THE ADVANCED NEUTRON SOURCE--
DESIGNING TO MEET THE NEEDS
OF THE USER COMMUNITY

F. J. PERETZ
Advanced Neutron Source Project
Oak Ridge National Laboratory
P. O. Box 2009
Oak Ridge, Tennessee 37831-8218

THE ADVANCED NEUTRON SOURCE--DESIGNING TO MEET THE NEEDS OF THE USER COMMUNITY

F. J. PERETZ
Advanced Neutron Source Project
Oak Ridge National Laboratory
Oak Ridge, Tennessee, USA

Abstract

The Advanced Neutron Source (ANS) is to be a multipurpose neutron research center, constructed around a high-flux reactor now being designed at the Oak Ridge National Laboratory (ORNL). Its primary purpose is to place the United States in the forefront of neutron scattering in the twenty-first century. Other research programs include nuclear and fundamental physics, isotope production, materials irradiation, and analytical chemistry. The ANS will be a unique and invaluable research tool because of the unprecedented neutron flux available from the high-intensity research reactor. But this reactor would be ineffective without world-class research facilities that allow the fullest utilization of the available neutrons. And, in turn, those research facilities will not produce new and exciting science without a broad population of users from all parts of the nation and the world, placed in a stimulating environment in which experiments can be effectively conducted and in which scientific exchange is encouraged. This paper discusses the measures being taken to ensure that the design of the ANS focuses not only on the reactor, but on providing the experiment and user support facilities needed to allow its effective use.

---

1. INTRODUCTION

The Advanced Neutron Source (ANS) is to be a multipurpose neutron research center, constructed around a high-flux reactor now being designed at the Oak Ridge National Laboratory (ORNL). Its primary purpose is to return the United States to the forefront of neutron scattering in the twenty-first century. It will provide state-of-the-art facilities for nuclear and fundamental physics research using neutron beams ranging from thermal to "ultra-cold" energies and specialized cold neutron beam facilities for analytical chemistry applications. Exceptional thermal flux irradiation facilities will be available for activation analysis and isotope production, with low fast neutron and gamma contamination levels. Although spatially limited, extremely high flux facilities will be available for epithermal and fast neutron irradiations, supporting structural materials irradiation programs and the production of californium, einsteinium, and other transuranic isotopes. The ANS is to be a national user's facility, catering to researchers from throughout the United States and the world.

Prepared by the OAK RIDGE NATIONAL LABORATORY, Oak Ridge, TN 37831; operated by MARTIN MARIETTA ENERGY SYSTEMS, INC., for the U.S. DEPARTMENT OF ENERGY under Contract No. DE-AC05-84OR21400.

Often, in designing such a facility, so much attention is given to the reactor itself that the research facilities do not allow the fullest use of the facility. Therefore, this paper addresses those early planning and design efforts that address the needs of the users, both in terms of experiment facilities and of the support facilities and programs for the users themselves. But first, an overall description of the reactor and facilities must be given.

The ANS reactor will be a compact, 300-MW, heavy-water-cooled, moderated and reflected reactor fueled with enriched uranium. Innovative arrangements of coolant and fuel elements will allow the production of a thermal neutron flux approaching 10^{20} $m^{-2}{\cdot}s^{-1}$ in the large heavy water reflector. Two annular fuel elements are provided, each with hundreds of involute-shaped fuel plates. The lower element has an outer radius smaller than the inner radius of the upper element (Fig. 1). Separate, parallel coolant paths lead into each element, reducing the effective heated length of the core. This allows a relatively thin fuel zone that results in a high efficiency for neutron leakage into the reflector while increasing the amount of heat that can be removed from the core. Control rods are located in the central hole of the core, minimizing their impact on the flux in the reflector. Pressurized-heavy-water coolant flows up through a core pressure boundary tube located just outside the fuel; no flow reversal is necessary in the transition to natural circulation for long-term decay heat removal. Two liquid deuterium cold sources are located in the reflector, each feeding seven horizontal cold beam guides and a single-slant, very-cold neutron (VCN) guide. A graphite hot source located at the outer perimeter of the reflector feeds two beam tubes. Thermal beams include six tangential beam tubes, one through tube, and a radial supermirror guide.

Positions for fast neutron materials irradiation samples, including five instrumented capsules, are provided just inside the upper, wider fuel element. Positions for production of californium and einsteinium are located just outside the lower fuel element. Both are cooled by the pressurized-heavy-water coolant. Thermal irradiation facilities include static irradiation tubes and both hydraulic and pneumatic rabbit facilities. Regions near the outside of the reflector tank provide thermal fluxes in excess of $5{\cdot}10^{20}$ $m^{-2}{\cdot}s^{-1}$, with very low fast flux contamination and relatively low gamma heating rates. A single hydraulic rabbit tube located near the core pressure boundary tube provides a high epithermal component, and slant tubes allow irradiation of materials capsules in a similar flux region.

The ANS is designed around four main, interconnected structures (Fig. 2). The central reactor building is a cylindrical structure with a diameter of 60 m. This provides ample space for beams around the reactor shield structure located in the center. An attached guide hall, which provides experiment space along the horizontal cold guides, is a wedge-shaped structure with radial-segment bridge cranes moving across the guides. Reactor equipment, including the primary pumps and heat exchangers, is located in the reactor support building. An office building provides space and laboratories for users and for certain reactor staff members.

The elevations around the reactor pool are seen in Fig. 3. The ground floor is dedicated to beam use. The second floor (Fig. 4) is used by a variety of experimenters and is partially interrupted by the spent fuel pool and pipe chase. Preliminary concepts for beam facilities include the two VCN guides and a single slant cold guide for depth profiling work. One of the two VCN guides feeds a "neutron turbine" to provide ultra-cold neutrons, which are transmitted to a number of stations surrounding the turbine. The other may be used

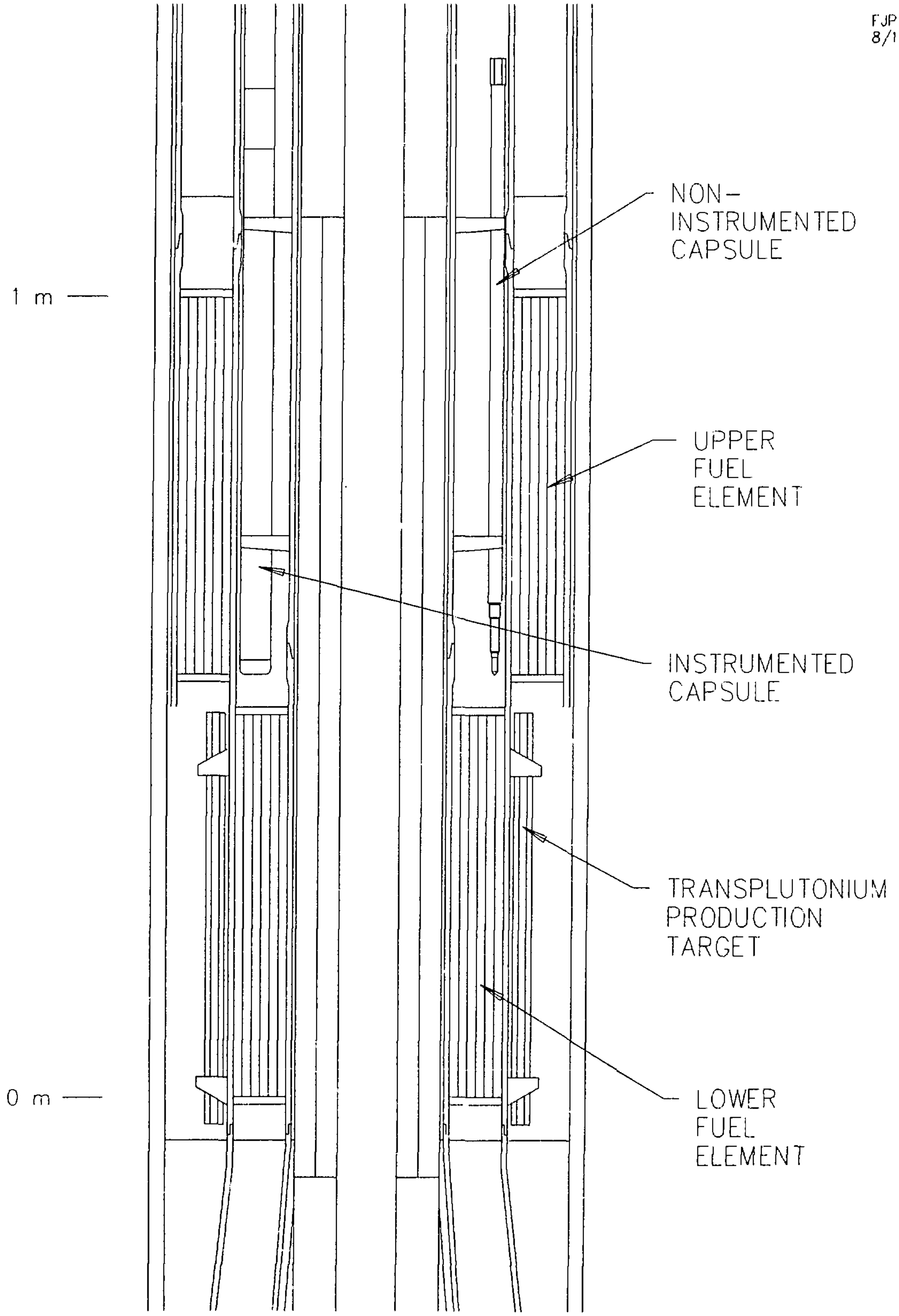

Fig. 1. ANS core and central irradiation facilities.

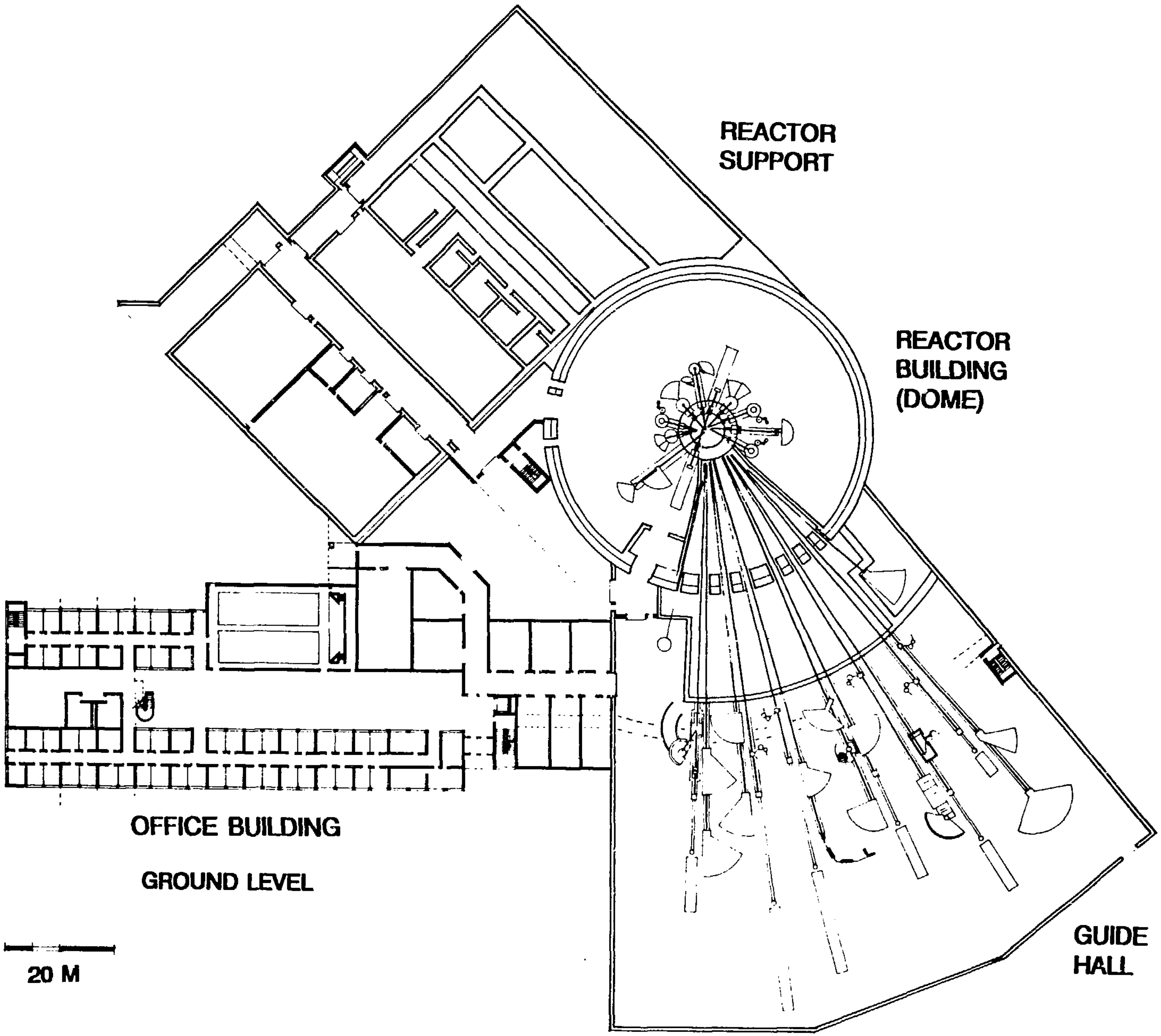

Fig. 2. Ground floor plan of the ANS.

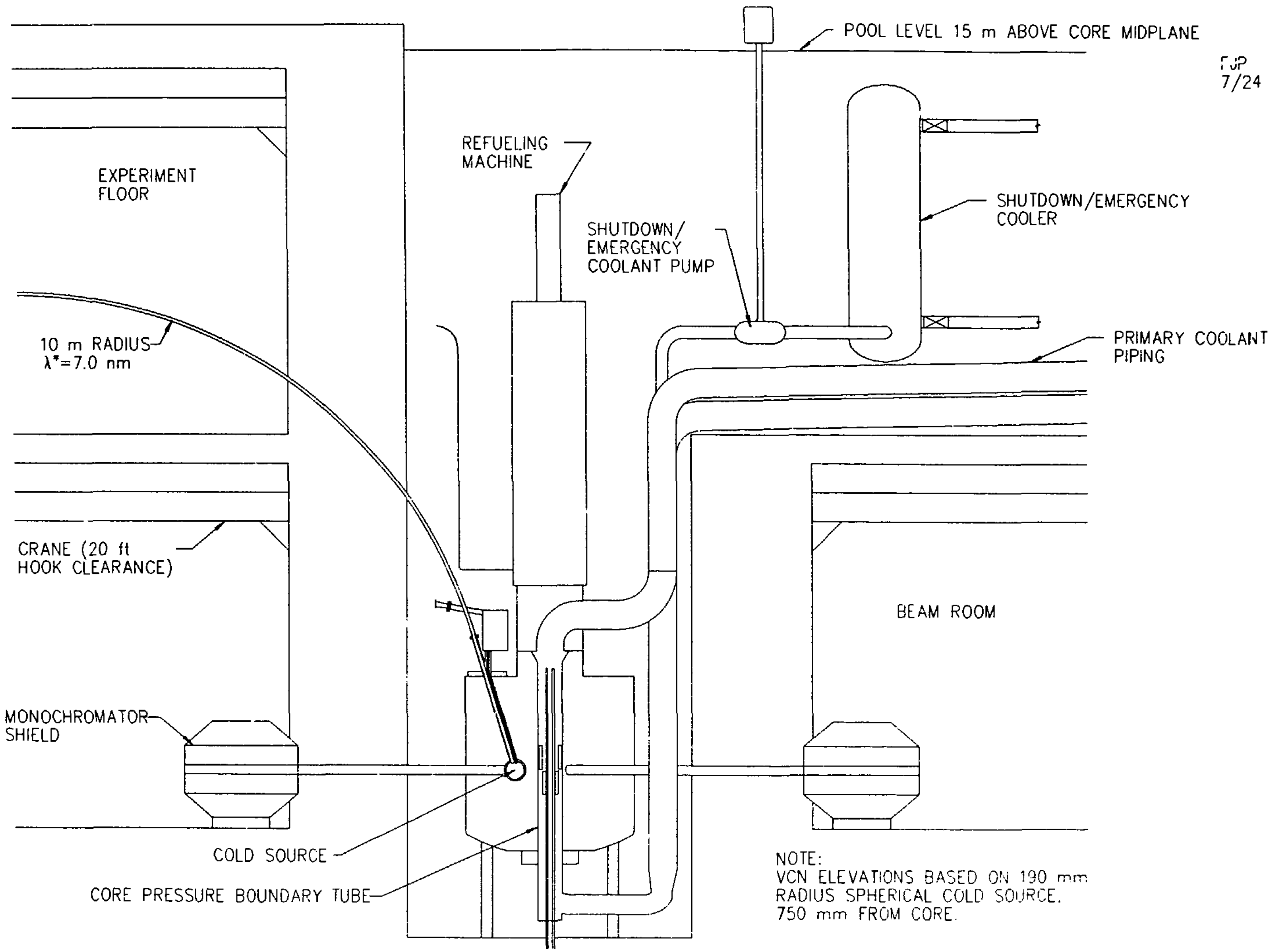

Fig. 3. Section of ANS reactor pool.

1340

FJP
6/9

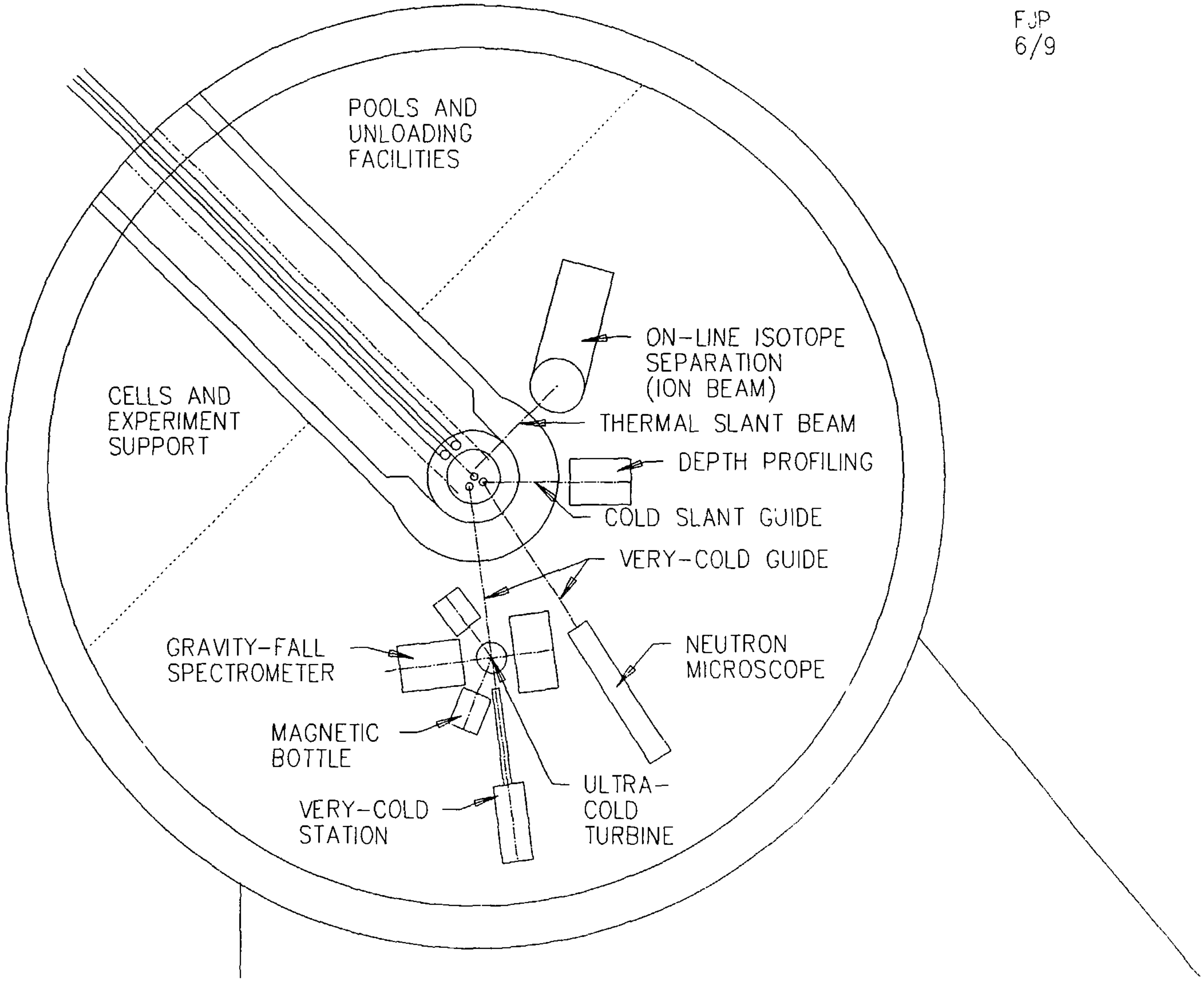

Fig. 4. Plan view of second floor experiment areas.

directly in the very-cold range, for example in neutron optics work. Other portions of the second floor are occupied by the lower structures of the refueling machinery, including cells for removing, segmenting, and packaging of irradiation capsules. Rabbit tube stations and gas and instrument facilities for irradiation facilities are also located on the second floor. The high bay floor is used for refueling and maintenance of the reactor.

2. DEFINING THE USERS

The ANS will serve as a focal point for neutron beam research both in the United States and internationally. More than 1000 users are expected annually, with the typical user being a university, government, or industrial researcher who comes to the ANS for about two weeks to run an experiment, then returns to his own laboratory to analyze data and publish results.

The first step in designing such a facility to meet the needs of the users is, obviously, to establish who the users are and what needs they have. Early in the ANS project, a survey was made of plans for new or upgraded facilities throughout the world.[1] This survey was judged to be an excellent approach to examine other opinions as to where priorities of users at other sites were being placed. It also offered a means of placing the ANS into a more global perspective and assessing what objectives are appropriate for the ANS and what needs are already being met at other locations. Workshops were held with various user communities, such as the neutron scattering community[2,3] and the users of californium isotopes.[4] Representatives of many of the user communities have been working at ORNL for many years, and representatives from these researchers were recruited for participation on the ANS design teams. Not only were these representatives solicited for input into routine design decisions, but they were, in turn, urged to contact coworkers at other sites. In several cases, questionnaires were given wide distribution in an attempt to broaden the input into the facility design. As the project continues to mature, regular newsletters are being produced, again soliciting input on project priorities and other design matters.

A more formal procedure for polling the user communities and obtaining the appropriate balance of emphasis for the ANS is the formation of the National Steering Committee for an Advanced Neutron Source (NSCANS). Participation on this steering committee was carefully apportioned to ensure balanced membership from the primary disciplines involved in beam research and the various communities interested in the use of irradiation facilities. It was also balanced between university, government, and industrial researchers. Regular meetings of the executive and full committee provide review and overall guidance on the ANS design from a user's perspective; subcommittee meetings of the individual disciplines offer the potential for more focused discussions. Membership on NSCANS is now being rotated to ensure that guidance is not limited to the opinions of a small group.

3. DESIGNING FOR THE USER COMMUNITIES

The general requirements for a research reactor such as the ANS call for two distinct populations on the site, each with its own procedures and obligations. The first is the reactor operations staff, which is trusted with the responsibility of ensuring that the reactor is operated safely and that no radioactive releases occur during either routine long-term operation or any upset, and which is responsible for both the well being of others at ORNL and of the general public. The second is the outside user community, which requires open access to research instruments and supporting laboratory, office, and computing facilities with on-site safety training programs commensurate with visits as short as a few days.

The design of the ANS addresses the basic needs of these two populations by zoning the facility into research and operations areas. The guide hall and office/laboratory buildings are accessible to users with minimal restrictions. The ground floor of the reactor building is also readily accessible, with personnel training and monitoring levels as appropriate for entering reactor containment. The high bay of the reactor building and the entire reactor support building (including the reactor control room) are designated as operating areas, and access is restricted to the operations staff. Here, greater levels of training, security, and monitoring are applied to limit the possibility of a reactor incident or a release of contamination. All reactor equipment likely to become significantly activated or contaminated (with the exception of beam tube assemblies and the small activity present in research samples) is located in the operations areas. The second floor of the reactor building, including facilities associated with irradiation experiments, is split between the two groups. Part of the second floor is used for nuclear and fundamental physics and analytical chemistry applications, using bent guides or slant beams; the other part is associated with the operations and handling of irradiation capsules and rabbits. In the latter case, the actual loading and handling of capsules and rabbits is conducted by the operations staff. Control of irradiation capsules and rabbits is closely supervised by the operations staff, in accordance with preapproved procedures. At the juncture of the office, guide hall, and reactor buildings is a focal point area where incoming guests can obtain badges and directions to the appropriate facilities. It will also be used as an information center, so that users will be provided with ample data on reactor operation and will have no need for access to the control room.

The design activities for experiments are again split along the lines of beam instruments and irradiation facilities. The primary purpose of the ANS is neutron scattering, and thus the facility is optimized for beam work. The ground floor beam room totally encircles the reactor, with the exception of the pool needed to pass the cold guides into the guide hall. Every attempt is also being made to provide space on the second floor to meet all needs, spatial and otherwise, for beam research applications without precluding irradiation facilities. The guide hall is a wedge-shaped structure, rather than a rectangle, to allow an open layout of instruments without limiting the useful length of any guide as a result of that guide meeting a side wall. The overall layout of the main complex limits the arc of the reactor building taken up by the support and office buildings, allowing for the addition of further guide hall space in a direction counterclockwise from the initial hall; this may be of particular interest should the development of supermirror technology allow the efficient transmission of thermal neutron beams, eliminating much of the crowding around the shield wall.

Designs for beam transport systems must balance flexibility over the life of the facility against unusual needs of specific experiments. To the greatest extent practical, standard beam-instrument interfaces will be used. Even when special beam interfaces are required, these will be designed to be replaceable with a standard plug. Straight neutron guides will generally be used rather than curved guides, to avoid incorporating a wavelength filter that could not easily be altered. Provisions for filters will be accommodated in the beam-instrument interface. The ANS will be used to extend neutron-scattering techniques into new subject areas, including problems where the effects being studied are very small or where only very small samples can be prepared. These needs will be met by providing a mix of the very best classical instruments, having the highest possible intensity, together with instruments that push the state-of-the-art into regions of uniquely high resolution. Specialty instruments, such as nuclear physics stations, will be designed for complete removal and replacement. Handling facilities will be designed to allow replacement of any instrument while adjacent stations are in operation.

Likewise, irradiation facilities will be designed so that positions of fast, high-epithermal, and thermal spectrum can be made available to all users. Irradiation capsules will be designed to allow instrumentation and gas lines to the extent that the integrity of the primary coolant boundary is not compromised. Facilities not only include the irradiation positions themselves, but also target handling cells (including cask loading facilities), pneumatic and hydraulic rabbit tube unloading stations, and instrumented capsule control stations. Supporting laboratory space will also be provided.

Finally, the facility design must accommodate the needs of the users themselves. Estimates are being made of desirable office and laboratory space, based on experience at successful European and American centers. It has been estimated[5] that space and facilities should be provided for six persons, on the site, for each beam instrument. A central data collection and communication center is also planned, aiding the user in transporting data to his home location and allowing communication and collaboration with colleagues during an experiment. An organizational structure is being developed in which permanent staff will be assigned to groups of instruments, ensuring support for outside users in setting up and operating experiments. The office building is designed with a central open area, encouraging free discussions between the occupants. Researchers will also be able to take advantage of research teams and other facilities located at ORNL, including libraries, supercomputer facilities, and the nearby Holifield Heavy Ion Research Facilities (HHIRF). A number of general personnel support facilities will be located between the HHIRF and the ANS, creating a large users complex on the east end of ORNL.

4. CONCLUSION

The ANS will be a unique and invaluable research tool because of the unprecedented neutron flux available from the high-intensity research reactor. But this reactor would be ineffective without world-class research facilities that allow the fullest utilization of the available neutrons. And, in turn, those research facilities will not produce new and exciting science without a broad population of users from all parts of the world, placed in a stimulating environment in which experiments can be effectively conducted and in which scientific exchange is encouraged. The design of the ANS focuses not only on the reactor, but on providing the experiment and user support facilities needed to ensure its effective use.

5. REFERENCES

1. MOON, R. M., "A review of current and proposed reactor upgrades", Proc. Neutron Scattering in the 'Nineties, IAEA, Julich, (January 1985) 119-134.
2. Scientific Opportunities with Advanced Facilities for Neutron Scattering, Shelter Island Workshop, CONF-8410256 (1984).
3. Proceedings of the Workshop on Instrumentation for the Advanced High-Flux Reactor, CONF-8405192 (1984).
4. Proceedings of the Californium-252 Workshop, presented by Oak Ridge National Laboratory (April 13-14, 1988).
5. HAYTER, J. B., personal communication (February 1989).