ORNL/TM-11625

OAK RIDGE
NATIONAL
LABORATORY

MARTIN MARIETTA

# Plant Design Requirements



Advanced Neutron Source

OPERATED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

ORNL/TM-11625, 7/90

# ADVANCED NEUTRON SOURCE

# PLANT DESIGN REQUIREMENTS

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for the
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ORNL/TM-11625, 7/90

# ADVANCED NEUTRON SOURCE PLANT DESIGN REQUIREMENTS

## APPROVALS

C. D. West
ANS Project Director
Chairman, ANS Project Review Committee

7-27-90
Date

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# LIST OF ACRONYMS

| | |
|---|---|
| ALARA | As Low As Reasonably Achievable |
| ANS | Advanced Neutron Source |
| CPBT | Core Pressure Boundary Tube |
| DOE | Department of Energy |
| EAB | Exclusion Area Boundary |
| EIS | Environmental Impact Statement |
| ER | Environmental Report |
| FSAR | Final Safety Analysis Report |
| HFIR | High Flux Isotope Reactor |
| ILL | Institut Laue-Langevin |
| INZ | Immediate Notification Zone |
| LPZ | Low-Population Zone |
| NRC | Nuclear Regulatory Commission |
| NSCANS | National Steering Committee for the Advanced Neutron Source |
| ORNL | Oak Ridge National Laboratory |
| ORR | Oak Ridge Reservation |
| PDR | Plant Design Requirements |
| PMP | Project Management Plan |
| PRA | Probabilistic Risk Assessment |
| PSAR | Preliminary Safety Analysis Report |
| REDC | Radiochemical Engineering Development Center |
| QA | Quality Assurance |
| SDD | System Design Description |
| SEMP | Systems Engineering Management Plan |

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# PREFACE

This document provides the plant-level requirements for the design, construction, and operation of the Advanced Neutron Source (ANS). It is a "living document" and will be revised throughout the life of the project to reflect the current configuration of the ANS. The distribution of this document is being conducted in a controlled manner. Holders of controlled copies are to acknowledge receipt of the original issue and all revisions and are expected to keep the manual updated throughout the project. If a controlled copy is no longer needed, it shall be returned to the ANS Project Office.

Because of the large number of revisions that will be issued for this document, the following numbering scheme is being used for tables, figures, and references. The first two numbers are those of the two-digit section in which the cite first occurs. The third number is a sequential ordering within that section. For example, Table 4.1.2 is the second table in Sect. 4.1. This arrangement will minimize the extent to which tables, figures, and references are renumbered as the document is revised, while avoiding excessively long and cumbersome reference numbers.

## ABSTRACT

The Advanced Neutron Source (ANS) is a new, world class facility for research using hot, thermal, cold, and ultra-cold neutrons. At the heart of the facility is a 350-$MW_{th}$, heavy water cooled and moderated reactor. The reactor is housed in a central reactor building, with supporting equipment located in an adjoining reactor support building. An array of cold neutron guides fans out into a large guide hall, housing about 30 neutron research stations. Office, laboratory, and shop facilities are included to provide a complete users facility. The ANS is scheduled to begin operation at the Oak Ridge National Laboratory at the end of the decade.

This Plant Design Requirements document defines the plant-level requirements for the design, construction, and operation of the ANS. This document also defines and provides input to the individual System Design Description (SDD) documents. Together, this Plant Design Requirements document and the set of SDD documents will define and control the baseline configuration of the ANS.

# 1. SCOPE

## 1.1 INTRODUCTION

This Plant Design Requirements (PDR) document defines the plant-level requirements for the design, construction, and operation of the Advanced Neutron Source (ANS). This document also defines and provides input to the individual System Design Description (SDD) documents. Together, the PDR document and the SDD documents define and control the baseline configuration of the ANS.

The top-level requirements specified in this PDR include those developed to meet the ANS user community needs as defined by the National Steering Committee for the Advanced Neutron Source (NSCANS); those defined in Department of Energy (DOE) orders applicable to the design and construction of DOE-owned reactors; other federal and state agency regulations, standards, and guidelines; national codes and standards that are applicable to the ANS; and those specific requirements identified in the design, safety and environmental studies conducted as part of the ANS Project. The safety and environmental studies will be documented in the Preliminary Safety Analysis Report (PSAR), the Final Safety Analysis Report (FSAR), a Probabilistic Risk Assessment (PRA), the Environmental Report (ER), and the Environmental Impact Statement (EIS). This PDR follows the format outlined in NE F 1-2T.[1.1.1] The project organization and management structure is defined in the Project Management Plan (PMP),[1.1.2] the project quality assurance program is defined in the Quality Assurance Plan (QA Plan),[1.1.3] and other assessments and supporting documents are described in the Systems Engineering Management Plan (SEMP).[1.1.4]

## 1.2 PROJECT PURPOSE

The ANS will meet the recognized national need for an intense, steady-state, broad spectrum source of neutrons for research.[1.2.1-11] The ANS will provide the American scientific community with a crucial tool for cross-disciplinary 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 neutron-based research. The top-level technical objectives of the project are listed in Table 1.2.1.

## 1.3 PROJECT SCOPE

The ANS Project includes all aspects of the design and construction of the Advanced Neutron Source defined in the construction project data sheet 92-ORNL-KC(AF)-1, dated April 1990. The project includes (1) safety analyses and documentation to support funding requests and permitting; (2) environmental reports, assessments, and impact statements to support funding requests and permitting and; (3) research and development necessary to provide data for the safety analyses, environmental analyses, and design. All work elements within the project are defined by a work breakdown structure (Fig. 1.3.1).

The scope of the project has been defined through comprehensive interaction with all of the relevant scientific communities whose purposes may be served by the ANS. Contacts have been fostered by widespread discussion and dissemination of information about the project at national and international professional society meetings, by journal articles, by seminars, by both broad-based and focused newsletters, by mailed questionnaires, and by direct personal contacts within the neutron research community. The NSCANS has served as a clearinghouse for the information garnered and has acted as a review body, both directly and via special subcommittees.

The project will construct a neutron research laboratory based on a high-flux reactor that has a minimum unperturbed thermal flux in the reflector exceeding the best currently available in the world [unperturbed thermal flux of $1.5 \times 10^{19}$ $m^{-2} \cdot s^{-1}$ at the Institute Laue Langevin (ILL) High Flux Reactor and the High Flux Isotope Reactor (HFIR)] by at least a factor of 5. The reactor will also provide materials irradiation and transuranic isotope production capabilities that match or exceed the capabilities of the HFIR. Facilities for radioisotope production and for analytical chemistry will be accommodated in the reflector. Safe operation of the reactor and efficient utilization of the experimental facilities will be

Table 1.2.1. ANS Project technical objectives.

---

To design and construct the world's highest flux research reactor for neutron scattering

- Provide 5-to-10 times the flux of the best existing facilities

To provide isotope production facilities that are as good as, or better than, the HFIR

To provide materials irradiation facilities that are as good as, or better than, the HFIR

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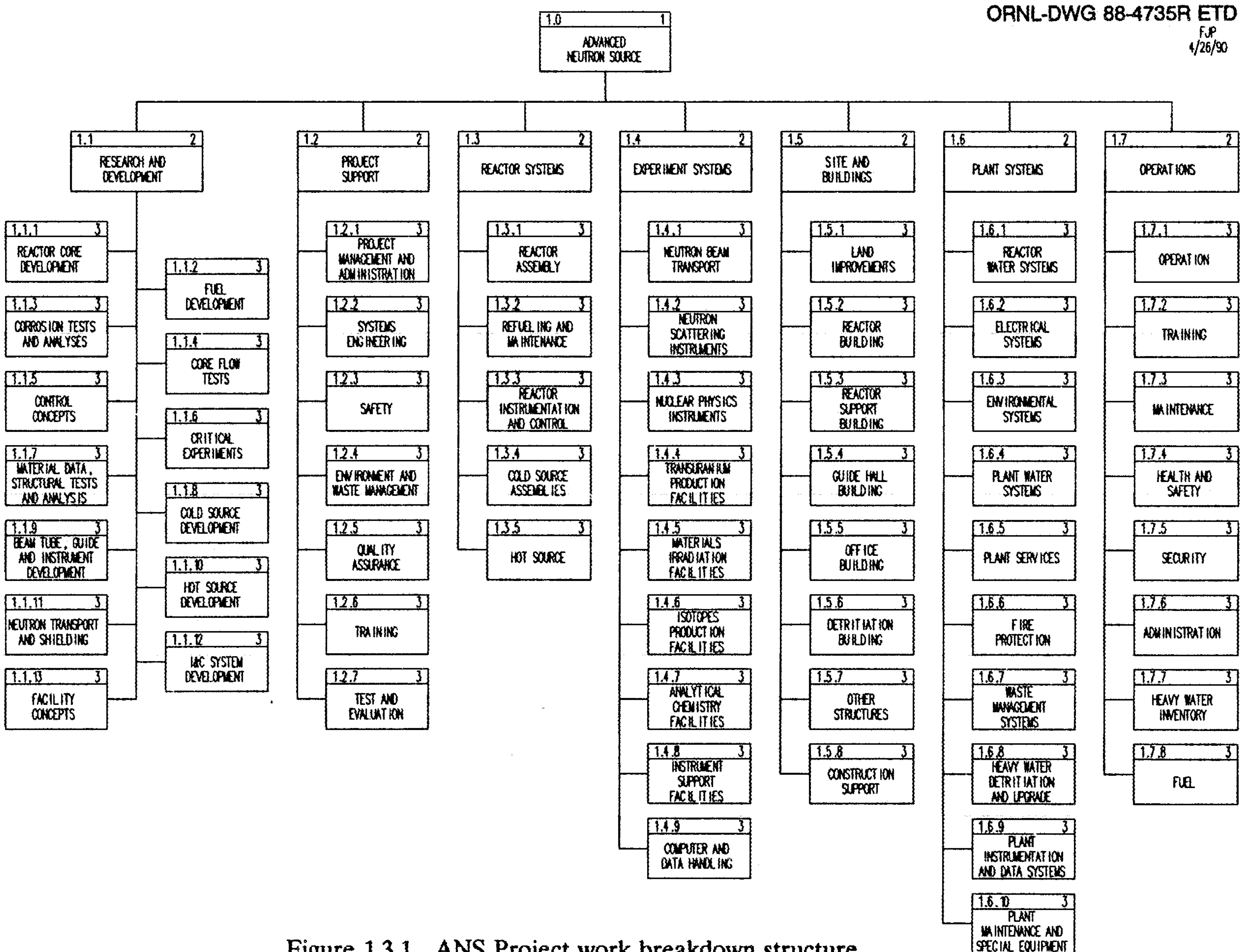


Figure 1.3.1. ANS Project work breakdown structure

provided by a suitable on-site infrastructure, appropriately interfaced to the facilities offered locally or by other DOE operations.

# 2. DESIGN GOALS

## 2.1 RESEARCH FACILITY GOALS

The ANS will provide equipment and facilities for

(1). hot, thermal, cold, very cold, and ultracold neutron beam stations, with optimized neutron beam delivery systems;

(2). state-of-the-art spectrometers for neutron scattering and nuclear and fundamental physics research;

(3). irradiation of structural materials and nuclear fuels foreseen by fission, fusion, and other materials irradiation research programs;

(4). activation analysis and related materials analysis capabilities.

Specific major criteria for the implementation of the project technical objectives (Table 1.2.1) are given in Table 2.1.1. The design criteria follow the recommendations of the ANS user community as defined by NSCANS and others.[2.1.1-43] The ability to adapt varied experimental facilities to changing future priorities through modular design and operational adjustments is a fundamental objective to be met by facility design.

## 2.2. PRODUCTION FACILITY GOALS

The ANS will provide production facilities for transuranium and other isotopes, as specified in Table 2.1.1.

## 2.3 REACTOR DESIGN GOALS

If the project is to fulfill its purpose, the source of neutrons (i.e., the reactor) must meet certain minimum performance specifications for neutron flux, neutron spectrum, and experimental space. Consideration will also be given to performance beyond minimum specifications, to maximize the research value of the ANS by providing for optional research capability during initial plant design. This means that if additional performance or facilities,

Table 2.1.1. ANS design goals

| Parameter[a,b] | Criterion |
|---|---|
| | *Neutron scattering* |
| Hot neutrons | |
| Thermal flux at hot source | ≥1.0 |
| Number of hot sources | 1 |
| Number of hot beam tubes | 2 |
| Thermal neutrons | |
| Peak thermal flux in reflector | ≥7.5 |
| Thermal:fast ratio | ≥80:1 |
| Number of thermal tangential tubes | 6 |
| Number of thermal radial tubes | 1 |
| Cold neutrons | |
| Thermal flux at cold sources | ≥2.0 |
| Number of cold sources | 2 |
| Number of horizontal cold guides | 14 |
| Number of slant cold beams | 1 |
| | *Nuclear and fundamental physics* |
| Number of thermal through tubes | 1 |
| Number of slant thermal beams | 1 |
| Number of slant very cold beams | 2 |
| | *Materials irradiation* |
| Small specimens | |
| Fast flux | ≥1.4 |
| Fast:thermal ratio | ≥1:2 |
| Total number of positions | 10 |
| Number of instrumented positions | 5 |
| Damage rate (dpa/y in stainless steel ) | ≥30 |
| Nuclear heating rate (w/g in stainless steel) | ≤54 |
| Axial flux gradient over 200 mm | ≤30% |
| Available diameter (mm) | ≥17 |
| Available length (mm) | ≥500 |

Table 2.1.1 (continued)

| Parameter | Criterion |
|---|---|
| Larger specimens[c] | |
| Fast flux | ≥0.5 |
| Fast:thermal ratio | ≥1:3 |
| Number of instrumented positions | ≥8 |
| Damage rate (dpa/y in stainless steel) | ≥8 |
| Nuclear heating rate (w/g in stainless steel) | ≤15 |
| Axial flux gradient over 200 mm | ≤30% |
| Available diameter (mm) | ≥48 |
| Available length (mm) | ≥500 |
| *Isotope production* | |
| Transuranium production | |
| Epithermal flux | ≥0.6 |
| Epithermal:thermal ratio | ≥1:4 |
| Allowable peak heat flux ($MW/m^2$) | ≥4.0 |
| Total annual production: | |
| $^{252}$Cf (g) | 1.5 |
| $^{254}$Es ($\mu$g) | 40 |
| Epithermal hydraulic rabbit tube | Epithermal flux peak position |
| Epithermal:thermal ratio | ≥1:4 |
| Allowable peak heat flux ($MW/m^2$) | ≥1.75 |
| Other isotopes | |
| Thermal flux | ≥1.7 |
| Number of reflector positions | ≥4 |
| *Materials analysis* | |
| Activation analysis pneumatic tubes | |
| 40 $cm^3$ rabbits in reflector | 4 |
| 1 $cm^3$ rabbits in reflector | 1 |
| Thermal flux at reflector rabbit positions | ≥0.2 |
| Heating rate: | |
| Temperature in a 40 $cm^3$ high density polyethylene rabbit (°C) | ≤120 |

Table 2.1.1 (continued)

| Parameter | Criterion |
|---|---|
| Rabbit tubes in light water pool | 2 |
| Thermal flux at light water rabbit positions | ≥0.04 |
| Prompt-gamma activation analysis cold neutron stations | |
| Low-background (multiple beam) guide system | 1 |
| Neutron depth profiling | |
| Number of slant cold beams | 1 |
| Gamma irradiation | |
| Irradiation positions in spent fuel | ≥1 |

Notes:

[a] All fluxes in units of $10^{19}$ $m^{-2} \cdot s^{-1}$, unperturbed.

[b] Neutron spectra are defined as follows:
Fast > 0.1 MeV
101 eV > Epithermal > 0.414 eV
Thermal < 0.625 eV

[c] The large materials irradiation specimens are intended to replace irradiation facilities in the HFIR removable beryllium region. It is unlikely that ANS will be able to meet these goals, since the simultaneous requirements of high fast:thermal flux ratio, high fast flux, and low heating rate are intrinsically incompatible with the physics of an undermoderated core (see Sect. 6.2.2).

beyond the minimum specification, can be provided without significant penalties, they should be evaluated for incorporation into the plant design. If the impact is significant, the opportunity to retrofit such capability at a later date should, to the extent feasible, be retained. Table 2.1.1 lists the major flux and spectrum specifications.

The size and configuration of the core must be such that the necessary space is available to accommodate and cool the transuranium production and materials irradiation facilities (see Sects. 2.2, 2.1, respectively). Access must be provided for electrical leads and gas lines for the instrumented irradiation capsules.

The size and configuration of the reflector tank must be such that the space and cooling requirements of the isotope production facilities, materials analysis facilities (rabbit tubes), cold sources, cold neutron guides, and neutron beam tubes are accommodated.

The hot source can, as dictated by safety and neutronic requirements, be placed outside or inside the reflector tank.

To avoid the coolant flashing to steam in the event of depressurization, the bulk coolant outlet temperature will be below the normal boiling point.

To minimize safety questions and technical risks, the reactor design must be based as far as possible on known technology; in particular, the design should not rely on the invention of new technology to meet the minimum quantitative design goals. This goal, and the performance requirements, lead to the design choices shown in Table 2.3.1.

## 2.4 USER AND SYSTEM SUPPORT GOALS

The ANS facility will be capable of handling at least 1000 short-term (1 to 2 weeks) scientific visitors per year, as well as providing support for permanent on-site staff. The environment for short-term users of standard beam facilities will be as similar as possible to that found in the best research laboratories (such as the ILL), including the availability of adequate in-house scientific and technical staff support. To facilitate achieving this goal, the ANS plant will be designed and constructed with secure physical barriers between beam research and related support areas, on the one hand, and reactor operations areas on the other. Users will be processed at an on-site reception area and given access to the research area, inside of which passage between the different beam rooms, shops, and laboratories will

Table 2.3.1. Design choices for the ANS Reactor

| | |
|---|---|
| Type | Compact undermoderated core in a reflector region |
| Power level | ≤ 350 MW (thermal power into fuel coolant) |
| Coolant | Heavy water |
| Reflector | Heavy water |
| Fuel type | Highly enriched, aluminum-clad, fuel formed into involute plates |
| Cold sources | Two, with liquid deuterium moderator |
| Cooling systems | Maximum use of passive or inherent safety features |
| Coolant gap | ≥ 1.25 mm |
| Plate thickness | ≥ 1.25 mm |

Sources:

*Proceedings of the workshop on An Advanced Steady-State Neutron Facility*, "Report on the Working Group on Critique of Source Concepts", J. A. Lake and C. D. West, *Nuclear Instrumentation and Methods*, Vol. A249, No. 1, pp. 125-131, August/September 1986.

*Advanced Neutron Source Project Annual Report, April 1987 - March 1988*, Appendix B, "Core Comparison Workshop Summary", ORNL/TM-10860, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab., February 1989

*Advanced Neutron Source Final Preconceptual Reference Core Design*, ORNL/TM-11234, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab., August 1989

*Report of the Advanced Neutron Source Safety Workshop, October 25-26, 1988*, CONF-8810193, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab., December 1988

J. A. Young and J. U. Koppel, "Slow Neutron Scattering by Molecular Hydrogen and Deuterium," *Phys. Rev.*, 135, p. A603, August 1964

be as free as possible, consistent with keeping radiation exposures as low as reasonably achievable (ALARA) and with normal laboratory security requirements.

The ANS facility, in context with facilities available at Oak Ridge National Laboratory (ORNL) and the other DOE sites at Oak Ridge, will provide the necessary offices, shops, change facilities, maintenance, and storage areas to support the operation of the reactor and research facilities. Existing facilities and labor pools will be utilized to the greatest extent practical. The ANS facility will be integrated into the site infrastructure of the Oak Ridge Reservation (ORR), including roadways, utilities, and monitoring systems. Security and fire protection will be provided by ORNL Laboratory Protection. Interfaces will be defined between on-site operations support facilities, and other facilities on the DOE reservation. The spare parts and supplies inventory needed to support operation will be defined, and the appropriate storage environment will be provided at existing facilities, if possible, or at the ANS site, if necessary.

An appropriate interface will be provided to existing handling and separation facilities at ORNL, with particular reference to the transuranium facilities at the Radiochemical Engineering Development Center (REDC). Users will interface directly with reactor operations staff for research programs which involve interaction with operation of the reactor or the handling of highly active materials (such as materials irradiation, pneumatic rabbit tubes, or isotope production.)

Interfaces will be provided to reactor fuel storage and shipment facilities, covering receipt and storage of fresh fuel as well as shipment of spent fuel. Secure storage for unirradiated fuel will be identified, responsibilities for protection of the fuel will be assigned, and anticipated schedules for fuel handling will be established and integrated into the design of security systems at the ANS.

# 4. SAFETY AND LICENSING REQUIREMENTS

## 4.1 SAFETY GOALS

### 4.1.1 Licensability

The ANS is to be designed, built, and operated under DOE ownership, and is therefore exempt from the Nulcear Regulatory Commission (NRC) licensing process under 10 *CFR* 50.11. However, DOE orders require DOE reactors to meet the standards, codes, and guides that are applied to comparable licensed facilities. Therefore, the ANS shall be "licensable", and the standards, codes, and guides applied to the ANS design must be those by which the NRC would judge the ANS.

### 4.1.2 Risk Limitation

The ANS risk limitation goals are based on the NRC Policy Statement dated August 21, 1986[4.1.1] and upon the similar DOE Draft Nuclear Safety Objectives Policy Statement dated February 9, 1989.[4.1.2] These policies are directed at radiological risks associated with hypothetical severe accidents. Both short-term (prompt fatality) and long-term (latent fatality) risks are considered: prompt fatality refers to an acute radiation dose of magnitude sufficient to cause death within a short period of time, and latent fatality refers to an initially sublethal dose of radiation that may cause cancer that, in turn, causes death, perhaps years later.

The basic principle upon which both NRC and DOE policies are grounded is that radiological accident risks must be a small fraction of the risks to which individuals are normally exposed. The limit for radiological accident risk is, therefore, set by comparison with other risks. Prompt fatality risk is compared with normal, non-nuclear accidents risk, and latent fatality risk is compared with the normal, background rate of cancer in the general population.

Two basically different populations must be considered: the off-site residents and the on-site workers and visitors. The risks attributable to nuclear accidents are allowed to cause only an insignificant increase in these pre-existing normal risks, as published by the U.S. Bureau of Census.[4.1.3] The latent (cancer) fatality risk is treated the same for both groups; that is, the basis for comparison is the background cancer death rate within the general population ($\sim 2 \times 10^{-3}$ per year per person). The prompt fatality risk limitation for the off-site residents is compared with accident fatality risk prevalent in the general population ($\sim 4 \times 10^{-4}$ per year, per person). For on-site workers and visitors, the prompt fatality risk limitation is based on the average occupational death rate in the United States ($\sim 1 \times 10^{-4}$ per year, per worker). The ANS risk goals are expressed in Table 4.1.1.

The risk limitation goals are conceptually simple, but achievement of the goals can only be evaluated after a detailed multistep calculational process. It is possible to state simpler, more directly usable goals which, if met, ensure that the ultimate health risk limitation goals will be met. Toward this end, the following auxiliary goals are specified:

1. Core melt risk. The median probability of severe core damage or meltdown due to internal events shall not exceed $1 \times 10^{-5}$ per year. The DOE draft safety objectives policy[4.1.2] specifies this goal for new production reactors. A major NRC risk study[4.1.4] of five representative existing power reactors has published core damage frequencies ranging from $8 \times 10^{-6}$ to $1 \times 10^{-4}$ per reactor year; $1 \times 10^{-5}$ should therefore be a reasonable goal for a new plant. While not an inflexible limit, this goal shall be utilized to guide design decisions. Internal events are those initiated by equipment or operator failure.

2. Large release risk. The median probability of a large release shall not exceed $1 \times 10^{-6}$ per year, including both internal and external events. A large release is one that, considering reasonable emergency actions and realistic meteorological conditions, would be capable of causing prompt fatalities [i.e., exposure > 200 rem (2 Sv)] to workers outside the reactor containment or to the general public. This definition is consistent with that applied in NUREG-1150.[4.1.4]

3. Inherent safety characteristics. ANS safety related systems (see Sect 4.4 for system classification requirements) will be designed with the maximum practicable degree of inherent or passive safety. The primary objective of passive cooling is

Table 4.1.1. Radiological accident risk goals for the ANS

| Population | Risk mode | Comparison basis for goal | Risk to average individual |
|---|---|---|---|
| Off-site residents within 1.6 km (1 mile) of reservation[a] boundary | Prompt | 0.1% of all normal accident risk | $4 \times 10^{-7}$/year |
| On-site workers and visitors within 1.6 km (1 mile) of the ANS facility security fence[b] | Prompt | 1% of average U.S. occupational fatality risk | $1 \times 10^{-6}$/year |
| Off-site residents within 16 km (10 miles) of the reservation boundary, and on-site workers and guests | Latent | 0.1% of U.S. average cancer death risk | $2 \times 10^{-6}$/year |

[a] This refers to the property boundary of the DOE ORR. The current preferred site for the ANS is in eastern Melton Valley, about 2 km from the southern boundary of the ORR, which winds along Melton Hill Lake.

[b] A security fence will surround the ANS facility to facilitate control of access to the facility buildings and immediate vicinity. Precise specification of the location of the security fence is not essential for this goal; the location of the fence will be set by security considerations.

to reduce dependence on operator actions and upon active components. The capability to go into natural circulation cooling for decay heat removal shall be emphasized and the dependence upon active components shall be minimized. The high priority on natural circulation decay heat removal extends to spent fuel cooling, reactor containment cooling, and the containment or retention of fission products.

### 4.1.3 Pressure Boundary Integrity

The ANS primary coolant pressure boundary shall be designed to minimize rupture probability. The reactor assembly and related systems shall be designed to maximize ability to withstand pressure boundary ruptures. The following subgoals implement the general goal:

1. The primary coolant system piping and associated leak detection instrumentation shall be designed and analyzed in accordance with the Leak-Before Break Evaluation Procedures as detailed in Sect. 3.6.3 of the *Standard Review Plan*[4.1.5] [NUREG-0800, as amended by *Federal Register*, 52 (167), (1987)].
2. With regard to a design basis pipe break, the ANS design shall accommodate pipe break sizes up to the diameter of the piping that comprises the four individual heat exchanger loops. In this context, accommodation includes the maintenance of effective average channel core cooling and the preservation of overall core geometry and decay heat removal capability. Risk of pipe break exceeding the design basis is minimized by the provisions of paragraphs (1) and (3) of this subsection.
3. The total mean probability of catastrophic rupture of the core pressure boundary tube or any primary coolant pipe larger than the design basis break (see Sect. 4.1.4 item 2) shall be limited to $< 5 \times 10^{-7}$ per year. Catastrophic rupture is defined as any failure that initiates or results in fuel melting. This goal ensures that the risk contribution from unprotected pressure boundary failure is a small fraction of the total fuel damage risk. The current NRC screening criterion for through-wall reactor vessel crack probability is $5 \times 10^{-6}$ per reactor year.[4.1.6] The

goal stated in this paragraph for the ANS is significantly lower because it deals with catastrophic failure, not just through-wall cracking.

### 4.1.4 Defense-in-Depth

The ANS reactor shall be designed in accordance with the defense-in-depth concept, in which succeeding layers of safety are built into the design and operations of the facility, and excessive reliance upon any one element is avoided.

1. The reactor shall be designed and built such that it will, with a high degree of reliability, operate without failures that could lead to accidents.
2. Protection devices and systems shall be provided to ensure that anticipated transients and off-normal conditions will be detected and either arrested or accommodated safely.
3. To provide additional margins in the plant design in order to protect the public, the reactor shall be housed in a building capable of retaining radioactive nuclides that might be released in the event of a hypothetical severe fuel damage accident.
4. To ensure the public safety in the event of failure of all other levels of defense-in-depth, on-site and off-site emergency procedures shall be maintained. The on-site plans and equipment shall support prompt and accurate accident assessment and protective action decision making for workers on the reservation, transients on or near the reservation, and residents off the reservation. Off-site plans and equipment shall support a range of protective actions (including evacuation), and the prompt communication to residents, civil authorities, and the press of any needed protective actions.

### 4.1.5 Respect for the Environment

The ANS reactor or facility shall not have a deleterious effect on the environment, as determined by the Environmental Impact Statement (EIS).

### 4.1.6 Ensured Site Suitability

The ANS reactor and containment shall be designed such that the emergency planning zones for the ANS are compatible with the existing ORNL planning zones,[4.1.7] including the 3.22-km (2-mile) Immediate Notification Zone (INZ) radius. Additionally, the radiation exposure criteria for the Exclusion Area Boundary (EAB) and Low Population Zone (LPZ) specified in the NRC 10 *CFR* 100 "Reactor Site Criteria"[4.1.8] must be satisfied. This means that the ANS design basis site suitability source-term accident (i.e., large loss-of-coolant accident with total failure of primary cooling) must not cause radiation exposures exceeding the limits specified by Table 4.1.2.

Calculations performed to monitor compliance with the values of Table 4.1.2 shall utilize the assumptions of *Regulatory Guide 1.4*[4.1.9] relating to the release of radioactive material; that is, that 100% of the noble gas fission products, 25% of the iodine nuclides, and 1% of all other fission product nuclides escape from the damaged fuel to the containment atmosphere. For the EAB and LPZ limits, the meteorological dispersion coefficients shall be calculated in accordance with the approach outlined in *NRC Regulatory Guide 1.145*, "Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants".[4.1.10]

Criteria used to select the site shall include seismic response characteristics, wind characteristics, and flooding characteristics that are consistent with a design which meets the probability goals set out in this chapter for core damage and for release of radionuclides to the public.

Table 4.1.2. ANS accident-related radiological exposure limits

| Zone | Radial Distance | Time | Exposure Limits[a] [Sv (rem)] Thyroid | Exposure Limits[a] [Sv (rem)] Whole Body |
|---|---|---|---|---|
| Exclusion area boundary[b] | 1000 m | 2 h | 0.25 (25) | 0.05 (5) |
| Low population zone[c] | 2000 m | Duration of release | 0.25 (25) | 0.05 (5) |
| Immediate notification zone[d] | 3220 m (2 miles) | 2 h | 0.05 (5) | 0.01 (1) |

[a] Maximum dose calculated at radial distance noted.

[b] Chosen to include the ANS site but exclude workers at other major sites (e.g., HFIR and ORNL.

[c] Chosen to lie entirely within the ORR. Excludes all of the general public except transients.

[d] Notification zone currently in use for ORR facilities (includes a limited number of private residences).

# 5. OPERATION AND MAINTENANCE REQUIREMENTS

## 5.1 PLANT AVAILABILITY GOAL

Other than during scheduled major maintenance periods, the plant availability will be at least 80%. Global availability (including major maintenance) will be at least [TBD] %.

## 5.2 PLANT PREDICTABILITY GOAL

Reactor cycles and maintenance schedules will be predictable and scheduled with a lead time of at least 9 months once normal reactor operation is achieved. The reactor should be in operation, at full power, at least [TBD] % of the scheduled operating times.

## 5.3 PLANT LIFETIME REQUIREMENTS

The design lifetime of the ANS will be 40 years. This lifetime is consistent with the maximum NRC license period allowed in 10 *CFR* 50. The design of the ANS shall not knowingly preclude lifetime extensions beyond 40 years.

# 7. QUALITY ASSURANCE PROGRAM REQUIREMENTS

## 7.1 QUALITY ASSURANCE PROGRAM

The QA Program for the ANS Project shall meet the requirements of DOE Order 5700.6 "Quality Assurance"[7.1.1] and the intent of 10 *CFR* 50, "Appendix B",[7.1.2] as elaborated in Sect. 17 of the *USNRC Standard Review Plan* (NUREG-0800).[4.1.5] The ANS QA Program is documented in the *ANS Quality Assurance Plan* (ORNL/TM-11446)[1.1.3] and addresses the basic and supplemental requirements of ASME NQA-1.

The responsibility for the quality of ANS structures, systems, components, or activities shall reside with the line management of the project and the various supporting organizations and contractors. Subtier ANS QA Plans shall be required of contractor support organizations with extensive multidisciplinary scopes of work. Such plans shall be reviewed for acceptability by the ANS Project organization before contractors begin project design work.

A major component of the ANS QA Program shall be a group of quality controls collectively referred to as the Configuration Management System. The Configuration Management System shall ensure that the performance requirements and design features of the facility are identified, documented in a controlled reference source, and distributed to project organizations involved in the design of the facility.

The performance requirements and design features for the ANS are initially defined in this PDR document and shall be further detailed in the SDDs. These requirements shall establish the objectives of the facility design effort and serve as the benchmarks by which the success and acceptability of the design will be measured. They shall also serve as the standards of acceptance for the operability performance testing. As the facility design evolves, established requirements may not be achievable. To ensure proper interfacing of systems and components, the requirements documents shall be revised to reflect the achievable parameter.

Configuration Management shall involve multiple aspects of the project quality assurance program including: control of personnel training, control of design, control of computer codes, control of drawings, control of safety analyses, control of procurements, control of procedures, control of documents, control of materials, control of tests, control of nonconformances and control of quality records.

Configuration Management shall be practiced throughout the life of the facility. The system shall ensure that the facility performs as intended throughout its life cycle and that plant modifications do not compromise the defined function of the facility. It shall also ensure that the actual physical configuration of the facility is accurately reflected in the facility documentation (drawings, reports, analyses, etc.).

## 7.2 DEFINITION OF QUALITY LEVELS

The ANS QA program provisions shall apply to ANS structures, systems, components, and activities in a graded manner commensurate with the assigned Quality Level and Safety Classification designation:

Quality Level 1 shall apply to items and activities that impact nuclear safety of the facility.

Quality Level 2 shall apply to items and activities, other than those assigned Quality Level 1, that are vital to the performance of the facility or effect personnel safety.

Quality Level 3 shall apply to items and activities, other than those assigned Quality Level 1 or 2, that require quality controls in excess of standard practice or commercial quality.

Nonsafety classified structures, systems, components, or activities shall have QA Program provisions selectively applied to provide an appropriate level of confidence that the items function in accordance with their design or that activities are performed as intended.

# 12. REFERENCES


1.1.1 *Preparation of Plant and System Design Description Documents*, NE Standard F 1-2T, Jan. 1989

1.1.2 *Advanced Neutron Source Project Management Plan*, to be published at Oak Ridge Natl. Lab.

1.1.3 *Advanced Neutron Source Quality Assurance Plan*, ORNL/TM-11446, Martin Marietta Energy Systems, Inc, Oak Ridge Natl. Lab., Dec. 1989

1.1.4 *Advanced Neutron Source Project Systems Engineering Management Plan*, April 1990 draft, to be published at Oak Ridge Natl. Lab.

1.2.1 S. Shapiro and L. M. Corliss, eds., *Report on the Workshop on Intense Neutron Sources, May 30-June 1, 1973*, Brookhaven Natl. Lab., 1973.

1.2.2 Letter from R. D. Cheverton, Oak Ridge Natl. Lab., to M. C. Wittels, U.S. Atomic Energy Commission, *Advanced Research Reactors*, Dec. 7, 1973.

1.2.3 Letter from J. Hastings, Chair, Workshop on Intense Neutron Sources held July 10-11, 1974, Brookhaven Natl. Lab., to J. M. Teem, U.S. Atomic Energy Commission, Oct. 25, 1974.

1.2.4 *Report of the Oak Ridge Natl. Lab. Neutron Source Committee*, R. M. Moon (Chair), Martin Marietta Energy Systems, Inc, Oak Ridge Natl. Lab., May 20, 1976.

1.2.5 R. M. Moon, ed., *Proceedings of the Conference on Neutron Scattering*, ORNL-CONF-760601-P1 and P2, Martin Marietta Energy Systems, Inc, Oak Ridge Natl. Lab., Sept. 1, 1976.

1.2.6 National Research Council Panel on Research Facilities and Scientific Opportunities in the Use of Low-Energy Neutrons, G. K. Teal (Chair), *Neutron Research on Condensed Matter: A Study of the Facilities and Scientific Opportunities in the United States*, National Academy Press, Washington, D.C., 1977.

1.2.7 *Report of the Review Panel on Neutron Scattering*, W. Brinkman (Chair), Ames Laboratory, IS-4761/UC-25, 1980.

1.2.8 *Current Status of Neutron Scattering Research and Facilities in the United States*, National Research Council Panel on Neutron Scattering, J. J. Rush (Chair), National Academy Press, Washington, D.C., 1984.

1.2.9 *Major Facilities for Materials Research and Related Disciplines*, National Research Council Major Materials Facilities Committee, F. Seitz and D. Eastman (Chairs), National Academy Press, Washington, D.C., 1984.

1.2.10 *Review of the National Research Council Report "Major Facilities for Materials Research and Related Disciplines*, Energy Research Advisory Board Report, DOE/S-0037, U.S. Department of Energy, June 1985.

1.2.11 *Review of the Basic Energy Sciences Program*, Basic Energy Sciences Advisory Committee Report, DOE/ER-0359, U.S. Department of Energy, Dec. 1987.

2.1.1 R. M. Moon, D. E. Bartine, F. J. Peretz and J. A. Murray, *Feasibility Study for High Flux Isotope Reactor II*, X-OE-265, Martin Marietta Energy Systems, Inc, Oak Ridge Natl. Lab., Sept. 1984.

2.1.2 R. M. Moon, ed., *Proceedings of the Workshop on Instrumentation for the Advanced High Flux Reactor, May 30, 1984*, CONF-8405192, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab., 1984.

2.1.3 G. H. Lander and V. J. Emery, eds. *Proceedings of a Workshop on Scientific Opportunities with Advanced Facilities for Neutron Scattering October 23-26, 1984*, CONF-8410256, Argonne Natl. Lab., 1984; *Nuclear Instruments and Methods*, B12, 525 (1985).

2.1.4 R. M. Brugger, ed., *Proceedings of the Workshop on an Advanced Steady-State Neutron Facility, December 16-18, 1985*, Nuclear Instruments and Methods, A249 (1986).

2.1.5 M. K. Wilkinson, *Minutes of the National Steering Committee for the Advanced Neutron Source Meeting*, NSCANS, Oct. 27, 1986.

2.1.6 J. M. Carpenter, R. Carter and W. Whittemore, *Minutes of the National Steering Committee for the Advanced Neutron Source Neutron Source Subcommittee*, NSCANS, Oct. 27, 1986.

2.1.7 G. L. Greene, ed., *Proceedings of a Workshop on the Investigation of Fundamental Interactions with Cold Neutrons*, National Bureau of Standards Special Publication No. 711 (1986).

2.1.8 Letter from D. M. Engelman, Yale Univ., to J. J. Rush, Chairman, National Steering Committee for the Advanced Neutron Source, May 22, 1987: *Instrumentation for Biology*.

2.1.9 M. K. Wilkinson, *Minutes of the National Steering Committee for the Advanced Neutron Source Meeting*, NSCANS, June 18, 1987.

2.1.10 Memorandum from R. S. Carter, J. Carpenter, and W. Whittemore, National Steering Committee for the Advanced Neutron Source Neutron Source Subcommittee, to J. J. Rush, Chairman, National Steering Committee for the Advanced Neutron Source, *Response to Request to Guidance from Advanced Neutron Source Design Teams*, July 9, 1987.

2.1.11 Letter from R. Pynn, Los Alamos Natl. Lab., to I. Thomas, U.S. Department of Energy, *Improved Neutron Scattering Instrumentation at Department of Energy Facilities*, Sept. 3, 1987.

2.1.12 M. K. Wilkinson, *Minutes of the National Steering Committee for the Advanced Neutron Source Meeting*, NSCANS, May 23, 1988.

2.1.13 Letter from A. Steyerl, Univ. of Rhode Island, to S. Raman, Oak Ridge Natl. Lab., *Ultracold Neutrons at the Advanced Neutron Source*, Aug. 22, 1988.

2.1.14 Letter from R. Wilson, Harvard Univ., to S. Raman, Oak Ridge Natl. Lab., *Nuclear Physics at the Advanced Neutron Source*, Aug. 25, 1988.

2.1.15 Letter from G. L. Greene, Natl. Institute of Standards and Technology, to S. Raman, Oak Ridge Natl. Lab., *Nuclear, Particle and Fundamental Physics at the Advanced Neutron Source*, Sept. 20, 1988.

2.1.16 Letter from R. C. Greenwood, Idaho Natl. Engineering Lab., to S. Raman, Oak Ridge Natl. Lab., *Proposed ISOL Facility for the Advanced Neutron Source Reactor*, Sept. 23, 1988.

2.1.17 A. N. Goland, *Report of the Ad Hoc Subcommittee on Materials Irradiation Facilities for the Advanced Neutron Source*, NSCANS, Nov. 10, 1988.

2.1.18 Letter from S. J. Freedman, Univ. of Chicago and Argonne Natl. Lab., to S. Raman, Oak Ridge Natl. Lab., *Fundamental Physics at the Advanced Neutron Source*, Jan. 3, 1989.

2.1.19 Memorandum from R. S Carter and J. Carpenter, National Steering Committee for the Advanced Neutron Source, Neutron Source Subcommittee, to J. J. Rush, Chairman, National Steering Committee for the Advanced Neutron Source, *Report on Advanced Neutron Source Informal Workshop on Instrumentation*, Jan. 9,1989.

2.1.20 Memorandum from F. F. Dyer, Oak Ridge Natl. Lab., to J. Corum, Oak Ridge Natl. Lab., *Facilities in the Advanced Neutron Source for Analytical Chemistry*, Feb. 13, 1989.

2.1.21 Memorandum from K. R. Thoms, Oak Ridge Natl. Lab., to R. T. Primm, Oak Ridge Natl. Lab., *Spectrum Information for the Advanced Neutron Source PS-2 Reference Core*, Feb. 17, 1989.

2.1.22 Letter from R. K. Genung, Oak Ridge Natl. Lab., to J. L. Burnett, U.S. Department of Energy, *Probable Status of the Radiochemical Engineering Development Lab. When the Advanced Neutron Source Becomes Operational,* March 30, 1989.

2.1.23 Memorandum from C. Alexander, Oak Ridge Natl. Lab., to J. B. Hayter, Oak Ridge Natl. Lab., *Status of Advanced Neutron Source $^{252}$Cf Production Calculations*, April 7, 1989.

2.1.24 Letter from R. F. Casten, Brookhaven Natl. Lab., to S. Raman, Oak Ridge Natl. Lab., *Nuclear Physics at the Advanced Neutron Source*, April 11, 1989.

2.1.25 Memoranda from K. R. Thoms, Oak Ridge Natl. Lab., to D. L. Selby, Oak Ridge Natl. Lab., *Capabilities of Proposed Fast Neutron Irradiation Facilities in the Advanced Neutron Source*, April 12 and 14, 1989.

2.1.26 A. Steyerl, Univ. of Rhode Island, *Reply to Questionnaire on Nuclear and Fundamental Physics at the Advanced Neutron Source*, April 1989.

2.1.27 D. Hamilton, Univ. of Sussex, *Replies to Questionnaire on Nuclear and Fundamental Physics at the Advanced Neutron Source*, April 1989.

2.1.28 R. Wilson, Harvard Univ., *Reply to Questionnaire on Nuclear and Fundamental Physics at the Advanced Neutron Source*, April 1989.

2.1.29 G. Greene, Natl. Institute of Standards and Technology, *Replies to Questionnaire on Nuclear and Fundamental Physics at the Advanced Neutron Source*, April 1989.

2.1.30 Letter from R. C. Greenwood, Idaho Natl. Engineering Lab., to J. B. Hayter, Oak Ridge Natl. Lab., *ISOL Facility at the Advanced Neutron Source Reactor*, May 17, 1989.

2.1.31 Memorandum from F. F. Dyer, Oak Ridge Natl. Lab., to J. R. Stokely, Oak Ridge Natl. Lab., *Natl. Institute of Standards and Technology Workshop on Analytical Measurements with Cold Neutron Beams*, May 30, 1989.

2.1.32 J. D. Axe and J. B. Hayter, eds., *Proceedings of the Workshop on Neutron Scattering Instrumentation, June 5-7, 1989*, CONF-8906311, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab., June 1989.

2.1.33 M. K. Wilkinson, *Minutes of the National Steering Committee for the Advanced Neutron Source Meeting*, NSCANS, June 12, 1989.

2.1.34 Memorandum from F. F. Dyer, Oak Ridge Natl. Lab., to J. B. Hayter, Oak Ridge Natl. Lab., *Some Notes Concerning the Advanced Neutron Source Analytical Facilities*, July 11, 1989.

2.1.35 Memorandum from F. F. Dyer, Oak Ridge Natl. Lab., to J. B. Hayter, Oak Ridge Natl. Lab., *Analytical Facilities in the Advanced Neutron Source*, Sept. 5, 1989.

2.1.36 Letter from D. Hamilton, Univ. of Sussex, to J. B. Hayter, Oak Ridge Natl. Lab., *Nuclear Physics Stations*, Oct. 26, 1989.

2.1.37 J. B. Hayter, *Foreign Trip Report on ILL, Grenoble; IFF/KFA, Julich; and LLB, Saclay*, ORNL/FTR-3504, Martin Marietta Energy Systems, Inc, Oak Ridge Natl. Lab., Dec. 13, 1989.

2.1.38 Letter from K. R. Thoms, Oak Ridge Natl. Lab., to J. R. Ryskamp, Idaho Natl. Engineering Lab., *Materials Which Could be Irradiated in the Advanced Neutron Source*, Nov. 27, 1989.

2.1.39 Letter from R. G. Downing, Natl. Institute of Standards and Technology, to J. B. Hayter, Oak Ridge Natl. Lab., *Neutron Depth Profiling*, Jan. 22, 1990.

2.1.40 Letter from Nuclear Methods Group, Natl. Institute of Standards and Technology to J. B. Hayter, Oak Ridge Natl. Lab., *Irradiation Facilities for Analytical Chemistry in the Advanced Neutron Source*, March 30, 1990.

2.1.41 S. A. McElhaney and R. I. Vandermolen, *Two-Dimensional Position-Sensitive Detectors for Small-Angle Neutron Scattering*, ORNL/TM-11557, Martin Marietta Energy Systems, Inc, Oak Ridge Natl. Lab., May 1990.

2.1.42 Letter from F. F. Dyer and L. Robinson, Oak Ridge Natl. Lab., to J. B. Hayter, Oak Ridge Natl. Lab., *Analytical Facilities in the Advanced Neutron Source*, June 21, 1990.

2.1.43 M. K. Wilkinson, *Minutes of the National Steering Committee for the Advanced Neutron Source Meeting*, NSCANS, June 25, 1990.

4.1.1 U. S. Nuclear Regulatory Commission, "Safety Goals for the Operations of Nuclear Power Plants", *Fed. Regist.*, 51, (162), Aug. 21, 1986.

4.1.2 U. S. Department of Energy, *Policy Statement on Nuclear Safety Objectives for Department of Energy Facilities*, rev. draft, Feb. 15, 1989.

4.1.3 U. S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States - 1990.*

4.1.4 M. L. Ernst, *Reactor Risk Reference Document, Volume I*, NUREG-1150, U. S. Nuclear Regulatory Commission, Feb. 1987.

4.1.5 U. S. Nuclear Regulatory Commission, *Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants*, NUREG-0800, June 1987.

4.1.6 U. S. Nuclear Regulatory Commission, *Format and Content of Plant-Specific Pressurized Thermal Shock Safety Analysis Reports for Pressurized Water Reactors*, Regulatory Guide 1.154 (Draft), Jan. 1986.

4.1.7 J. D. Bolling et al., *Comprehensive Emergency Management Plan (CEMP)*, Y-JA346, Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Dec. 31, 1989.

4.1.8 10 CFR Pt. 100.

4.1.9 U.S. Atomic Energy Commission, *Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss of Coolant Accident for Pressurized Water Reactors*, Regulatory Guide 1.4 (Rev. 2), June 1974.

4.1.10 U.S. Nuclear Regulatory Commission, *Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants*, Regulatory Guide 1.145, Aug. 1989.

7.1.1 U.S. Department of Energy, *Quality Assurance*, Order 5700.6B, Sept. 23, 1986.

7.1.2 10 CFR Pt. 50.

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