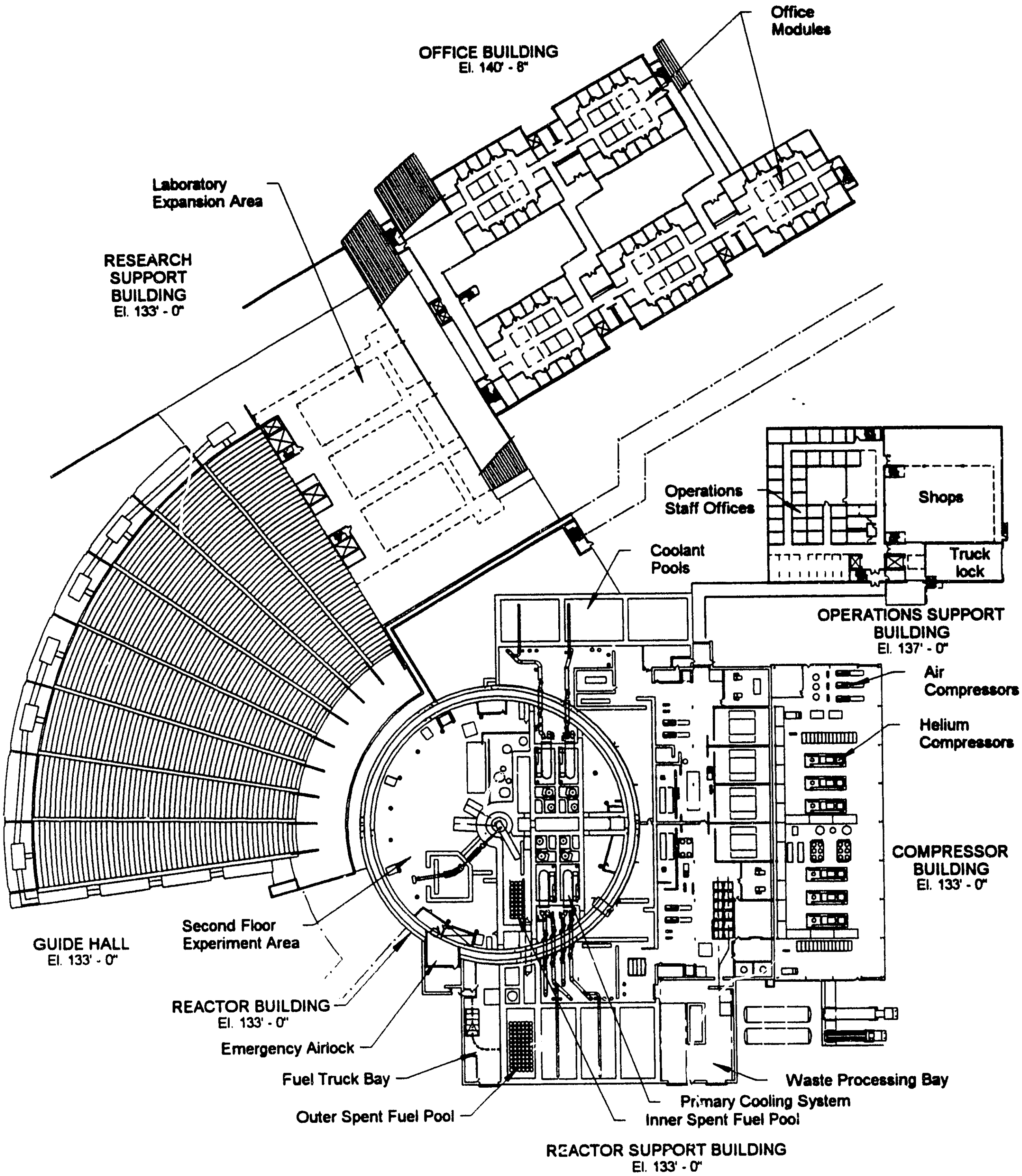
Floor plan of the main building complex at reactor midplane.

The illustration on the facing page shows the second floor plan in the reactor support building and other structures. This area contains access portals for the demineralizers and filters on the floor below, pipe galleries, ventilation equipment and other services. The plant simulator and associated training facilities are shown in the operations support building. Administrative support space is indicated in the office building.



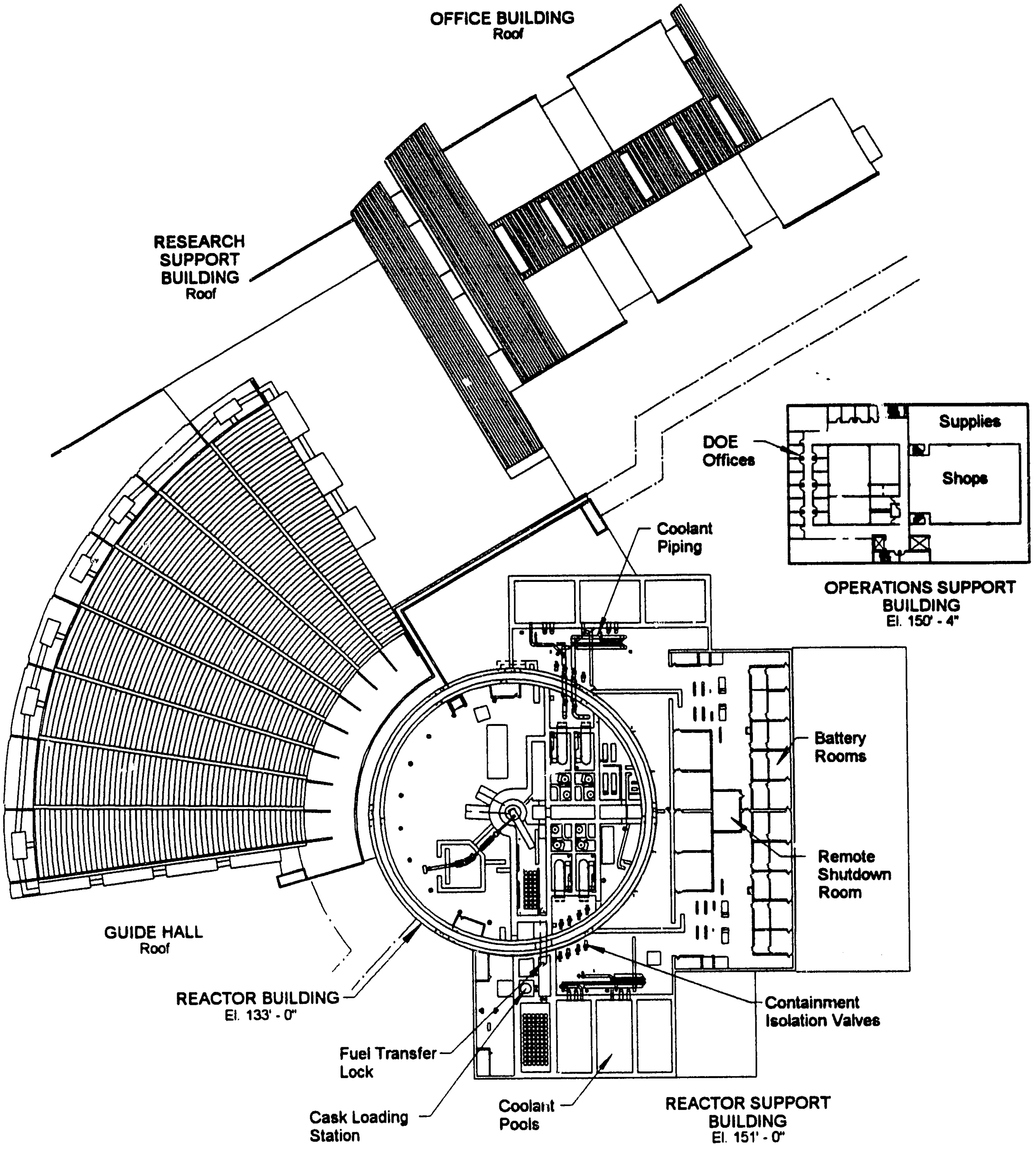
Floor plan of the main building complex 6 m above reactor midplane.

The illustration on the facing page shows the spent fuel pools, the heat exchanger pools and other reactor coolant loop equipment, the heat transfer basins adjacent to the reactor building, ventilation equipment, switchgear, the helium compressors for the cold source refrigerators, and additional offices and other facilities in the office and operations support areas.



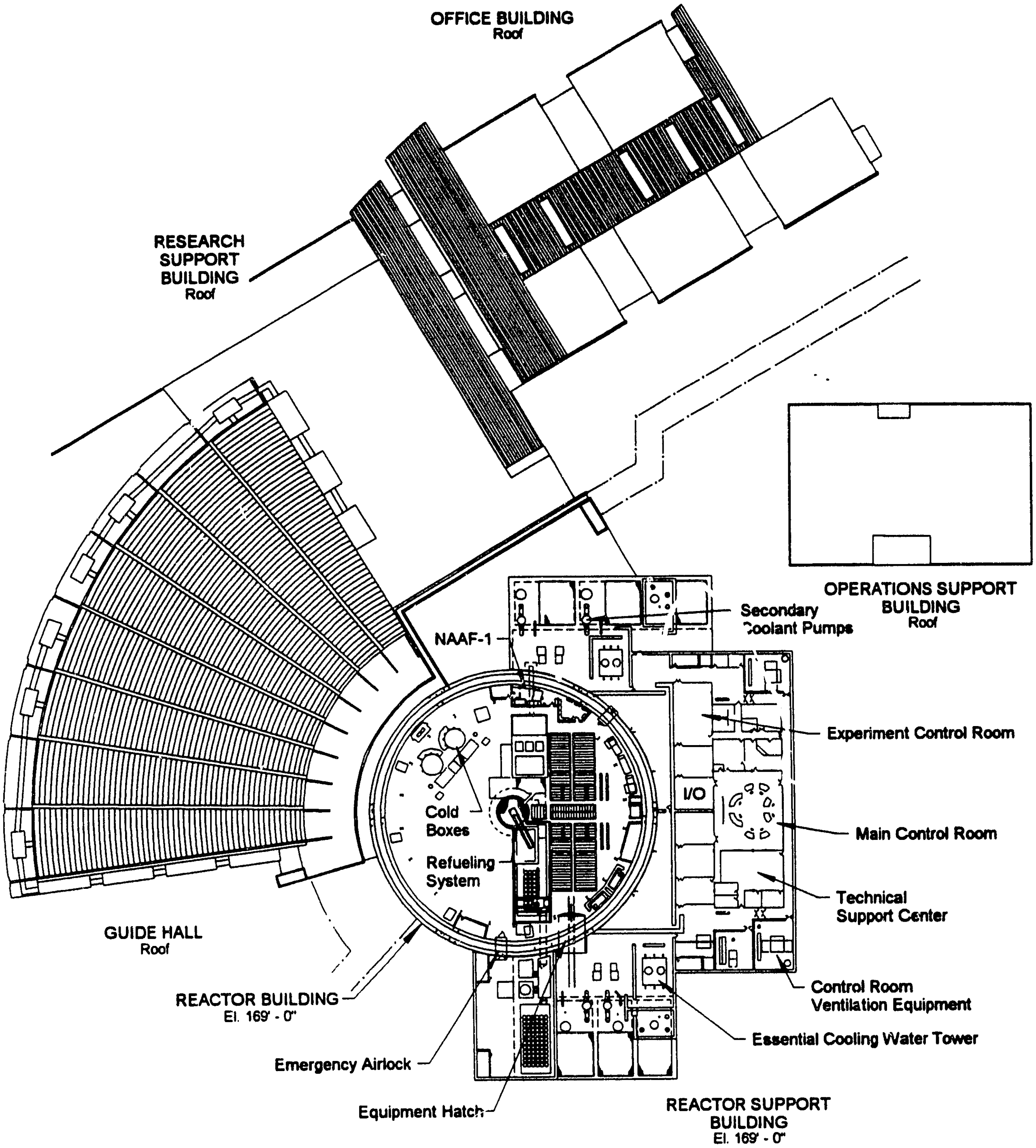
Floor plan of the main building complex 13 m above reactor midplane.

The illustration on the facing page shows the third floor of the reactor support building, housing cable spreading areas, batteries, switchgear and other equipment. The division of the two safety-classed chains of redundant facilities may be seen at this level. The wall dividing the two cable spreading areas is the division between the two safety trains. This separation is total and complete, including fluid handling, power and control systems.



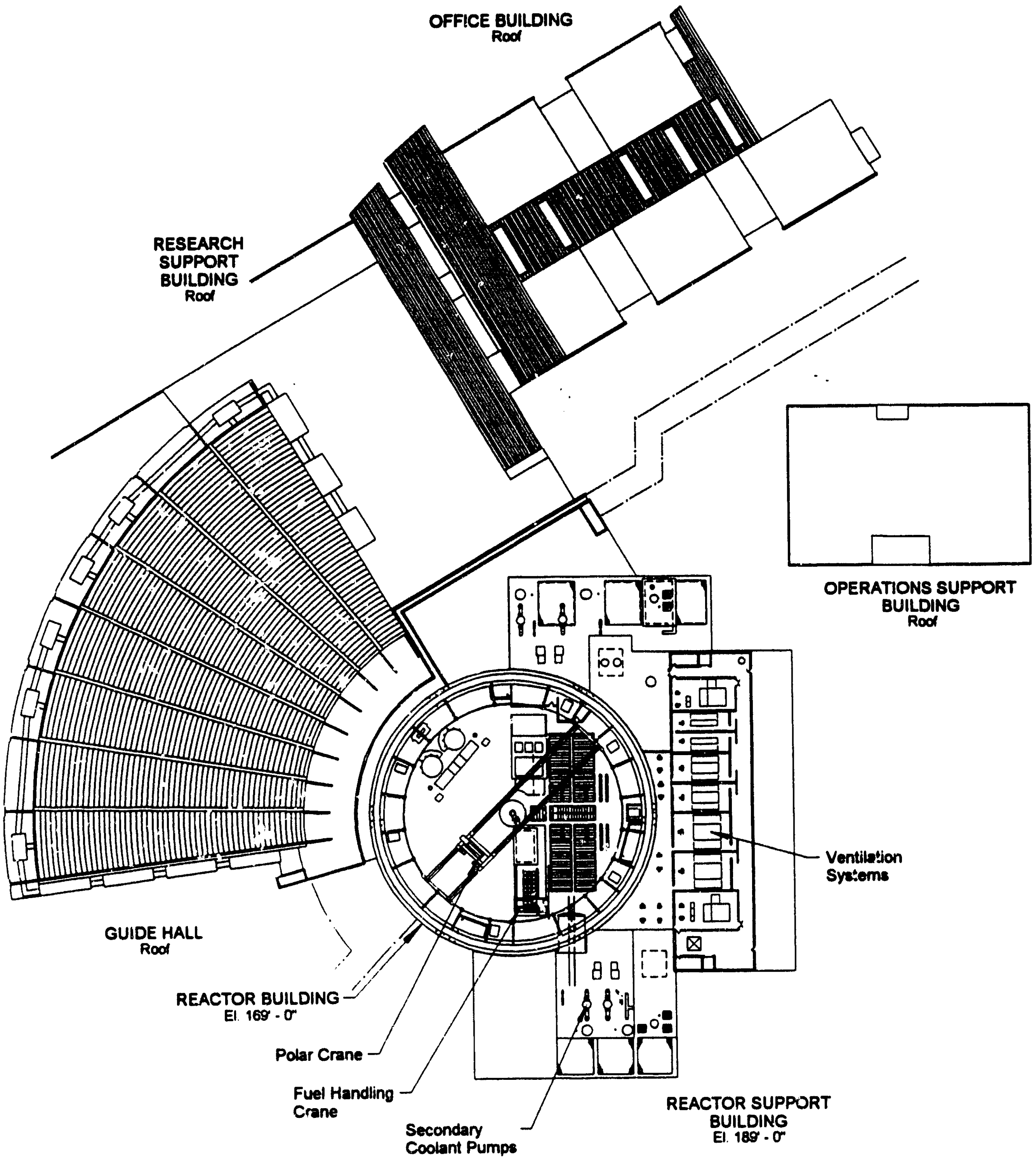
Floor plan of the main building complex 16 m above reactor midplane..

The illustration on the facing page shows the operating floor of the reactor building and the reactor support building. The pool covers for the heat exchange pools in the reactor building are visible, and the cold boxes serving the cold sources are also shown. Hot cells for servicing experiments are located above the pools. Rabbit tubes are provided to transport specimens into and out of the irradiation zones and to the laboratory areas. The main control room is visible in the reactor support building, along with an adjacent experiment control room. The control system will utilize the latest technology, including distributed digital control and fiber optic links.



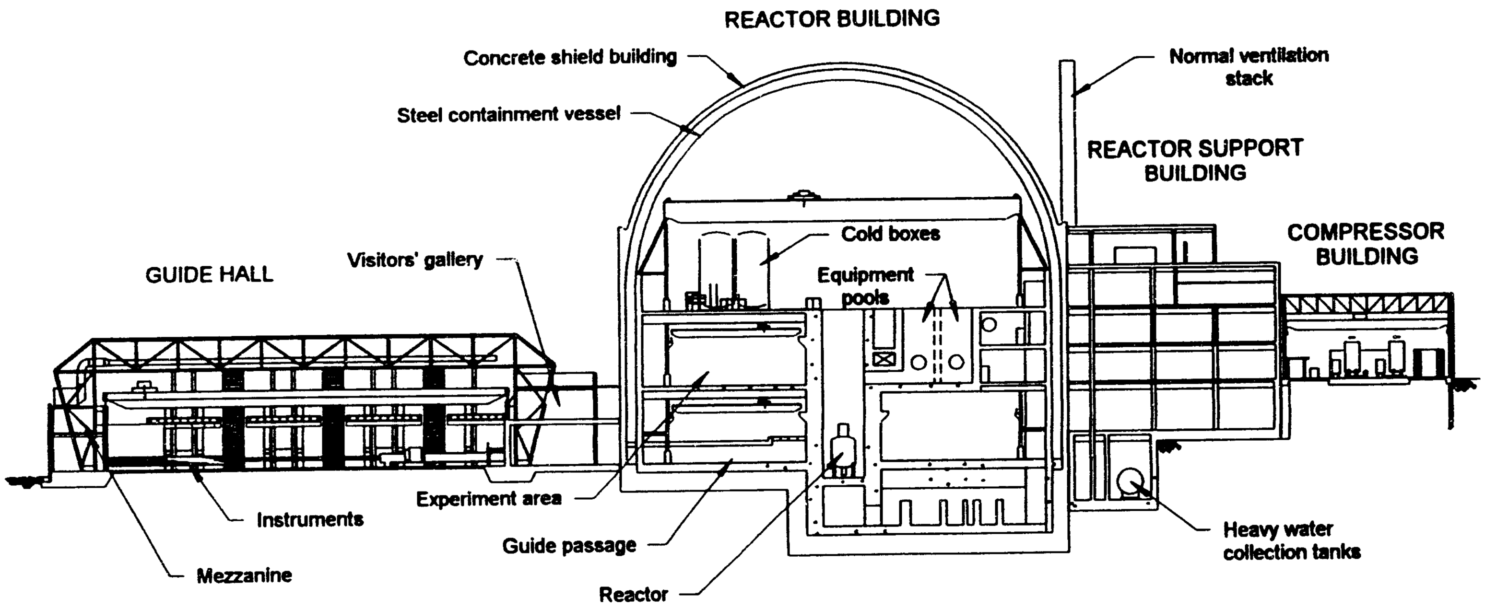
Floor plan of the main building complex 22 m above reactor midplane..

The illustration on the facing page shows the view from the top elevation of the facility and indicates the polar crane for servicing the equipment on the operating floor, ventilation equipment on the roof of the reactor support building, the roof of the guide hall and office building.



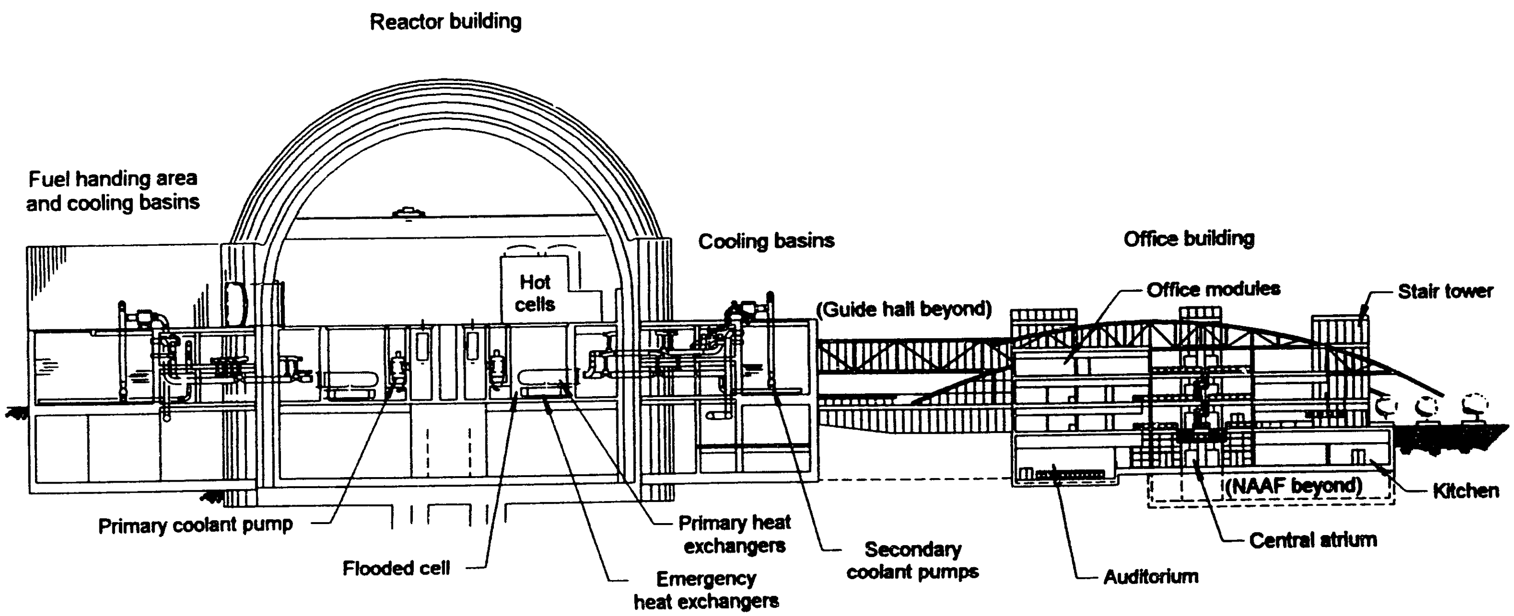
Floor plan of the main building complex 28 m above reactor midplane..

The illustration on the facing page is an elevation cross-section illustrating the relationship of the various floors and buildings. Note that there is a basement area under the reactor and reactor support buildings. The control rod drives for the reactor are located below the reactor in a subpile room. Tanks for draining the heavy water and other systems are also located in the basement of the reactor support building. At the preferred site, the natural grade and the subsurface rock slope from the compressor building area to the guide hall area, permitting the reactor building and reactor support building (safety-class structures) to be founded on rock. The guide hall is partially on rock, a requirement for a vibration free environment necessary for neutron scattering experiments.



Section through the guide hall, reactor building, reactor support building, and compressor building.

The illustration on the facing page is a cross section 90° from the previous cross-section illustration and shows the primary coolant heat exchangers, hot cells, fuel handling areas and coolant basins. The elevated basins and elevated, submerged primary coolant heat exchangers provide passive, natural circulation cooling for the reactor in the event of loss of electrical power.

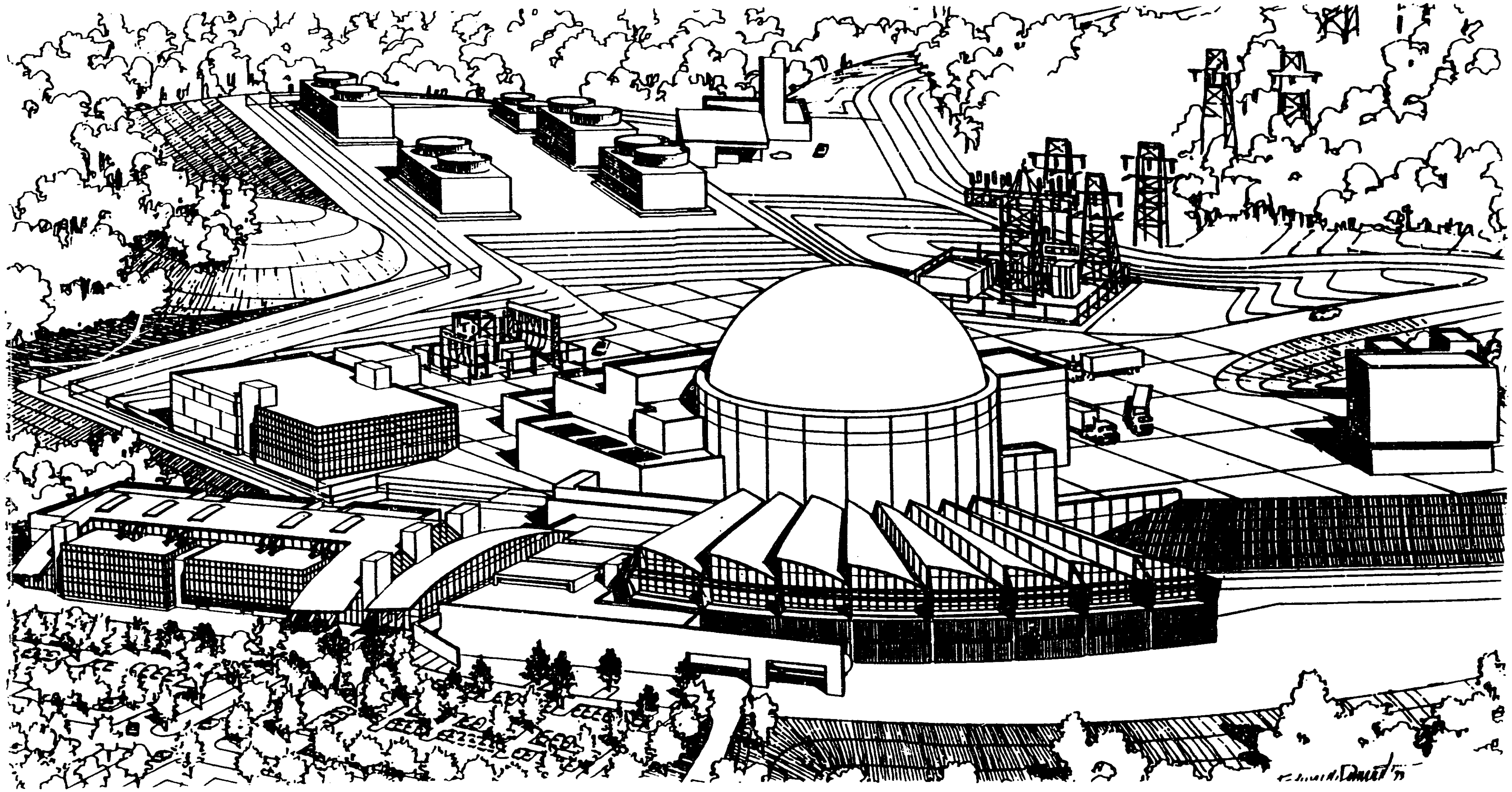


Section through the reactor building, secondary basin pools, and office building.

9. Summary

Two decades ago the primary use of neutron scattering was for research in solid-state physics. Today, while there is more solid-state research with neutrons than ever before, that field accounts for only about 10% of neutron scattering applications.

New applications in condensed-matter physics, polymers, colloids, biochemistry and other exciting and promising fields require facilities that can provide neutrons over a broad spectrum of wavelengths. The Advanced Neutron Source will provide the full capability required by the scientific community to support neutron scattering research and experimentation as well as isotope production and materials irradiation. From this facility and the activities it will support will come that most valuable of all possessions: new knowledge. From this new knowledge will come new products, new materials, new businesses and new technologies. It is an investment in America's future in a world where the right tools are essential to success in an increasingly competitive marketplace.



The Advanced Neutron Source (ANS) Facility

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