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Advanced Neutron Source: The Designer's Perspective

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Introduction

The Advanced Neutron Source (ANS) is a research facility based on a 350 MW beam reactor, to be brought into service at the Oak Ridge National Laboratory at the end of the century. The primary objective is to provide high-flux neutron beams and guides, with cold, thermal, hot, and ultra-cold neutrons, for research in many fields of science. Secondary objectives include isotopes production, materials irradiation and activation analysis.

The design of the ANS is strongly influenced by the historical development of research and power reactor concepts, and of the regulatory infrastructure of the Department of Energy (DOE) and the Nuclear Regulatory Commission (NRC). Current trends in reactor safety also impact the climate for the design of such a reactor.

Major Factors Influencing the Design

Research reactors were designed and constructed before commercial power reactors, and the basic principles for conducting research at such reactors were formulated in the 1950's and 1960's. Fundamental concepts were developed for beam experiments clustered around penetrations in the reactor shield, along with materials irradiation, fuels testing, and isotopes production facilities inside the reactor. The unique nature of such facilities required the talent of the supporting laboratory or university to ascertain the safety of such experiments. Although small university reactors have been constructed and licensed since, the construction of large research reactors in the United States ended in the late 1960's. Construction elsewhere, especially Western Europe, has continued. Not only is the U.S. now behind in research capabilities, but designers must look overseas to observe practices at the most modern facilities with cold sources and neutron guides, and to assess the licensing implications of incorporating such facilities into the reactor. In the mean time, the regulatory climate, especially at the DOE reactors, has changed dramatically. No longer is internal review accepted, and both the research facilities and the DOE must adjust to a new regulatory posture.

Power reactors share a common purpose, and all light water reactors share common design features. This leads to a more prescriptive regulatory climate, which can realistically be applied by the NRC through Title 10 of the Code of Federal Regulations, a series of Regulatory Guides, Standard Review Plans, and similar documents. The same procedure has been applied to research reactors outside the DOE, but the unique activities at these facilities, offset by the much lower intrinsic hazard levels, has led to a lesser degree of codification.

Debates over the hazards represented by nuclear decay heat, the potential for fission product release, and in the stored energy of the water coolant have resulted in proposed new designs emphasizing passive safety and low stored energy. These, too, influence the regulatory climate under which the ANS will be constructed. The challenge is to provide a level of protection appropriate for a high power research reactor, without impeding research, while conforming to a regulatory system based largely on power reactors.

Design Concepts for the Advanced Neutron Source

The beam research capabilities of the ANS are seen in Figure 1. The reactor assembly is surrounded by a large circular beam room, and cold neutron guides fan out into an even larger guide hall. The reactor is cooled and reflected by heavy water, enhancing the transport of neutrons to the beams. The core, using aluminum silicide involute plate fuel, is exceptionally small for the power level, resulting in an unprecedented flux approaching 10^{20} m^{-2} s^{-1}. The opportunistic use of areas in the center of the core and the reflector allow provisions for transplutonium production, materials irradiation, and activation analysis. Offices and laboratories are provided to ensure a totally integrated research facility.

The high power density of the core results in significant afterheat removal issues. The coolant system is designed to enhance natural circulation, and decay heat can be removed by such modes after about an hour following shutdown. The large beam room in the reactor building leads to a large, low pressure containment structure. The heavy water coolant is kept below 100° C, minimizing the stored energy in the coolant itself. Other design features provide passive coolant inventory control, and ensure sufficient coolant pressure to survive a transient. The reactor control system includes both independent and diverse absorber insertion assemblies. Security concerns are eased by an overall facility design in which users and operators are segregated into physically distinct parts of the facility.

Conclusions

The design of a new, high power research reactor presents many challenges. Influences from the research, power and regulatory communities appear to create conflicting requirements. However, the ANS design can satisfy requirements from each point of view.

FIGURE 1. PLAN VIEW OF THE ADVANCED NEUTRON SOURCE.