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ADVANCED NEUTRON SOURCE OPERATING PHILOSOPHY

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ABSTRACT

An operating philosophy and operations cost estimate were prepared to support the Conceptual Design Report for the Advanced Neutron Source (ANS), a new research reactor planned for the Oak Ridge National Laboratory (ORNL). The operating philosophy was part of the initial effort of the ANS Human Factors Program, was integrated into the conceptual design, and addressed operational issues such as

- remote vs local operation,
- control room layout and responsibility issues,
- role of the operator,
- simulation and training,
- staffing levels, and
- plant computer systems.

This paper will report on the overall plans and purpose for the operations work, the results of the work done for conceptual design, and plans for future effort.

I. INTRODUCTION

The Advanced Neutron Source (ANS) is a new basic and applied research facility that is based on a 330-MW, steady-state research reactor that will provide neutron beams for measurements and experiments in the fields of materials science and engineering, biology, chemistry, materials analysis, and nuclear science. The useful neutron flux for these experiments will be at least five times more than is available at the world's best existing facility, the Institut Laue-Langevin (ILL) in Grenoble, France. In addition, ANS will provide irradiation capabilities for the production of radioisotopes for medical applications, research, and industry. Facilities for materials irradiation testing will also be furnished. These irradiation facilities will match or exceed the capabilities of the existing High Flux Isotope Reactor (HFIR), which has been operated at the Oak Ridge National Laboratory (ORNL) since 1965. The ANS reactor is heavy-water-cooled, moderated, and reflected and includes cooling systems with many passive safety features that are similar in concept to the advanced light-water reactors (ALWRs) currently being designed for commercial power generation.

Applying human factors methodologies to nuclear facility designs is distinctive in that there are many regulatory requirements which *must* be met in the design. Several of these have to do with the training and qualification of operators, while others deal more with the physical parameters of the facility. These regulations furnish several constraints within which one must apply human factors methodologies. The application of human factors to this facility is unique because of the extra demands on operators in the main control complex. The ANS will have both a cryogenics facility and a detritiation facility, for which supervisory control from the main control room will be provided. The refueling operation will be automated to a degree determined from allocation of function decisions and will also be controlled from the main control room. Thus, in addition to the many human factors requirements that must be met at typical nuclear facilities, there will be new conditions which must be considered at the ANS facility. It is a challenge to propose methodologies for analyzing this advanced facility which comply with regulations and also address the special needs of a different type of design. Incorporating human factors into the conceptual design of the ANS will help to eliminate redesign and retrofit later on in the life of the project.

II. PURPOSE OF THE OPERATIONS WORK

The goal of making the ANS a "user facility" helped to shape the effort put forth for operations at a very early phase of the project. The operating philosophy and cost estimate information is compiled in the basis for operations portion of the Conceptual Design Report. The fivefold purpose of the operations document is to

1. survey current thinking on design,
2. provide input to the design process,
3. identify any discrepancies in thinking,
4. serve as a precursor for design goals, and

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5. create a cost estimate from appropriate cost bases for both steady-state operation and the first full year's operation.

The iterative nature of design will necessitate an iterative operating philosophy as well, with the operational basis becoming more detailed as the design itself becomes more detailed. The basis for operations will both give and receive input relating to the other formal human factors engineering activities and to activities connected with other less formal but equally human-centered design and analysis activities. An overview of the initial operational work may be found in the "Conceptual Design Report Summary."[1]

III. METHODOLOGY

A. Operating Philosophy

Both HFIR operations personnel and ANS design team members were consulted for information relating to ANS operations. By using a "lessons learned" approach from the HFIR facility and by gaining insight into the future vision for the ANS design, it was envisioned that both a feasible and a forward-thinking operating philosophy could be developed. Issues that have yet to be resolved were gathered from ANS design team members. Problems and/or issues that have been encountered in HFIR operations were identified for possible application to the ANS. Pertinent literature was consulted for input into solving problems. Discussions of various discrepancies and proposed areas for future study were included.

B. Cost Estimate and Staffing Levels

The HFIR facility at ORNL was used as the starting point for ANS operations cost information. To estimate costing rates for various types of personnel used at a reactor facility, the HFIR operating costs for fiscal year (FY) 1992 were divided by the number of personnel in each area. This rate was then applied to the numbers of personnel estimated for the ANS facility to obtain costs for staffing. Current ORNL costing rates per person were used for craft personnel within the maintenance organization and also for ANS employees in Research Operations. Operating cost estimate information from the Atomic Vapor Laser Isotope Separation (AVLIS) project was also consulted for costing methodology.

The basis for projecting staffing levels at ANS was staffing at the HFIR facility. Several of the personnel experienced in HFIR operations, training, maintenance, and other areas of work were consulted to help estimate the staff needed for the new facility. A computerized data base for space allocation maintained by the ANS project was also consulted. Input to this data base was derived from task-analysis-based questionnaires completed by HFIR personnel. The data obtained from HFIR were compared with staff levels at other nuclear facilities, such as the High Flux Beam Reactor (HFBR), the University of Missouri Research Reactor (MURR), the Fast Flux Test Facility (FFTF), the Advanced Test Reactor (ATR), and ILL. Those levels are listed in Table 1. Research Reactors Division (RRD) personnel at ORNL considered FFTF to be the closest comparison to ANS in terms of function, regulatory requirements, and modernity. FFTF has approximately 200 maintenance personnel and 800 total staff, not including safety staff. The estimates made for reactor technology personnel especially reflect this comparison, although the numbers are not as large as those at FFTF.

Table 1—Staffing Levels at Nuclear Facilities

Facility	Total Staff
FFTF	~800[a]
ANS	557
ILL	486[b]
HFIR	214[c]
ATR	186[d]
MURR	151.5[e]
HFBR	139[f]

[a]Basis for comparison with FFTF is information obtained through HFIR's membership in the Association for Excellence in Reactor Operations. Number does not include safety personnel.
[b]From the 1987 annual report.
[c]Operations staff plus extra maintenance.
[d]Rough estimate from conversation with ATR operations personnel. Actual number may be higher than the figure shown.
[e]From 1991 annual report.
[f]Scientific/professional plus other technical.

IV. RESULTS

A. Philosophical Issues

1. *Training.* The level of training at ANS is planned to be higher than that presently conducted at the HFIR facility because of increasing regulatory requirements. Currently, HFIR Operations and Reactor Technology personnel spend 20% of their time in training. If the training level is increased at ANS, even more care must be given to the placement and scheduling of training activities. The locations of the simulator and mock-up areas are of prime concern. The feasibility of conducting some types of training away from the ANS site is also being explored.

2. *Simulator.* The simulator at the ANS facility will have a greater scope than most simulators because of the inclusion of the auxiliary operations. It will provide representation of all main control room operations, including reactor operations, detritiation facility operations, irradiation facility interface operations, cold source operations, and cryogenic facility operations. Consideration is being given to the inclusion of the shutdown control station as part of the simulator. The simulator will be used for both training and engineering purposes.

3. *Mock-up.* The ANS reactor will utilize a full-scale working mock-up for fitting components, training operators, evaluating handling methods, and testing the refueling machines. Many components inside the reflector vessel require substantial room for clearance and will become activated due to ANS operations; thus, rehearsal of handling methods is crucial. Beam tube and cold source replacement rehearsals will also be included in the utilization of the mock-up.

Materials irradiation personnel have requested a staging area near the reactor pool where a mock-up of the central device holding the experiment can be placed. This would be used to "trial-fit" experiments during the cycle before they will be performed or during shutdown. This mock-up is envisioned as being somewhere in the high-bay area of the Reactor Building.

HFIR training personnel have stressed the need to have a clean area for the reactor mock-up. A set of spare components and clean tools is essential for learning and investigating maintenance methods on the reactor. It would be desirable to have the mock-up located with the simulator in a building separate from the reactor building, preferably in the training center.

4. *Maintenance.* Several maintenance issues will require further study as the design progresses. Maintenance and calibration frequency, replacement of irradiated reactor components, personnel qualification, and other issues all need to be explored further.

5. *Plant computer systems.* A non-safety-related Plant Control and Data Acquisition System (PCDAS) is expected to handle most plant supervisory and control applications [including those for power and heating, ventilation, and air conditioning (HVAC) systems]. This system will provide man-machine interface equipment in the main control room and several local control rooms. A class 1-E qualified PCDAS (called 1EPCDAS) provides engineered safety feature actuation, and a class 1-E qualified Reactor Protection System (RPS) provides reactor shutdown. There will be a non-safety-related PCDAS and a 1-E safety-related PCDAS, as specified by regulatory requirements. The operator should see no difference in the displays of these two systems, even though their electrical configurations are independent. These control computer systems will be interconnected via qualified isolation devices to provide a highly integrated and efficient operator display.

The current thinking is that the plant data system will be such that any reactor operator can use the computer, but it will be restrictive so that only those with the correct code can make actual adjustments. There probably will be an overlay for each system controlled, and an override will be provided for some functions. One proposition is that the displays be prioritized so that the system will pop up the display needed or alarm the display needed.

The experiment systems network and the data-handling network will be two separate systems, but both will be connected to a plantwide communications backbone that is, in turn, connected to ORNL networks. ORNL networks can be accessed from other national laboratories. The data-handling system will use one type of hardware for each class of workstation. This network currently includes both high-end workstations, which contain equipment for viewing and working on computer-aided drafting (CAD) drawings, and low-end workstations, which consist of office-type personal computers. The mix of workstations to be included will be determined as the design progresses. Various options regarding the host computer to be used are being considered. In making the equipment decision, consideration will be given to the operator actions that are required if failure occurs. The dual-host system requires only limited operator or user action to access the alternate system if the primary system fails. The basic server option has no redundant capabilities, whereas the fault-tolerant server implementation has a full backup should any component fail. No operator or user intervention will be needed because of a component failure, and the component will be replaced without having to shut down the system. Questions such as space requirements, staffing, organizational issues, and screen structure have not yet been addressed.

The data-handling system will contain information pertaining to the day-to-day operation of the ANS facility. That information includes a record of valve positions, CAD drawings, dose levels, training information, maintenance procedures, vendor documents, electronic mail, and all other plant business operations. Most work locations at the ANS will at least have "read files" for access to the system. The training and orientation required to use the data-handling system is expected to be minimal, with some instruction perhaps being done on-line. More consideration needs to be given to this issue.

The experiment systems network at ANS will provide the user with a window-type interface, complete with provisions for a mouse and a keyboard, to be similar in all hardware situations. Experiments will look like computer terminals to the network. The office complexes attached to the experimental stations will contain machines similar to the ones to which the experimenters are accustomed. Familiarity with the equipment will make for easier use of both the data-handling system and the experiment systems network. Currently, the thought is that the operator must be physically present at the experiment station to change the physical configuration of the instrument, but that data may be accessed and analyzed from any location.

The computer systems will also include a security system. The security system will control badge reader access systems and a Perimeter Intrusion Detection and Assessment System (PIDAS).

Research was done to determine the effect of the proposed comprehensive business software system on the total staffing level. Both academic literature and other facilities were consulted. The evidence suggests that business software would not reduce staffing levels but would increase productivity. Savings would therefore take the form of cost avoidance. Cost reductions can also be expected from operating in a less paper-driven environment. A substantial savings may be realized in reproduction costs, as has been evidenced by the Plant Information Management System (PIMS) at the Diablo Canyon Nuclear Power Plant.[2]

6. *Refueling*. Refueling is complicated by the D_2O/H_2O interface. The robotic trolley/toolhead interface connector has four interacting operations—fuel insertion and removal, hot cell operation, interim storage, and spent fuel storage. The operator interface consists of manipulating remotely operated equipment that is necessary because the radiation levels are higher than acceptable for human exposure. The robotic trolley will be programmed for fuel insertion and removal and spent fuel storage and transfer. There will be ten or more different and distinct toolheads for replacement of the following components: (1) neutron shield plug, (2) irradiation capsule assembly, (3) diverter elbow, (4) inner core pressure boundary tube, (5) upper fuel element with poison, (6) lower fuel element with poison, (7) core pressure boundary tube, (8) transuranic (TRU) rod assembly, (9) outer control rod assembly, (10) inner control rod assembly, and others, as needed. It is intended that the tool itself be simple, with several steps and/or tool changes required for each operation. This is in contrast to a complex tool that would do several tasks but would be more expensive to maintain.

The only human interfaces in these operations are those of starting up the equipment, monitoring the operation, and correcting any malfunctions. Human factors issues associated with manual control in the case of malfunction need further study. It is imperative that all of the tooling used to remove the fuel be recovered. The operator must follow the process visually because these operations are critical. The viewing will be made possible by the opportune placement of miniature cameras, which are able to give only a limited viewing angle but are the best option currently available. These robotic operations will be very interactive, consisting of a series of permissives between the program and the operator in which the operator must give an "okay" before certain steps are executed and may take over command from the program if needed. The particular method of correcting malfunctions so as to continue the operation is still to be determined.

The refueling hot cell operation will probably be quite extensive, consisting of any repair work that must be done on equipment. The work will be accomplished either by a large teleoperated servomanipulator or by a combination of master-slave local manipulators. The people who operate the hot cell may or may not do other fuel operations, depending on the level of involvement needed in a particular area. The refueling operator must be qualified, and a shift supervisor should be present to supervise the operation.

7. *Procedures display*. Regulatory philosophy on procedures display probably will evolve further in the time needed to complete the ANS. Currently, operators must have a hard copy of the procedure in hand for important operations, and each step must be signed off after completion. Consequently, it is not acceptable for much of the procedures display to be electronic. For example, reactor startup at HFIR is a lengthy procedure (more than 20 pages), and some checks must be done in the plant. Some procedures, however, such as those involving particular annunciators, are more suitable for electronic checklists. Operators generally have such procedures memorized, but they are supposed to look at the written documentation nonetheless. Most of these procedures do not require sign-off. Another option is a hand-held display that could be plugged in wherever needed to make a check-off. It is expected that at least some of the ANS procedures will be displayed and signed off electronically.

8. *Automation issues*. Function allocation decisions determine the degree of automation that will be required for the ANS facility. These decisions are typically made in formal design development meetings, and the degree of human involvement is often dictated by environmental constraints, government regulations, and the nature of detailed functions involved. Government regulations require that most control functions be allocated to equipment components. Human involvement is required to verify the operation of automatic controls and to intercede by performing the same or alternative functions if needed. The degree to which detailed control functions are variable affects allocation decisions. However, for control purposes that vary according to events and their effects on plant conditions, the trade-offs between equipment and humans must be appraised.[3] It is possible to allocate some functions to "joint cognitive systems," consisting of the operator and the automated equipment.

Trade-off decisions must be made for some control functions in order to allocate them appropriately to either equipment or humans. Design costs, reliability, and the effects of various allocations on the complete structure of personnel tasks must be considered. A method of function allocation for nuclear power plants is proposed by Price, Maisano, and Van Cott.[3] Results of this activity will affect how the staffing is structured at ANS and how many people are needed for operation.

An area of concern for the ANS facility is the "boredom factor" resulting from automation. The current expectation is that relatively few operator activities will be required during normal operation and even fewer critical actions during off-normal operation. Even at HFIR, operator activities have tended to be relatively nontaxing during normal operations. It is important to design job descriptions that utilize more fully the capabilities of operators. One suggestion is that plant simulators could be installed on the cathode-ray tubes (CRTs) in the control room. The reactor operator could practice various scenarios while on shift. The PCDAS would alert the operator to any problems. All sorts of regulatory concerns would have to be addressed if this method were employed. More study will be given to the automation-boredom correlation.

Another concern is the loss of the "big picture" of reactor operations caused by CRT controls. The large display in the main control room will help mitigate this problem, but control and display issues having to do with emergency procedures still need to be addressed. One possibility is that of using yes-no emergency operating procedures such as the nuclear power industry uses to deal with a great number of varying scenarios. These concerns need more study.

9. *Main control room layout.* The current layout for the main control room shows eight computer-type workstations. The senior reactor operator and the reactor operator occupy prominent positions in front of the three large display panels. The shift supervisor and the shift technical advisor have locations the farthest back from the screens, with the auxiliary operators facing outside in the side positions. Offices for the shift technical advisor, shift supervisor, operating engineers, and operations and technical support center personnel are located around the perimeter of the control room. There is only one badge reader for the security envelope surrounding the control room, and only authorized personnel can enter the area.

In the initial control room layout, the traffic pattern for the ANS staff required travel through a portion of the control room itself in order to access offices surrounding the room. Some concern was expressed about this setup because movement along the edges of the control room can distract the operators. HFIR personnel provided input for a modification of the original layout that minimizes traffic through the main control room; further modifications may be made in subsequent revisions. The orientation of the auxiliary operators' consoles is likely to be changed so that they face the display panels. A three-dimensional model of this control room is proposed for evaluation in FY 1993. Work on this three-dimensional model of the ANS main control complex is reported in another paper at this meeting.[4]

10. *Remote versus local control.* Most plant operations will be done remotely in the control room, if possible. According to operations personnel at HFIR, a means to rank the importance of controls is needed in the control room. Any control that is important in keeping the reactor running should be in the main control room. Controls needed intermittently, however, probably should be under local control. The latter include items such as the sumps, basin-level indicators, certain valves, and beam and water controls. It would be desirable to have a manual override for valves in nonradiological areas during operations so that if the switch failed in the main control room, the valve could be operated locally.

11. *Responsibility issues.* There needs to be clear documentation of the lines of responsibility for each person present in the main control room. For ANS, some disagreement still remains over the amount of experimental information that should be displayed in the main control room and the degree to which the reactor operator should be familiar with the experiments. A well-defined training program should be in place for the materials irradiation facility operator, with emphasis on the "big picture" of reactor operations. In addition, the delineation between the reactor operators and the auxiliary operators needs to be clearly specified. This will require more examination in the future.

Another area of concern is the number of extraneous people in the control room area. Thought needs to be given to which staff members will be given access to the shift supervisor's office.

Heavy water storage and transfer, detritiation, deuteration, and dedeuteration operations will be intermittent and will be controlled locally at locations yet to be determined. The processes deal with tritium in the primary coolant loop and the heavy water/light water exchanges associated with refueling. The detritiation facility operator will perform these operations if he or she is on duty when they are needed. One of the auxiliary operators probably will perform them if the detritiation controls are transferred to the main control room, as is foreseen to be the case on the off-shifts. More study needs to be done on the particulars of this process and on the interaction required with operators in the main control room.

12. *Materials irradiation.* It has been proposed that the materials irradiation facility control room be in the area of the main control room. The experiments in this area involve gas-containing capsules inside the reactor. If the pressure in the capsules increases above specific limits (levels that would damage an experiment), the reactor power can be reduced. If this mechanism fails to control the pressure, the reactor can be scrammed. Currently at the HFIR facility, some experimenters have the capacity to reduce reactor power automatically, and others send a request to the reactor operator to reduce the reactor power. Study is needed on how this will be accomplished at ANS.

Knowing the physical locations of the instruments is a major element in being qualified to perform materials irradiation duties. The current method of training for this position at HFIR is mainly on-the-job. Attention needs to be directed to how this training will be accomplished at ANS.

The interface of the irradiation experiments in the core with the refueling operation is another area that needs additional attention. The entire experimental device will have to be moved out of the reactor during refueling and be stored at some interim location. Typically, multiple experiments will be run simultaneously, although on different schedules. The method for the moving of these experiments under water or to a hot cell requires further study. Various methods, including a "dismantling hot cell" such as was used at the Oak Ridge Research Reactor, are being explored.

13. *Experiment stations.* The main control room will provide control and monitoring of utilities dealing with the reactor facility itself (for example, the cooling water, facility vacuum system, and inert gas). Experimenters will be responsible for setting up the utilities related to their experiments. For example, experimenters are responsible for their own experimental vacuum systems. The experiment station

should display reactor status parameters such as the power level and the time before refueling. There is no impact from the experiment stations on the reactor, however; each station is simply a passive recipient of neutrons. A personal computer at each experiment station will be connected to the experiment system computer network, which will store data in two 50-Mbyte optical juke boxes.

Automatic closure of the primary beam shutters whenever the reactor shuts down would be a desirable design feature. The reactor operator could have control of these primary shutters and open them when the reactor returns to safe operation. The secondary shutters would always be under the experimenter's control.

B. Staffing

1. *Overall staffing.* As noted in Section III.B, above, staffing levels for ANS were estimated on the basis of comparisons with personnel levels at the HFIR facility and information from other facilities in the Association for Excellence in Reactor Operations. A total staff of approximately 560 people was postulated. This number includes an estimate of almost 200 experimental support personnel (see Table 2). Reactor technology engineers are also estimated at a greater level than at HFIR. The estimate comes primarily from assuming system engineers for each of the plant systems, which is current practice in the nuclear industry. Maintenance staff estimates are based on HFIR historical data. The other personnel estimates are based on general factors known about similar facilities. A few staff areas will be discussed in more detail.

2. *Training.* More training personnel are required at ANS than at HFIR because of the greater complexity and size of ANS, plus the more rigid application of the many regulatory requirements. The addition of the senior reactor operator position, based on current nuclear industry practice, is also partially responsible for the increase in reactor operator, senior reactor operator, and shift supervisor instructors. The addition of the auxiliary operator position, commensurate with the design and function of the various ancillary processes at the ANS facility, also will result in an increase in the training staff. Instructors have to be provided to train and cross-train the auxiliary operators in the operation of the cryogenic facility, the detritiation facility, heavy water storage and transfer, the power switchyard breakers, and other designated plant systems. Emergency preparedness and records personnel also add to the total training staff. Instructors for technical staff and maintenance personnel were included, as well as simulator instructors.

3. *Main control room staffing.* The main control room staff includes the following positions: reactor operator, senior reactor operator, shift supervisor, shift technical advisor, and auxiliary operators to perform key functions. Either the shift supervisor or the senior reactor operator should be present in the control room at all times to direct and manage reactor and plant operations and coordinate various endeavors being carried out both on-site and off-site during normal plant operations and during plant emergencies. In addition, a shift technical advisor should be present on the ANS site at all times. Requirements for the positions of reactor operator, senior reactor operator, and shift technical advisor are delineated in DOE Order 5480.20. Further requirements may be forthcoming because of the unique design of the ANS facility. Operating engineers will also be available on each shift when required. All of these identified positions will have space set aside within the control room security envelope. Offices, conference room(s), files, and other support space will also be provided in this area.[5]

The main control room reactor staffing was based on a five-shift rotation, with 20% of the personnel time being spent in training. One more shift was then allowed for day operations and vacation relief. This is comparable to current HFIR practice. Two positions with unique application to the ANS control room will be discussed further—the auxiliary operator and the refueling operator.

Table 2—ANS Total Staffing Components
(in full-time equivalents)

Job Area	Staff	
REACTOR OPERATIONS		
Technical	8.0	
Operating Engineers	5.0	
Shift Supervisors	7.0	
Reactor Operators	19.0	
Sr. Reactor Operators	6.0	
Auxiliary Operators	14.0	
Shift Tech. Advisors	7.0	
Drafting Tech.	10.0	
Engineers (Reactor Tech.)	81.0	
Computer Support	5.5	
Detritiation Operators	3.0	
Subtotal		165.5
TRAINING	25.0	25.0
MAINTENANCE		
Craft	41.9	
Noncraft	18.0	
Subtotal		59.9
SECURITY	13.0	13.0
HEALTH PHYSICS	24.0	24.0
QUALITY ASSURANCE		
Quality Assurance	9.0	
Technical Compliance	9.0	
Subtotal		18.0
MGT. AND PLANNING	29.0	29.0
ADMINISTRATIVE SUPPORT	54.0	54.0
Subtotal (Nonresearch)		388.4
RESEARCH OPERATIONS		
Visitor Processing	4.0	
Scientific/Research	96.0	
Tech./Lab. Support	54.0	
Materials Irradiation	2.0	
Analytical Chemistry	13.0	
Subtotal (Research)		169.0
Total		557.4

4. *Auxiliary operator.* Auxiliary operators will monitor and operate designated plant equipment and systems throughout the plant from the main control room or from local area panels or control stations. Auxiliary operators will be fully trained, qualified, and certified for the equipment or systems to be monitored or operated. Auxiliary operators will have access to the control room when needed to perform designated plant operations such as

- detritiation facility monitoring and heavy water transfer;
- operation of power switchyard breakers (the auxiliary operator will perform this operation and/or coordinate it with the K-25 Site central control facility);
- cold source monitc.ing and control;
- experimental systems coordination between experimental areas (including the materials irradiation control room) and the main control room; and
- operation of designated plant systems (as indicated in each auxiliary operator's job description and certification).

The number of auxiliary operators to be situated concurrently in the main control room will be determined by the number of simultaneous operations being performed there. Auxiliary operators will be cross-trained, so that one can help the other if problems arise. At least one auxiliary operator will be in the control room on each shift during usual circumstances. This will require further study as the design of the ANS progresses.

The relationship between a reactor operator and an auxiliary operator will also require further study. At industrial reactor facilities, reactor operators "work their way up" from being auxiliary operators. ANS has unique auxiliary functions, so this system may not be desirable for the ANS facility. The degree to which reactor operators should know auxiliary operators' functions is also yet to be determined. The type of supervision and administration required for an auxiliary operator will also be unique. All of these types of managerial questions need to be addressed as the design of the ANS progresses.

5. *Refueling operator.* The refueling operator will be a reactor operator who will specialize in refueling duties during that cycle. This staff member can perform various reactor operator functions during the operation part of the fuel cycle. A total of three reactor operators per shift is proposed, as is the current practice at the HFIR facility.

6. *Detritiation facility operator.* The detritiation facility operator will perform heavy water upgrade and detritiation facility operations from a local control room. A facility shift supervisor will also be present in or close to the detritiation facility control room. Both persons will be on shift whenever the monitoring and operation of the facility need operator attention. Each person will be fully trained, qualified, and certified for the operation of this facility and will possess a defined minimum amount of operator performance experience. The shift supervisor must have been a senior operator with operations experience. The final requirements for each position will be decided later and defined in the ANS operator position descriptions. Two detritiation facility operators will be staffed in the detritiation facility control room on the day shift. The monitoring and control mode of the facility will be transferred to the main control room in the reactor support building during the off-shift. Maintenance will also be done during the off-shift.

7. *Research staff.* The research staff probably will consist primarily of two physicists and one technician per instrument for the 48 instrument stations. Additional staff are likely to be obtained from universities on an as-needed basis. Participating research teams will also be invited to build and staff certain instruments. These teams will consist of groups who design, build, and operate an instrument in return for access to ANS. As a user facility, ANS will probably have over 1000 users per year, with each group being on site for approximately one to two weeks. Accordingly, office space was allocated for approximately 60% more personnel than the base staff. At existing American neutron facilities, an average of five to six people are involved per experiment. In Europe, the number is closer to seven.

VI. FUTURE PLANS

The ANS human factors plan, another portion of the Conceptual Design Report, lists activities and level of effort for a number of human factors analyses. The ANS project is now in the advanced conceptual design phase. The issues identified in the first iteration of the basis for operations will be studied in further detail. The functional allocation process will be done at this stage, with initial attention being given to refueling and maintenance. This work will feed into the task analyses and job descriptions that will be done subsequently. The operating philosophy and staffing estimates will continue to be updated as more information becomes available and more issues are resolved.

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