UNITED STATES DEPARTMENT OF COMMERCE
National Bureau of Standards
Gaithersburg, Maryland 20899

50-184

September 19, 1986

Director
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Sir:

The National Bureau of Standards requests an exemption from conversion from HEU fuel on the basis that the NBS reactor serves a unique purpose. The justification for the request is enclosed.

Sincerely,

Robert S. Carter

Robert S. Carter
Chief, Reactor Radiation Division

Enclosure

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Request for a Determination
that the NBSR Has a Unique Purpose

The National Bureau of Standards (NBS) requests that the NBS reactor (NBSR) be permitted to continue operating with highly enriched uranium fuel (HEU) on the basis that the NBSR serves a unique purpose that cannot be met with low enriched uranium fuel (LEU) as substantiated below and in the attached documentation.

From its inception, the NBSR was designed as a national resource with the most flexible and highest quality facilities for its power level. Every effort was made to optimize the design to achieve maximum output and performance. The NBSR operates continuously, shutting down only to replace spent fuel and supports 25 thoroughly automated experimental instruments (more than at any other U.S. reactor), most of which are unique or world-class. These facilities are used annually by more than 300 scientists and engineers from 85 industrial, government, and university organizations from all over the U.S. and from abroad. Furthermore, the NBSR is the only reactor in the U.S. designed to accommodate a large cold source with the versatility to support a large neutron guide hall. Such a facility, currently unavailable in the U.S., is the top short-term priority of a National Academy Committee recently established to recommend priorities for major new national facilities in the fields of materials science, condensed matter physics, and chemistry. The President's FY87 budget, now before Congress, contains funding for such a facility at NBS. The proposed facility would provide 15 instruments, each with capabilities greater than any now available in the U.S., which would allow U.S. materials science and technology to become internationally competitive (with Western Europe and Japan) in the critical new area of cold neutron research.

Both the existing programs, costing $15,000,000 or more annually, and the proposed national center for the application of cold neutrons in areas of research and engineering would be severly impacted by the decreased capabilities of the NBSR resulting from conversion to LEU even if suitable LEU fuel were available. The use of LEU fuel would reduce the thermal flux in the NBSR by the order of ten percent and, at the same time, harden the neutron spectrum and increase the background. These losses cannot be compensated for by increasing the reactor power or extending the operating time because the reactor is already operating at its maximum safe power on a full time schedule. The combination of decreased signal and increased background would significantly reduce the signal-to-noise ratio available for almost all experiments and thus down-grade the capability of the NBSR to meet its unique purpose as a national center for the application of neutron methods to a wide variety of problems of national importance. Many of the most important experiments already have very low signal-to-noise ratios and would not be feasible with the degraded beams resulting from the use of LEU. In addition, certain standard radiation fields and beams have been established in the NBSR to serve national needs in radiation dosimetry and nuclear technology. Several years of precise measurements and calculations were required to fully characterize these facilities. The change in reactor spectrum caused by the use of LEU would require a major effort to recharacterize these standard, national-reference facilities, making them unavailable for a year or more.

The advanced research carried out by the NBSR contributes in many areas to the international competitiveness of the U.S. through its extensive collaboration with industry. Improving the international competitiveness of the U.S. is a major objective of the Department of Commerce, which has strongly supported every effort to optimize the capabilities and performance of the NBSR. Therefore, the use of LEU fuel in the NBSR is not in the national interest because it will lower the reactor's capabilities and performance, adversely affecting many technological areas of national concern. The full complement of research projects currently underway, as well as the possibility of realizing the full advantages of the proposed cold neutron facility, can be achieved only with the neutron flux levels and spectra attainable with HEU fuel. Therefore, NBS requests that it not be required to convert from its present fuel to LEU on the bases of its unique purpose as outlined above.

Supporting Documentation for an NRC finding of
"Unique Purpose" for the NBSR

Introduction

The National Bureau of Standards reactor (NBSR) was funded by Congress in 1960 to meet the varied research needs of NBS and the Mid-Atlantic Region. Since then, it has developed into a national center for the application of neutron methods to a wide variety of material and radiation measurement problems of national importance.

The reactor was designed to provide the highest quality facilities for the power level at which it could operate. To achieve this, heavy water was chosen as the coolant, moderator, and reflector at a significant cost in both dollars and maintenance access. The use of heavy water not only provided more neutrons per megawatt of power (~ 10% more) but also permitted a core configuration that provided a higher cadmium ratio, i.e., a higher signal-to-noise ratio for the type of experiments for which the reactor was designed. To further enhance this important feature (high signal-to-noise ratio attained by lowering the fast neutron background), the NBSR incorporated a unique split-core design that decreased the fast neutron background in the beam tubes. The heavy water/core configuration also made it possible to extract more and larger beam tubes than at any other reactor in the U.S., including those operated by the DOE.

Recently, with congressional funding, the power of the NBSR was doubled to 20 MW to meet new and increased research demands, making it the highest powered research reactor licensed by the NRC. Although still at somewhat lower power than the two major DOE research reactors, the greater number and larger size of the NBSR beam tubes makes its overall programs fully competitive with the DOE reactors.

Another unique feature of the NBSR is that it is the only reactor in the U.S. designed to accommodate a large cold neutron source and associated versatility of access. Such a source will be installed shortly and will require the optimum in neutron level and quality.

Thus, a great deal of effort and money has gone into all aspects of optimizing the capability of the NBSR, and any reduction in that capability would undermine the extensive effort (funded by Congress) and innovation through which the NBSR has become a true national resource.

Current Research Programs

The NBSR now serves more than 300 scientists and engineers annually from many divisions within NBS, 16 other federal agencies, 24 industrial laboratories, 30 universities, and 14 foreign laboratories. Major programs which would be affected by the conversion include:

Hydrogen in Metals

The NBS neutron scattering group has the best capability in the world for studying the behavior of hydrogen in metals and alloys. In particular, advanced instrumentation with very low background has been developed to allow neutron spectroscopic studies of the local environment and bonding of very low levels of hydrogen (down to 0.1%) inspite of the very low signals available from these materials. This capability represents a new, powerful, and sensitive probe of mechanisms for mechanical effects (e.g., embrittlement, corrosion) and physical effects (e.g., electronic structure in amorphous semiconductors and metals, superconductivity) which affect the development, performance, and failure modes of metals and semimetals in a wide range of technological applications. Many scientists from universities, industrial laboratories in the U.S., and from foreign research centers are participating in research using this powerful tool at the NBS reactor.

Catalysis

NBS has established the leading effort in the United States in the application of neutron scattering methods in the study of the structure, molecular processes, and bonding states of molecular species in industrial catalysts. Neutron methods are especially powerful for such research because they are specifically sensitive to hydrogen and other light atoms which dominate the structure and molecular species which are critical to catalytic processes, and the great penetrability of neutrons allows in-situ studies to be made under pressure and temperature conditions present during catalysis. The importance of this work is reflected by the fact that industrial labs (e.g., Exxon, Mobil, Dupont, W. R. Grace) and universities (e.g., U. California, Auburn, U. Maryland) from all over the U.S. are participating in this neutron research. Again, high signal-to-background ratios are essential to allow probing of critical molecular species which are often present as only a small fraction of the catalyst material.

Electronic Materials

There is an extensive research program at the NBSR in using advanced neutron diffraction and inelastic scattering methods to investigate the submicroscopic properties and phase transformations of new kinds of ionic conductors, ceramics, superconductors, and semiconductors which are being developed for future use in high-technology devices and products. Neutrons provide a special probe of light atom arrangements, diffusion mechanisms, and subtle interatomic interactions and phonon modes which are a key to the understanding of the properties of these new materials. Modern ultra-high resolution neutron powder diffraction and spectroscopic methods, which need the highest possible neutron beam intensities, are required for these studies. There are a wide range of participants in this research, including scientists from AT&T, GTE, MIT, Purdue, and several European laboratories.

Biomolecular Structure

NBS has developed at the NBSR one of three facilities in the world for the study of the structure of biomolecules, such as enzymes and other proteins. These studies provide unique information on the nature of hydrogen bonds and water molecules which play a critical role in biochemical processes in biological materials. This research not only is at the core of the NBS biotechnology program, but involves cooperative research arrangements with NIH and a number of universities around the world. Due to the great need for higher spatial resolution and improved intensity, a new biological diffractometer is being planned for installation at beam tube 8 of the NBSR. Given the complexity of these large molecules requiring the analysis of thousands of reflections, these biological structure studies require many weeks to complete even with the highest neutron fluxes.

Ceramics

One of the major areas of opportunity for U.S. materials based industries is the development of new or improved ceramic materials with superior mechanical and refractory properties to allow their use (often substituting for much heavier, more expensive metals) in advanced products and applications ranging from automobile engines to aircraft turbine blades, to semiconductor devices. The existing thermal neutron scattering spectrometers and developing cold neutron instrumentation at the NBSR offer the best U.S. resource for precise studies of the atomic structure, phase transformation, residual stresses, and submicroscopic voids and microstructures which control the critical physical and mechanical behavior of all classes of advanced ceramics, and which affect their use and durability in technological application. The need for higher resolution neutron diffraction and small angle scattering to probe more complex ceramic structures and microstructures, and to remain internationally competitive in this research area requires the highest possible neutron flux and low background. Even with the excellent facilities available at the NBSR, some important experiments are marginal because of low signal-to-noise ratio. These marginal experiments could not be attempted with the reduction of the signal-to-noise ratio that would result from converting the NBSR to LEU fuel.

Magnetic Materials

The magnetism and magnetic materials program at NBSR is involved with studies of new high-technology magnetic materials using neutron scattering techniques. The program includes active collaboration with Allied Signal, IBM, Naval Surface Weapons Center, Naval Research Lab, and many universities. The magnetic materials studied at the NBS reactor range widely from amorphous materials which show promise as new low-loss inductor cores to new rare earth-based compounds which have application in permanent magnets and magnetostrictive transducers. These systems and experiments are at the cutting edge of new materials technology, and, as such, place stringent demands on the experimental facilities and techniques used to probe the details of the microscopic magnetic order. In particular, the maximum achievable neutron flux and, more importantly, the highest attainable signal-to-noise ratio are critical factors in determining the success or failure of many of the experiments. A reduction in either of these may not simply mean that an experiment requires longer counting times, but rather that it can not be done at all because the signal-to-noise ratio would fall below acceptable levels, and/or the experimental times would be beyond acceptable limits. Many new "in-situ" types of experiments involve time-dependent phenomena, where the phenomena under study decay with time, making maximum available fluxes and minimum counting times essential.

Nuclear Methods of Chemical Analysis

The impact of conversion from HEU to LEU fuel in the NBSR would have a significant and negative effect on the quality of the work done by the Nuclear Methods Group. To achieve even the degraded level of operations resulting from conversion to LEU would require a substantial investment of both time and money for recharacterization of facilities during which time, vital work would have to be suspended. The Group uses the reactor in two fundamentally distinct ways--as a beam measurement facility, and as an incore irradiation facility. The beam instruments would suffer a degradation proportional to the reduction in reactor flux. Since the facilities are now used at 100% capacity, a nominal 10% reduction in beam flux would mean that 10% of the measurements now done would be lost.

To put the reduction of measurement capability in context, it should be realized that in both the area of neutron activation analysis (NAA) and in the area of the newer beam techniques, the work at the NBSR is among the most important and powerful in the U.S. and, in some cases, the world. In particular, the Standard Reference Material production at NBS depends heavily on both the accuracy and sensitivity of NAA as developed here for crucial certification measurements. These Standards provide not only the basis for commercial and technological development and world competitiveness, but also serve as the foundation of the important clinical, medical, health, and environmental measurements necessary for improvement in these areas, as well as rational government regulation. A strong and innovative program, and, in the case of Neutron Depth Profiling, the premier national facility, exist at NBS. These measurement capabilities are heavily used in collaboration with researchers from many of the most farsighted U.S. industries. The ability to carry out these unique materials analysis measurements is only now beginning to be duplicated by overseas competitors. To degrade the capability of this important U.S resource would no doubt be done at the price of reduced innovation and standards' accuracy in the future.

The impact on the in-core irradiation facilities would be even more severe. In addition to the 10% loss in sensitivity, extensive facility recharacterization would be necessary. More than two staff-years would be required to accurately measure the flux, the flux gradient within an irradiation capsule, and elemental interferences due to spectrum shape. All of these must be known and stable in order that the accurate measurements done by this Group can be maintained. Even the threat of such a conversion has the chilling effect of stopping the planned development of monitor activation analysis, which requires a stable spectrum shape. The continuous variation in the neutron spectra, as the LEU was phased in, would make such precise calibration useless until the phase-in was completed a year later.

High Technology Metals

Neutron scattering has proven to be a valuable tool for the nondestructive characterization of residual stress and distributed damage in, for example, high technology metals and alloys important to many industrial areas, such as aerospace. With regard to residual stress, NBS has been a leader in the development of energy dispersive diffraction techniques resulting in the ability to map residual stress throughout the volume of thick (~several cm), even highly textured, specimens for comparison with macroscopic mechanical property tests. With the present NBS instrumentation and neutron flux, residual stress can be determined with a spatial resolution of about 1 mm. In many cases, residual stress measurements on a finer scale (~10 microns) are required. Efforts are underway to use focusing monochromators (to concentrate the available flux on smaller sample volumes) and position-sensitive detectors (to record as much of the relevant scattered radiation as possible) to improve the spatial resolution to this level. Any drop in available thermal flux or increase in beam contamination would, of course, severely hamper these efforts and would limit the future development of this valuable technique.

A similar situation pertains to the characterization of distributed damage (e.g. cavitation and micro-cracking produced by creep and fatigue) by small angle neutron scattering (SANS) in high strength metals such as new precipitation strongband steels and super alloys. With SANS, the volume fraction and size distribution of submicron flaws and defects can be determined in bulk specimens providing a better understanding of how damage develops and leads to fracture. SANS measurements at the early stages of damage formation, when defects are small and few in number, are difficult and require the best signal-to-noise conditions possible. Any degradation in signal-to-noise would have a direct adverse effect on measurements of this type making some measurements impractical and increase the time for others by 20-30%.

Polymers

NBS is one of the major centers in the U.S. for the application of neutron methods to the characterization of polymers. Extensive collaboration exists with industrial laboratories, including Exxon, IBM, DuPont, and Eastman-Kodak. The development and application of neutron scattering techniques has provided information on the chain conformation in bulk polymers, which cannot be obtained by any other method, and forms the basis for understanding the structure of model polymer systems at the molecular level. The success achieved on model systems is leading to the application of these techniques to more complex, higher molecular weight systems typical of commercial materials and to measurements under simulated processing conditions. In both of these areas, the possibilities are ultimately limited by flux and background. For example, through the use of position-sensitive detectors a neutron scattering pattern, which provides a "snapshot" of the material's microstructure, can be recorded in a matter of several minutes in which virtually all of the scattered neutrons are detected. Reducing this measurement time to times which are relevant to polymer processing is, therefore, presently limited by the available incident flux and background. Measurements on higher molecular weight materials require that the scattering at very small angles be measured, which in turn requires the best possible beam collimation. Here again the limit on what materials can be studied is imposed by the available flux and background. Thus in both these cases, and in others as well, a reduction in flux or signal-to-noise ratio would adversely affect just those areas, such as real-time measurement, where neutron scattering research on polymers is currently advancing.

Neutron Fields Standards

The NBS Neutron Dosimetry Group is engaged in the development and application of benchmark neutron fields as permanent facilities for neutron dosimetry standardization, for neutron detector calibrations, and for reaction rate cross-section measurements. Strong interactions with outside organizations, both in the federal and private sector, are important programmatic characteristics. A substantial component of the Group's activities make use of the reactor thermal column. These facilities depend upon core leakage radiation for their operation. Any change in the neutron energy spectrum and neutron-to-gamma ratios of that radiation would affect important characteristics of the neutron fields which have been developed with the present core design, and would require extensive recharacterization.

Neutron Dosimetry Standards

Filtered beams at the NBSR are unique national standards for testing and calibrating neutron instruments. There are no similar high quality sources of KeV neutrons anywhere in the world, and they are used by everyone developing new types of neutron instruments, as well as for long term quality control tests of existing instrument designs. Their characteristics were very carefully established when the beams were first made operational and we depend upon these characteristics staying constant. Any change in the neutron spectra of the NBSR would present serious problems. If the spectra were ever changed, the required restandardization would be a very major undertaking, and would require a reassessment of the quality control programs, as well.

Fundamental Physics

The advancement of neutron physics and of fundamental measurements involving neutrons is another area where NBS has had a significant role. The importance of signal-to-noise for such efforts is aptly illustrated by a recent experiment (T.M. Giebultowicz, et al., Phys. Rev. Lett. 56, 1485 (1986)) carried out at the NBSR in which the existence of charge density waves (CDW) in a simple metal (potassium) was, for the first time, convincingly demonstrated. A CDW is a modulation of the spatial distribution of the conduction electrons in a metal which in turn causes a small, periodic distortion of the lattice. The distortion gives rise to secondary (or satellite) Bragg reflections which are extremely weak in intensity (less than 10^{-5} of the primary Bragg peaks). The existence of such a phenomenon was predicted more than twenty years ago, but was confirmed only recently as a result of a combination of factors, including: 1) the growth of a large, high quality single crystal sample; 2) months of painstaking measurements at NBS; and 3) the availability at NBS of a neutron spectrometer with high flux and extremely low background (less than 1 count/5 min). This discovery is of fundamental importance to the theory of simple metals and could not have been achieved without the lowest noise conditions to permit detection of the very small (much less than background) true signal.

A number of experiments of fundamental importance (e.g., an improved measurement of the lifetime of the neutron) are now being planned for the NBS reactor. In every case, signal-to-noise determines the ultimate limits of what can be obtained. A degradation of the signal-to-noise at the NBSR would make these experiments much more difficult or not feasible at all.

Neutron Radiography

In addition to the normal neutron radiographic activities similar to those carried out at many reactors, NBS is collaborating with the Smithsonian Institution in the study of works of art. In particular, NBS has the only facility in the U.S. for the autoradiography of paintings. Paintings up to several feet on a side can be exposed at the face of the thermal column and then removed to a dark room for the exposure of film to form an image. The gamma-ray spectra of the painting materials are obtained at the same time. This provides detailed information on the paint pigments used and shows the image of any painting or foundation work that may lie below the surface painting. This is not only of great value in the authentication of paintings, but also provides the art historian with a wealth of information not obtainable in any other way. Because many of these paintings are of great value (Rembrants have been studied), radiation damage is of great concern. The NBS thermal column is probably the best place in the world for such a facility because the thermal column has a D_2O moderating tank in addition to the normal graphite moderator, a thick D_2O reactor reflector, and a permanent D_2O cooled bismuth shield. Any decrease in thermal neutron flux relative to fast neutrons and gamma-rays would increase the radiation damage to these rare works of art.

Many of the above programs are the focal point for such activities in the U.S. All are competitive with the best in the U.S. and some are at the apex of international effort. (Last year, 30 foreign scientists chose to spend time at the NBSR although excellent facilities were available to them in Europe or Japan.)

Cold Source Initiative

The above summarizes the major programs that are currently being carried out at the NBSR. However, because of its large cold source, the NBSR is the only U.S. reactor with the potential to develop a neutron guide hall and associated instruments that would be fully competitive with those in Europe and funded for Japan. Included in the President's FY87 budget is a request for $27,000,000 over three years to realize this potential This would implement a top priority recommendation of a National Academy Committee. In November 1983, the President's Office of Science and Technology Policy asked the National Research Council of the National Academy to assist in establishing priorities for major facilities for materials research. A prestigious committee was set up co-chaired by Frederick Seitz (a past president of the National Academy) and Dean Eastman of IBM. After many months of intensive work, the committee recommended major facilities in priority order in two categories: major new facilities, and new capabilities at existing facilities. "Centers for Cold Neutron Research" were their first priority in the latter category. Specifically, they recommended "Guide halls and instrumentation for exploiting the only cold neutron sources in the U.S. located at Brookhaven National Laboratory and at the National Bureau of Standards should be developed in an orderly fashion." NBS was chosen as the first facility to be funded because of its larger cold source and greater accessibility to the source. The U.S. position in fundamental materials research using neutron methods has steadily fallen behind that in Europe because the U.S. is many years behind the Europeans in developing cold neutron research capabilities. The Department of Commerce is now trying to redress this imbalance by utilizing the capabilities of the NBSR, but these efforts could be thwarted by the significant reduction in NBSR capabilities that would result from the requirement to use LEU.

Summary

- The NBS reactor is a National Center for the application of neutron methods to scientific and technological problems of national importance.

- A great deal of money and effort has gone into optimizing the performance of the NBSR. It operates at its safe technical limit continuously, 24 hours a day, except for refueling.

- The many experimental facilities are state-of-the-art, and several are the best in the United States. The NBSR provides the Nation the only opportunity to develop a Center for Cold Neutron Research comparable to those in Europe.

- o The research programs are world-class, serving the needs of many agencies, universities, and industrial laboratories. They are an essential ingredient in maintaining and improving the United States' international competitiveness in science and technology.

- o Conversion to LEU fuel would:

  1. Reduce the productivity of all the research programs by 10 to 30% depending on the difficulty of the experiments.

  2. Some of the more important experiments would no longer be feasible.

  3. Certain standard reference beams and fields would require extensive recharacterization and be unavailable for one to two years.

  4. Adversely affect the Department of Commerce's efforts to maintain and improve the international technologically competitive position of the United States.

Clearly, the NBSR serves a "unique purpose" in providing the Nation with the measurement capability to address a large variety of technologically important research areas. Conversion to LEU fuel would significantly reduce the ability of the NBSR to provide this urgently needed function.