

NUREG-0963

Review and Evaluation of the Nuclear Regulatory Commission Safety Research Program for Fiscal Years 1984 and 1985

A Report to the Congress
of the United States of America

Advisory Committee on Reactor Safeguards
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555



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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

February 18, 1983

The Honorable George H. W. Bush
The President of the Senate

The Honorable Thomas P. O'Neill, Jr.
The Speaker of the House

Gentlemen:

I am pleased to transmit to the Congress the report of the Advisory Committee on Reactor Safeguards on the Nuclear Regulatory Commission Safety Research Program for Fiscal Years 1984 and 1985. This report is required by Section 29 of the Atomic Energy Act of 1954 as amended by Section 5 of Public Law 95-209.

Part I of this report is intended to serve as the Executive Summary. Part II includes specific comments and recommendations on the research involved in various Decision Units of the NRC research program.

A copy of this report is being sent to the Chairman of the Nuclear Regulatory Commission.

Respectfully submitted,

A handwritten signature in cursive script that reads "Jeremiah J. Ray".

Jeremiah J. Ray
Chairman

TABLE OF CONTENTS

	<u>PAGE</u>
PREFACE	vii
PART I - GENERAL COMMENTS AND RECOMMENDATIONS	1
1. Introduction	3
2. General Recommendations	4
3. Some Matters of Special Importance	4
4. Budget Recommendations	10
5. Specific Comments and Recommendations	13
Table 1 - Proposed Budget for the NRC Safety Research Program for FY 1984 and FY 1985	14
PART II - SPECIFIC COMMENTS AND RECOMMENDATIONS	15
1. Reactor and Facility Engineering	17
2. Facility Operations	24
3. Thermal Hydraulic Transients	33
4. Siting and Health	37
5. Risk Analysis	40
6. Accident Evaluation and Mitigation	46
7. Loss of Coolant Accidents	52
8. LOFT	54
9. Advanced Reactors	55
10. Waste Management	58
APPENDIXES	65
Appendix A - References	67
Appendix B - Glossary	69
Appendix C - ACRS Charter and Membership	72

PREFACE

This is the sixth report by the Advisory Committee on Reactor Safeguards (ACRS) that has been prepared in response to the Congressional requirement for an annual report on the Nuclear Regulatory Commission (NRC) Reactor Safety Research Program. As previously requested by the Congress, the timing of this report has been adjusted to enable the ACRS to address the proposed budget for FY 1984 and 1985 that has been submitted to the Congress by the President.

Detailed comments and recommendations are focused primarily on the research programs and budget proposed for FY 1984. Due to lack of specific details on programs and budget proposed for FY 1985, similar detailed comments are not provided at this time for FY 1985.

As in previous reports, we have interpreted the words "reactor safety research" to include safety-related research in all phases of the nuclear fuel cycle and power plant operations, excluding only those having to do with nonsafety-related environmental concerns.

Part I is a compilation of our general comments and recommendations regarding the NRC Safety Research Program, and includes our budget recommendations and an identification of matters of special importance that deserve increased emphasis. It is intended to serve as an Executive Summary.

Part II is divided into ten chapters, each of which represents a Decision Unit of the NRC research program. In each chapter, we have included specific comments on the research involved in the Decision Unit, an assessment of priorities, and recommendations regarding new directions and levels of funding.

All references to funding in this report relate to funds budgeted for program support and equipment. Funds allocated for NRC personnel and administrative support have not been included.

PART I
GENERAL COMMENTS
AND
RECOMMENDATIONS

GENERAL COMMENTS AND RECOMMENDATIONS

1. Introduction

This report provides a review of the Nuclear Regulatory Commission (NRC) Safety Research Program with comments in depth on the activities and budget proposed for FY 1984. The nature of the program and planning is such that similar detailed comments cannot be provided at this time on the research and budget proposed for FY 1985.

The research programs for FY 1983 and those proposed for FY 1984 and 1985 are in many ways moving in new directions quite different from the previous programs, many of which were initiated by the Atomic Energy Commission prior to the creation of the NRC. The extensive program on large loss-of-coolant accidents (LOCAs) has essentially been completed, and operation of the Loss of Fluid Test (LOFT) Facility has been transferred to the Department of Energy (DOE). New programs related to new needs and consistent with the increasing number of operating reactors have been begun. These include research related to the prevention and mitigation of severe accidents involving core damage or core melt; better definition of accident source terms; the development of methods of probabilistic risk assessment (PRA); the problem of pressurized thermal shock to reactor vessels; and improved understanding of phenomena and behavior relating to plant operational transients and small LOCAs. Another new area relates to the human factors and human engineering aspects of reactor operation during both normal and abnormal conditions.

The period FY 1983 through 1985 represents also a significant change in the trend of funding for the NRC Safety Research Program. It now appears that the funding for research program support will decrease in each of these years, in contrast to a steady increase prior to FY 1983. These decreases seem to be related chiefly to reductions in the National budget rather than to any real or perceived decrease in the need for research on nuclear safety. The decreases, at least through FY 1984, and probably through FY 1985, have been accommodated for the most part by reductions in those programs of lower priority. For this reason, we believe that the reduced funding for these years will not seriously impair the effectiveness of the NRC research program as it relates to the safety of operating reactors. However, this may not be true if the

funding for research is reduced further for these years or if funding continues to be reduced in future years, unless there is a corresponding reduction in the number or nature of the safety-related problems to be solved. We intend to follow closely the trends in funding in relation to needs.

2. General Recommendations

In our previous reports to the Congress (Refs. 1, 2)*, we have commented on the need for more policy guidance from the Commissioners on the directions and priorities of the NRC Safety Research Program. We note with approval a significant improvement in this area. For example, the reductions made in the programs to accommodate decreased funding in FY 1983 and 1984 were guided by the Commission policy that priority should be given to the safety of operating reactors, at the expense of programs related to such areas as fuel cycle safety, waste management, transportation, and socioeconomic factors. However, even more specific guidance from the Commissioners is desirable, and will be essential if the programs need to be reduced to accommodate further reductions in funding in the future. For example, the research related to severe accidents, chiefly in the Decision Unit on Accident Evaluation and Mitigation, is important and utilizes a large portion of the NRC safety research budget. As discussed in Chapter 6 of Part II of this report, we continue to believe that this program is not well focused. We believe that a better focused program, considering the comments in Section 3.6 of this Part and in Chapter 6 of Part II, might well lead either to reduced funding requirements or to better, more useful, and earlier results for the same money. To do this effectively, however, will require more guidance from the Commissioners than has been provided so far with respect to plant design features that must be considered.

3. Some Matters of Special Importance

3.1 Human Factors

Although the NRC has begun a research program in human factors, there remain some aspects that warrant additional emphasis, including the following:

- Development of an improved approach for determining the appropriate level of skill and knowledge of the operations staff and for judging that it is being achieved.

*References appear in Appendix A.

- Development of an appropriate basis for determining the relevant in-house experience and capability of the licensee's technical support staff.
- Determination of training requirements and skills for maintenance personnel and auxiliary operators.
- Development of improved computer-aided diagnostic techniques to assist the operator during complex transients.

We believe that the Human Factors Program, while addressing issues of vital importance to reactor safety, has been treated somewhat as an unwanted stepchild. This is true, partly because it involves areas of technology that are unfamiliar to the hard-science-oriented NRC Staff, and partly because it lacks strong advocacy within upper levels of the NRC Staff.

3.2 Occupational Protection

Records (Ref. 3) show that the collective occupational doses at commercial nuclear power plants have been increasing significantly in recent years. In fact, radiation doses are among the major considerations in decisions by the NRC Staff concerning inspections and backfitting of plant modifications. Because of the need to control average doses to individual workers, licensees sometimes use large numbers of lesser trained workers to conduct high-exposure tasks.

We believe that this situation can have an adverse impact on plant safety, and recommend that priority attention be given to better control of radionuclide production, movement, deposition, and removal within nuclear power plants. In particular, stronger efforts need to be made to determine how lower occupational doses have been achieved in certain foreign nuclear power plants and whether similar approaches could be applied in the United States. Related activities, including those of DOE and the Electric Power Research Institute (EPRI), should be accounted for in these efforts.

3.3 Seismic Risk

In our reports on several recent operating license applications, we have recommended that additional attention be given to assuring that the seismic safety margins provided are adequate to achieve safe shutdown in the event of a severe earthquake and, in a recent report to the Commission (Ref. 4), we have made recommendations as to how this might be accomplished. The work being performed under the Systematic Evaluation Program indicates that this is relevant

also to older plants. In addition, some of the most recent PRAs have included earthquakes as an accident-initiating event and concluded that this accident source may be one of the more important contributors to risk.

The NRC has an ongoing research Program in Seismology and Geology that has proven to be of considerable value and should be continued. The NRC also has sponsored the Seismic Safety Margins Research Program (SSMRP) that provides some of the methodology needed to better assess seismic risk. However, there is a need for improved but practical methods of probabilistic seismic safety analysis, for more and different analyses, and for better information concerning the ability of the various components and systems of a light-water reactor to perform appropriately during a severe earthquake. We believe that such a program should be developed cooperatively between the NRC and the nuclear industry, and that strong efforts should be made to collaborate with the Japanese in this regard, as is practical. We recommend that a focused program be developed and that necessary resources be provided.

3.4 Design Against Sabotage

The NRC has imposed fairly extensive requirements on access control for nuclear power plants for purposes of security, and has some programs to examine possible design improvements intended to reduce the likelihood of sabotage. However, the United States does not now include some protective measures that are required in several European countries and, although the NRC supports the concept of standard plants for the future, it has not developed design criteria to be used with regard to sabotage protection for such plants, except external access control.

The NRC research program has generated several useful reports that contain information that could form part of the basis for deciding whether the NRC should have a policy concerning design measures to protect against sabotage and, if so, what that policy should be. We believe that the evaluation and synthesis of the available information, the generation of additional information as may be needed, and the development of options, cost-benefit analyses, and trade-offs should be accomplished as part of the research program, with active input by the regulatory staff.

We believe that the matter of design measures against sabotage should be given higher priority and sufficient funding in FY 1984 and 1985 to determine appropriate requirements for both existing plants and for plants yet to be designed.

3.5 Use of PRAs in Decision Making

An increasing number of PRAs of varying depth and breadth have been completed or are under way. Furthermore, PRA methodology is being applied increasingly to a wide range of specific issues. This marked acceleration of the use of PRA suffers from several deficiencies, including the following:

- There exist no well-established quality assurance criteria for preparing PRAs.
- There exist no guidelines for when peer review is to be required and for what constitutes an adequate peer review of technical reports which will be used in licensing, whether prepared by the NRC Staff or by licensees or applicants.
- There exists no guiding philosophy on how to factor uncertainties in PRAs and in cost-benefit analyses into decision making.
- There exists no formal guidance concerning threshold criteria for action which would guide the NRC Staff and the industry in deciding as to when safety improvements should be made and on what timescale.

These are not simple matters; however, research could help provide a basis for an improved, more consistent, and better articulated approach than now exists.

3.6 Severe Accident Research Plan

In our report to the Congress on the NRC Safety Research Program for FY 1983 (Ref. 1), we commented on the lack of a well-focused program. We suggested that first priority be given to definition of the major questions that need answering and the policy alternatives available for dealing with severe accidents. With this background, specific research can then be proposed to provide the information needed for decision making. We observed that the NRC had made inadequate progress toward developing the information needed for decision making in regard to dealing with severe accidents. Although the NRC Staff has prepared a Severe Accident Research Plan (Ref. 5), we do not believe enough effort has yet been given to definition of the questions that must be answered before severe accidents can be dealt with in the licensing process.

As an example of one important question, we note the NRC Staff conclusion, in connection with the development of Safety Goals for

Nuclear Power Plants, that further information is needed before a criterion on containment performance can be developed. Nevertheless, the Severe Accident Research Plan does not describe the questions that need answering in this connection, nor does it describe a plan which will permit such a criterion to be developed.

We reiterate our belief that the severe accident problem should be dealt with for both existing plants and for those not yet in operation. We recognize that the approach may be different for these two classes. But for each class, we believe that some effort in developing possible approaches to licensing is necessary before a meaningful research program can be planned. We recommend that this matter receive high priority in the NRC Severe Accident Research Plan.

3.7 Design-Related Safety Research

Many of the current unresolved safety issues, as well as several other matters of interest, arise from the manner in which power plants have been designed for normal operation and for anticipated transients. Challenges to safety systems are more frequent than desirable. The nuclear utilities have asked that light-water-reactors (LWRs) be made more "forgiving" of operational upsets and malfunctions.

It is important that the NRC develop an improved understanding of how design can affect safety so that such knowledge can be factored into the regulatory requirements without specifying the design itself.

We recommend that the NRC institute a program of design-related safety research and analysis. To be meaningful, the formulation and execution of such a program must have the benefit of active participation or direction by personnel familiar with systems behavior, plant and reactor controls, thermal-hydraulic behavior, and nuclear steam supply system design. A major goal of the study should be to ascertain means of reducing the frequency of significant challenges to plant protection systems and to examine design approaches which make it less likely that anticipated transients will become severe.

3.8 LWR Safety Approach in Other Countries

There now exist sophisticated approaches to LWR safety in many foreign countries including France, the Federal Republic of Germany (FRG), Japan, Sweden and the United Kingdom. For example, the Japanese have specific approaches to seismic design and qualification, the British have developed a number of significant additional

safety requirements for their version of the Standardized Nuclear Unit Power Plant System (SNUPPS), the French have made or are making changes in their pressurized water reactors (PWRs), and the Germans and Swiss have developed special requirements for shutdown heat removal and sabotage protection.

The NRC Staff should prepare a detailed comparison of these regulatory approaches with those of the United States on all issues of safety significance, obtain as good an understanding as practical of the reasons for the differences, and develop a recommendation as to how the United States should proceed in light of these perspectives. Such a study could be of use not only with regard to existing plants but also could be important in developing criteria for future standard LWRs. These studies could be funded either within the NRC Safety Research Program or within the NRC Staff Technical Assistance Program.

3.9 Institute for Analysis of Reliability, Risk, and Cost/Risk/ Benefit

The use of probabilistic techniques is growing rapidly in many aspects of nuclear power plant design, operation, and safety. Quantitative risk analysis is being used in various ways, including the following: (1) to evaluate and prioritize unresolved safety issues; (2) to evaluate the impact of operating experiences; (3) to evaluate the potential for risk reduction of various measures to reduce the probability or consequences of accidents; (4) to evaluate the differences among various siting policies; and (5) to estimate the risk from individual nuclear facilities. However, probabilistic risk and quantitative reliability analysis is a relatively immature, still developing field with significant gaps in methodology and large uncertainties in data.

The NRC is not unique in facing a growing need to attempt to quantify risks as well as cost/benefit trade-offs. The Environmental Protection Agency (EPA), Food and Drug Administration (FDA), Department of Transportation (DOT), and Occupational Safety and Health Administration (OSHA), among others, all face severe problems related to a growing need for risk quantification in the face of large uncertainties.

It would be useful to have an independent group of experts who can be expected to present an unbiased and reliable technical review and evaluation of the various probabilistic studies of interest. It would be useful to have an institute which would be responsible to the needs of the NRC and other Federal agencies for in-depth peer review, and which also fills the needs of the Congress and the

public for meaningful risk estimates from a group of unimpeachable integrity.

We recommend that the Congress explore the desirability and feasibility of some such institute.

4. Budget Recommendations

4.1 General Budget Recommendations

The FY 1984 and 1985 safety research programs and budgets that have been submitted to the Congress are significantly smaller than those that we reviewed in our report to the NRC Commissioners in July 1982 (Ref. 6). For example, the FY 1984 budget for research program support and equipment has been reduced by \$33.7 million. Of this amount, \$17.5 million represents transfer of LOFT operations support to the DOE, and thus does not require a corresponding reduction in the research program. However, the remaining reduction of \$16.2 million, or about eight percent, has had to be accommodated by reductions in the safety research programs.

We have reviewed carefully the required reductions in programs for FY 1984 and believe that they can be accomplished without undue harm to the NRC Safety Research Program. A significant portion of the budget reduction has been in programs not related to reactor safety. The remainder has been accommodated by deferring or stretching out programs based on currently perceived priorities. Some internal reallocations have been made as a result of the decreased budget, others will have to be made as priorities change or new problems arise, and still others are recommended by us below in Section 4.2, and in Part II of this report. However, in general, we endorse the proposed budget for FY 1984 and its allocation among the various Decision Units as shown in Table 1.

For FY 1985, we believe that the proposed budget in Table 1 is appropriate. When we reported in July 1982 on the budgets proposed to the Commission, we felt that a reduction of about seven percent from FY 1984 to FY 1985 was too large, and commented as follows:

We are not at all comfortable with the proposed rather significant decrease in funding for FY 1985 as compared to FY 1984. Although some of the existing programs will be completed or greatly reduced in size as research objectives are reached, it seems highly likely that new questions will arise between now and the beginning of FY 1985. Unless these are as dramatic as the Three Mile Island Unit 2 (TMI-2) accident, it would seem more

desirable to budget for contingencies or for "new programs" rather than having to seek a supplemental appropriation.

As a result of our recommendations, the proposed FY 1985 budget was increased so that it represented a reduction of only about four percent from FY 1984. Since the budgets now proposed to the Congress are in about this same proportion, we consider the proposed FY 1985 budget acceptable at this time. Nevertheless, we call the attention of the Congress to the comment quoted above and, for the reasons given there, caution against any further reduction in the budget proposed for FY 1985.

4.2 Specific Budget Recommendations

The following more specific recommendations regarding the funds allocated to the various Decision Units are summarized from the discussions and recommendations in Part II:

- (1) Reactor and Facility Engineering: A portion of the reduction in funds may be accommodated by taking advantage of industry research or industry cooperation in the areas of equipment qualification and hydrogen control. Needed and planned research on integrity of containment penetrations following severe accidents should be given higher priority, with re-allocation of funds as necessary.
- (2) Facility Operations: Funding in this area has been reduced severely, with most of the reduction in the Human Factors Programs. In order for the reduced FY 1984 funding to satisfy programmatic needs, the proposed work must be better focused by improved planning. The funding for FY 1985 seems to be marginally adequate but, until the aforementioned planning has occurred, the funding requirements cannot be assessed properly.
- (3) Thermal Hydraulic Transients: The budget for this area has not been reduced since our review in July 1982 and is significantly higher than for FY 1983. We find this level of support appropriate and adequate.
- (4) Siting and Health: Funding has been reduced significantly from the July 1982 figure but is still slightly higher than that for FY 1983. Although we recommend some changes in emphasis as well as the assignment of priorities within this Decision Unit (see Part II, Chapter 4), we consider the funding level adequate.

- (5) Risk Analysis: In our previous reports (Refs. 1, 2), we have recommended expanded programs in specific areas in this Decision Unit and corresponding increases in funding. We are not satisfied with what has been accomplished or what is proposed and we have again provided specific recommendations for programs, directions, and emphasis in Chapter 5 of Part II. We consider the proposed level of funding for FY 1984 adequate for the kinds of programs we have recommended. We recommend that the Congress single out the matter of Severe Accident Policy and authorize the NRC to apply all necessary resources, as can meaningfully be used, in FY 1983 and FY 1984 to provide that information which appears to be relevant to timely policy decision making.
- (6) Accident Evaluation and Mitigation: Although funding has been reduced somewhat from the FY 1983 level and from the FY 1984 budget level proposed in July 1982, our concern with this Decision Unit is not with the levels of funding but with the research program proposed to provide a basis for a Commission policy relating to severe reactor accidents. Our concern is discussed at some length in Chapter 6 of Part II and in several reports (Refs. 6-9) we have made to the Commission. We believe that the proposed level of funding is adequate for a well-planned and well-focused program in this Decision Unit, especially if due regard is given to our recommendation that \$2 million be reallocated from the research on Damaged Fuel to that on Improved Safety Systems.
- (7) Loss of Coolant Accidents: The funding level proposed for FY 1984 is adequate. In general, we support international cooperative programs in this area but recommend that their cost-effectiveness be reviewed and considered before new agreements are entered into.
- (8) LOFT: We support the termination of NRC funds for the LOFT Program along with the transfer of the LOFT Facility operation to the DOE.
- (9) Advanced Reactors: The funding for research related to the Clinch River Breeder Reactor (CRBR) and for some more generally applicable Liquid Metal Fast Breeder Reactor (LMFBR) research is adequate for FY 1984. For FY 1985 and beyond, a funding level at least equivalent to this should be maintained and emphasis shifted to generic LMFBR research as the CRBR licensing needs are met. We support the funding for High Temperature Gas Cooled Reactor (HTGR) research only if there

is reasonable likelihood of a construction permit application being received within the next few years. If not, we recommend reallocation of the HTGR research funds to support other more urgent programs in other Decision Units.

- (10) Waste Management: Funding in this area has been reduced significantly in order to maintain support of higher priority programs related to reactor safety. We believe that effective programs can be conducted within the limits of the reduced budget request if due regard is given to our recommendations in Chapter 10 of Part II.

5. Specific Comments and Recommendations

Specific comments and recommendations regarding the scope, nature, and funding levels of the various elements of the NRC Safety Research Program are presented in Part II of this report.

TABLE 1

PROPOSED BUDGET
FOR THE NRC SAFETY RESEARCH PROGRAM
FOR FY 1984 AND FY 1985
(DOLLARS IN MILLIONS)

	FY 1984	FY 1985
1. REACTOR AND FACILITY ENGINEERING	39.8	41.8
2. FACILITY OPERATIONS	14.5	16.5
3. THERMAL HYDRAULIC TRANSIENTS	27.7	22.9
4. SITING AND HEALTH	8.6	9.1
5. RISK ANALYSIS	17.7	16.7
6. ACCIDENT EVALUATION AND MITIGATION	43.9	39.7
7. LOSS OF COOLANT ACCIDENTS	11.0	9.7
8. LOFT	0.0	0.0
9. ADVANCED REACTORS	9.9	9.0
10. WASTE MANAGEMENT	9.3	10.4
TOTAL	182.4	175.8

PART II
SPECIFIC COMMENTS
AND
RECOMMENDATIONS

1. REACTOR AND FACILITY ENGINEERING

1.1 Introduction

The programs in this Decision Unit are directed toward developing a basis for evaluating reliability and safety margins in mechanical components and structures, evaluating relative safety of various piping system arrangements, developing methods for evaluating seismic risks, validating methods for qualification of mechanical and electrical equipment, investigating the integrity of coolant system boundaries, evaluating nondestructive examination procedures, providing equipment qualification information for fire protection and plant aging, controlling normally produced or accidentally released combustible gases and radionuclides, and decommissioning of nuclear facilities.

1.2 Mechanical/Structural Engineering

1.2.1 Mechanical Engineering

The Mechanical Engineering Program emphasizes component structural integrity and operability, including equipment qualification. Work on probabilistic and mechanistic fracture evaluation of reactor coolant piping, that is intended to provide a basis for regulatory decisions on the integrity of piping systems, is being completed. We recommend that evaluation of the applicability of the results of these probabilistic studies to licensing requirements be expedited.

The programs planned for FY 1984 and 1985 address the behavior of piping systems under conditions for which current design limits are exceeded. These programs will provide information useful to regulatory actions pertaining to engineering flaws, faulty construction, and unanticipated design loads.

Studies of damping values and related structural behavior as applied to the seismic qualification of structures and piping systems have been initiated. The results of these studies should be useful in establishing more realistic safety margins under seismic loading conditions.

1.2.2 Structural Engineering

This program is concerned with the strength and behavior of containments and other structures important to safety, chiefly in

response to earthquakes and to internal pressures following an accident. Over half of the effort is devoted to tests to verify methods of calculating the internal pressures that would cause rupture of the containment shell. Although this information is needed, it must not be forgotten that the essential function of the containment following a severe accident is to prevent release of radioactive materials to the environment. Although rupture of the containment shell clearly would permit such leakage, this is not the only, or even the most likely, means. Of equal importance is the potential for excessive leakage through one or more of the many containment penetrations. For this reason, we recommend that research relating to penetration integrity be given high priority in this program. It is essential that such research be started in FY 1984, or earlier if possible, and coordinated closely with the ongoing research related to the strength of containment shells.

1.2.3 Seismic Safety Margins Research Program (SSMRP)

The SSMRP is a multi-year program that will be essentially completed in FY 1984. It has been redirected in recent years so that its principal objective is to develop analytical methods for incorporating the effects of earthquakes in probabilistic risk assessments (PRAs). Since the contribution of earthquakes to risk and to the uncertainties in PRAs may be significant, we support the continuation and proposed completion of this program through FY 1984.

1.3 Primary System Integrity

1.3.1 Fracture Mechanics

This program continues to have value over the long term in providing a basis for regulatory decisions on the integrity of pressure vessels and piping. The NRC Staff is developing a regulation based on a combination of deterministic and probabilistic analyses to establish requirements related to pressurized thermal shock (PTS). The NRC Staff has proposed materials property screening criteria for reactor vessels as a basis for further action concerning PTS. The NRC Staff indicates that several years are available before the first plant will exceed the screening criteria limits. A comprehensive research program on measures to protect against PTS is needed. The NRC Staff and the industry have not yet defined a suitable program. We recommend that the following be included as elements of such a program: improved nondestructive examination capability; further study of in situ reactor vessel annealing; improved fracture mechanics analysis methods and data that will account for realistic crack geometry, cladding effects, and crack

arrest phenomena; and use of three-dimensional and elastic-plastic techniques, where appropriate.

Thermal-hydraulics questions with regard to PTS need further clarification before the actual safety margins of the reactor pressure vessel can be confidently determined. Toward this end, the following items should be included in this research program:

- A thorough analysis of previously experienced overcooling transients that are affected by downcomer/cold-leg thermal-hydraulic conditions.
- Diagnostic capabilities and needs to enable operating personnel to respond effectively to PTS events.
- Assessment of those peculiarities of the several vendor-supplied nuclear steam supply systems that could affect PTS-induced vessel damage.

1.3.2 Steam Generators

A program involving the examination of the steam generator removed from the Surry nuclear plant is continuing. This program is now being partially funded by non-NRC participants from the U.S. industry and international sources. This program is attempting to establish the reliability of inspection techniques for steam generator tubing. Results of this program will strengthen the basis for current regulations. We recommend continuation of this program.

1.3.3 Environmentally Assisted Degradation of Fluid Boundaries

The principal threat to the integrity of piping in boiling water reactor (BWR) systems arises from stress-corrosion cracking of stainless steel piping. This program is investigating this slow degradation process. We recommend its continuation.

1.3.4 Nondestructive Examination

This program will include the development and evaluation of flaw-detection capability coupled with fracture mechanics models for reactor component integrity assessments, chiefly piping-vessel ultrasonic testing (UT) reliability, near-surface UT, ASME Code Section XI improvements, and qualification of equipment, personnel, and procedures.

Current UT techniques and procedures for inspecting large-diameter austenitic pipes and the pressure vessel wall near the wall cladding surface are not satisfactory. We recommend that priority be given to developing satisfactory UT techniques and procedures, methods, and regulatory requirements.

1.4 Equipment Integrity

The Equipment Integrity Program includes the study of environmental and seismic qualification methods for both electrical and mechanical equipment. This program will include testing and evaluation of methods for qualification of selected types of equipment, and continued research on various synergistic effects, on dose rate effects, and on sequential versus simultaneous applications of environmental test parameters. In order to complete this important phase of research, extensive cooperation will be required between NRC and the nuclear industry. We support efforts by the NRC to obtain industry cooperation.

The seismic qualification program for electrical equipment, and the environmental and seismic qualification program for mechanical equipment, are currently scheduled for completion during FY 1987 and 1988. It appears that the schedule for this research is such that it will provide little benefit to current regulatory work. We recommend that the NRC reevaluate the value of this program in meeting regulatory needs for nuclear power plants expected to be licensed in the near future. Industry cooperation may be needed to accelerate availability of the results.

1.5 Process Control

This program includes research on Fission Product Control, Hydrogen Combustion Control, Spent Fuel Storage, and Decommissioning. The objectives of these programs are to test analytical models for evaluating the effectiveness of light-water reactor (LWR) engineered safety features for fission product control; to determine the effect of multiple ignitions and inhomogeneous gas concentrations on combustion mitigation; to assess the behavior and integrity of spent fuel elements stored under wet and dry conditions (including evaluations of criticality); and to develop procedures for the evaluation of nuclear power plant decommissioning.

Except for the evaluation of the effect of reduced density in the cooling water, such as from pool boiling and fire sprays, the studies on criticality appear to be repeating work already done elsewhere. In addition, we believe that the existing research in this area should emphasize experimental rather than calculational

studies. Problems also exist with the research on hydrogen control; although the work on igniters and post-accident inerting is responsive to user needs, the studies on fogs and foams are not. It is therefore mandatory that these programs be redirected and better focused. Included in such reassessments should be a critical evaluation of whether some of these research projects should be conducted by the industry.

With regard to the research programs on Decommissioning, we believe that coordination is insufficient and that emphasis should be on the development of criteria for the control of the decommissioning process rather than on the development of the technology for its implementation. Related areas needing attention include the specification of nuclear power plant design features that will facilitate decommissioning and the development of acceptable limits for the release of materials removed from nuclear facilities for general public use. In addition, there is a need to consider special problems related to the cleanup and restoration of damaged nuclear power plants, such as Three Mile Island Unit 2 (TMI-2). One important issue is the need to establish criteria for the release of waste waters generated in the cleanup process.

We continue to believe that the programs on Process Control are in need of improved organization and a better definition of their goals. In fact, without these changes we suggest that funds currently being used to support these programs, except in the area of decommissioning, be considered for use elsewhere.

1.6 Recommendations

1.6.1 Overall Budget Recommendations

The currently planned budget for FY 1984 is \$39.8 million. We believe that the planned program can proceed effectively at this budget level.

1.6.2 Summary of Specific Recommendations

- a. The evaluation of the applicability of the results of the studies, related to probabilistic and mechanistic fracture evaluation of reactor coolant piping, to licensing requirements should be expedited (Section 1.2.1).
- b. The research relating to containment penetration integrity should be given high priority in the containment integrity program. Such research should be started in FY 1984, or

earlier if possible, and coordinated closely with the ongoing research related to the strength of containment shells (Section 1.2.2).

- c. A comprehensive research program on measures to protect against PTS is needed and the following elements should be included in such a program: improved nondestructive examination capability; further study of in situ reactor vessel annealing; improved fracture mechanics analysis methods and data that will account for realistic crack geometry, cladding effects, and crack arrest phenomena; and use of three-dimensional and elastic-plastic techniques, where appropriate (Section 1.3.1).
- d. Thermal-hydraulics questions with regard to PTS need further clarification before the actual safety margins of the reactor pressure vessel can be confidently determined (Section 1.3.1).
- e. Priority should be given to developing satisfactory UT techniques and procedures, methods, and regulatory requirements for inspecting large-diameter austenitic pipes and the pressure vessel wall near the wall cladding surface (Section 1.3.4).
- f. The value of the seismic qualification program for electrical equipment, and the environment and seismic qualification program for mechanical equipment, should be reevaluated in relation to its ability to meet regulatory needs for nuclear power plants expected to be licensed in the near future. Industry cooperation may be needed to accelerate availability of the results (Section 1.4).
- g. The programs on Process Control are in need of improved organization and a better definition of their goals. Without these changes, we suggest that funds currently being used to support these programs, except in the area of decommissioning, be considered for use elsewhere. Studies on criticality appear to be repeating the work already done elsewhere. Problems also exist with the research on hydrogen control; although the work on igniters and post-accident inerting is responsive to user needs, the studies on fogs and foams are not. It is therefore mandatory that these programs be redirected and better focused. Included in such reassessments should be a critical evaluation of whether some of these research projects should be conducted by the industry (Section 1.5).
- h. Related areas needing attention in the decommissioning area include the specification of nuclear power plant design features that will facilitate decommissioning and the development

of acceptable limits for the release of materials removed from nuclear facilities for general public use. In addition, there is a need to consider special problems related to cleanup and restoration of damaged nuclear power plants, such as TMI-2. One important issue is the need to establish criteria for the release of waste waters generated in the cleanup process (Section 1.5).

2. FACILITY OPERATIONS

2.1 Introduction

The Facility Operations Decision Unit includes programs on Human Engineering, Plant Instrumentation and Control, Occupational Radiation Protection, and Safeguards. It is concerned primarily with operationally oriented safety issues. Experience and risk analyses continue to indicate that these issues are of great importance to reactor safety; improvements in these areas can lead to substantial reduction in risk to the public health and safety.

2.2 General Comments

There has been a tendency for NRC research programs to concentrate in hardware-oriented and other technological areas to the neglect of operational issues. Special attention should be given to research related to human engineering, quality assurance (QA), emergency preparedness, occupational radiation protection, and plant instrumentation and control. We are concerned that the present budget represents a sharp reversal from the previous trend of increasing support for research directed toward the resolution of human factors issues. These are concerns about plant staffing and training, procedures, maintenance, management and organization, and the man-machine interface, which have been recognized in the past few years as being leading contributors to the risks of operating nuclear power plants. We understand that the reduction in human factors research from previously planned levels is for two reasons: (1) the overall reductions in the NRC budget, and (2) the perception by the NRC Staff management that some of the human factors programs were not well-enough formulated to promise useful results. While the first may be a necessity at present, the second demands corrective attention. We appreciate that there will be problems in developing effective research programs in unfamiliar, non-traditional areas. However, the need for such programs has been recognized for two or three years. These important needs should not remain unfulfilled indefinitely. Safety research resources should be directed to the areas of greatest need (viz., human factors research), not to the areas of greatest familiarity. We recommend that the level of funding for this Decision Unit be more commensurate with its relative risk reduction potential as compared to other Decision Units. We further recommend that increased attention be given to the formulation of effective programs in human factors research.

2.3 Human Engineering/Man-Machine

The goal of research in this area is to improve the NRC's and the nuclear community's basic understanding of the impact of humans on reactor safety and of the factors that affect the performance of the overall man-machine system. With improved understanding, the NRC will have the technical bases for conducting regulatory activities that serve to reduce the human contribution to risk. This program includes work on human reliability, personnel staffing and qualification, training, licensee examinations, procedures and testing, and design and evaluation criteria.

The Human Factors Program Plan (Ref. 10)*, issued in November 1982, described a coordinated Agency program, including research activities in human factors, through FY 1984 and 1985. We have previously endorsed this Plan, including the research activities proposed in that Plan. The sharp reduction in human factors research funds, discussed above, will require that the programs and schedules described in this Plan be revised.

We are pleased to note that some of the essential research remains in the FY 1984 budget, including simulator training studies, effects of stress (as in an earthquake) on operator performance, development of improved cognitive models, human factors considerations in maintenance, operating procedure effectiveness, and personnel selection and training. Although some of these are at reduced levels, we believe the direction of the research is appropriate.

Other research elements of the Human Factors Program Plan have been eliminated or greatly reduced in the FY 1984 budget. These include research on improved diagnostic aids and research into means that the NRC can use to assess and assure the effectiveness of licensee organizations to operate nuclear power plants. These programs have been sharply reduced in the FY 1984 budget because of the judgment by the NRC Staff management that they were not well-directed toward effective resolution of the important safety issues involved. While we have no reason to question this judgment, we must note that the safety issues remain. If the NRC is not prepared to undertake this research in FY 1984, necessary staff resources and management attention should be allocated to it as soon as possible.

* References appear in Appendix A.

Over the longer term, we believe that research in the human factors area should emphasize the following:

- Development of diagnostic aids, probably computer based, to assist control room operators in understanding and managing complex transients.
- Development of criteria to assess competence of a licensee's organization, including competence of the technical support staff.
- Development of standards for use in qualifying both maintenance personnel and auxiliary operators.
- Development of criteria for qualifying operator examiners.
- Evaluation of the effectiveness of operator training and licensing programs.

We believe it is important that a special effort be made to place research in the human factors area with academic and private/industrial research organizations rather than primarily with National Laboratories. The science and technology in this area have a fairly long history but have only recently been explicitly applied to reactor safety issues to the degree now considered appropriate. For this reason, we believe that the body of experience and expertise outside of the National Laboratories is an extremely important resource that should be used. Similarly, the NRC could make more effective use of industry and foreign research results related to human factors.

We believe that research directed toward understanding the effectiveness of traditional QA practices is warranted. QA practices add significantly to a plant's cost, and they carry a heavy share of the burden of assuring a plant's safety. For these reasons, optimization of QA practices is highly desirable. Because of the way in which QA has been historically applied in design and construction, a unique opportunity exists to assess its effectiveness. "Safety grade" components and systems in a plant are designed and constructed under formal QA practices; "non-safety grade" systems are not. By comparing the operating performance of safety grade versus non-safety grade systems through analysis of Licensee Event Reports (LERs) and other sources, such as the Nuclear Plant Reliability Data System (NPRDS), an indication of the effectiveness of traditional QA practices can be extracted. This can, in turn, lead to an optimization and sharpening of this expensive, but important tool. We believe that a modest program of this sort could provide valuable insights.

One important consideration in the management of accident situations is that the control room remain in a habitable condition. Reviews by the ACRS indicate that proper performance of the required heating, ventilating, and air conditioning systems, as well as supporting air cleaning systems is not assured under accident conditions. Accordingly, we recommend that studies be conducted to define the proper locations for control room air intakes, particularly under accident situations; that evaluations be made to assess the possible benefits of increasing the retention capacity of charcoal adsorption beds used to provide protection against inadvertent intakes of hazardous chemicals to control rooms; and that Failure Modes and Effects Analyses be performed for all systems related to control room habitability. As part of the research to support these efforts, we encourage the NRC to join the consortium that is being established to set up a testing facility for evaluating the dispersion of aerosols resulting from chemical spills.

Although research related to emergency preparedness following a seismic event has been expanded in recent years, we have identified two areas in need of attention. The first of these pertains to the possible effects of earthquake damage on the ability of emergency equipment, emergency response personnel, and the general population to respond to an accident at a nuclear power plant. The second area pertains to the need to broaden the scope of emergency planning research to direct more attention to minimizing population exposures due to the consumption of contaminated milk, food, and water during and after a major accidental release of radioactive materials. Specifically, there needs to be a better understanding of the behavior of radionuclides deposited on the ground and their subsequent movement within the terrestrial and aquatic environments. Attention should be given to these problems now and efforts should be undertaken to develop guidance for local officials in their actions during and following an accident. This program should be coordinated with related work being conducted by the Federal Emergency Management Agency (FEMA), the Environmental Protection Agency (EPA), and the Food and Drug Administration (FDA).

2.4 Plant Instrumentation and Control

This program addresses issues associated with the performance of instrumentation and control systems and the components of these systems, the adequacy of regulatory criteria, and the future use of new technology.

Work in this area is important and can produce useful results within a few years. Although the proposed budgets for FY 1984 and

1985 are significantly greater than that for FY 1983, we endorse the proposed levels as appropriate to the magnitude of the work needed. However, we have some reservations about the approach being proposed.

A major component of the work being proposed for this program is related to the unresolved safety issue (USI), Task No. A-47, "Safety Implications of Control Systems" (Ref. 11). The research programs, as currently planned, address issues that are broader than the resolution of this USI. We have two concerns about the planned approach. Our first concern is that the programs appear to focus almost exclusively on detailed computer modeling of existing power plant systems. We saw no evidence of effort to define the risk contributed by existing systems or to specify appropriate performance criteria on a risk or reliability basis. We recommend that before the computer modeling is carried out, there be a study to provide an initial definition of the problem. Although complete definition at this stage will not be possible, some work done at an early stage should serve to provide better focus for subsequent efforts. Secondly, the importance of this USI is such that we urge more emphasis on its early resolution, and less emphasis on broad and not yet well-defined areas. Experience gained in resolution of this USI would permit better definition of future work in more general problem areas.

The work on component assessment related to operational safety, and on diagnostic instrumentation seems to be well planned and should yield useful results. We believe that work done by the NRC on component assessment should continue to be confirmatory and not developmental. The industry should have the responsibility of demonstration, through tests if necessary, that equipment will perform to specifications.

The diagnostic instrumentation work appears responsive to needs expressed by the Office of Nuclear Reactor Regulation (NRR), and although it is exploratory it shows promise of success. It is important that the Office of Nuclear Regulatory Research (RES) maintain close liaison with NRR in this area. We recommend that more attention be given to interpretation of the considerable amount of data being collected in the Noise Analysis program.

We endorse the current level of effort aimed at evaluation of new technology and concur with both its purpose and scope.

2.5 Occupational Protection

The key issues concerning the operational aspects of occupational radiation protection at present are: (1) implementation of the

occupational exposure as low as reasonably achievable (ALARA) concept, (2) improvements in health physics measurements, (3) improvements in the control of the dose from internally deposited radioactive material, (4) improvements in radiation protection in the performance of personnel engaged in NRC-licensed activities, and (5) methods of reducing doses in nuclear power plants. The Occupational Protection Program is designed to ensure progress in each of these areas.

Records (Ref. 3) show that the collective occupational doses at commercial nuclear power plants have been increasing significantly in recent years. In fact, radiation doses are among the major considerations in decisions by the NRC Staff concerning inspections and backfitting of plant modifications. Because of the need to control average doses to individual workers, licensees sometimes use large numbers of lesser trained workers to conduct high-exposure tasks.

We believe that this situation can have an adverse impact on plant safety, and recommend that priority attention be given to better control of radionuclide production, movement, deposition, and removal within nuclear power plants. In particular, stronger efforts need to be made to determine how lower occupational doses have been achieved in certain foreign nuclear power plants and whether similar approaches could be applied in the United States. Related activities, including those of DOE and EPRI, should be accounted for in these efforts.

2.6 Safeguards

The objectives of the Safeguards Program are to improve the physical protection systems employed at nuclear facilities; to reduce the likelihood of radiological sabotage; and to improve the systems for control, accounting, and protection of special nuclear materials that could constitute a threat to either the health and safety of the public or national defense. Safeguards efforts in FY 1984 and 1985 will give priority to research to reduce the vulnerability of operating reactors to insider sabotage. Priority will also be given to the human factors aspects of the interactions between possible safeguards systems and the systems required for safe operation, particularly during safety emergencies.

We recommend that the NRC Staff evaluate sabotage protective measures employed by other countries. This evaluation should then be used in considering design or other criteria related to sabotage protection on standard plants.

2.7 Recommendations

2.7.1 Overall Budget Recommendations

We endorse the proposed funding of \$14.5 million for this Decision Unit in FY 1984. However, we believe that funding for this Decision Unit should be increased in future years.

2.7.2 Summary of Specific Recommendations

- a. Safety research resources should be directed to the areas of greatest need (viz., human factors research), not necessarily to the areas of greatest familiarity. We recommend that the level of funding for this Decision Unit be more commensurate with its relative risk reduction potential as compared to other Decision Units (Section 2.2).
- b. Increased attention should be given to the formulation of effective programs in human factors research (Section 2.2).
- c. Necessary NRC Staff resources and management attention should be allocated as soon as possible to human factors research to evaluate improved diagnostic aids and to assess and assure the effectiveness of licensee organizations (Section 2.3).
- d. Over the longer term, research in the human factors area should emphasize the following (Section 2.3):
 - Development of diagnostic aids, probably computer based, to assist control room operators in understanding and managing complex transients.
 - Development of criteria to assess the competence of a licensee's organization, including competence of the technical support Staff.
 - Development of standards for use in qualifying both maintenance personnel and auxiliary operators.
 - Development of criteria for qualifying operator examiners.
 - Evaluation of the effectiveness of operator training and licensing programs.
- e. The body of experience and expertise relating to human factors outside of the National Laboratories is an extremely important resource that should be used (Section 2.3).

- f. Research directed toward understanding the effectiveness of traditional QA practices is warranted (Section 2.3).
- g. Studies should be conducted to define the proper locations for control room air intakes, particularly under accident situations; evaluations should be made to assess the possible benefits of increasing the retention capacity of charcoal adsorption beds used to provide protection against inadvertent intakes of hazardous chemicals to control rooms; and Failure Modes and Effects Analyses should be performed for all systems related to control room habitability. As part of the research to support these efforts, we encourage the NRC to join the consortium that is being established to set up a testing facility for evaluating the dispersion of aerosols resulting from chemical spills (Section 2.3).
- h. The scope of emergency planning research should be broadened to direct more attention to minimizing population exposures due to the consumption of contaminated milk, food, and water during and after a major accidental release of radioactive materials. Specifically, there needs to be a better understanding of the behavior of radionuclides deposited on the ground and their subsequent movement within the terrestrial and aquatic environments. The NRC's effort in this regard should be coordinated with related work being conducted by FEMA, EPA, and the FDA (Section 2.3).
- i. The work related to the safety implications of control systems should be redirected to place more emphasis on the issues associated with the early resolution of the associated USI and less emphasis on broad and not yet well-defined areas. A study should be performed to provide an initial definition of the problem before computer modeling of existing power plant systems is carried out (Section 2.4).
- j. The work on component assessment related to operational safety should continue to be confirmatory rather than developmental. RES should maintain close liaison with NRR on work associated with diagnostic instrumentation. More attention should be given to interpretation of the considerable amount of data being collected in the Noise Analysis program (Section 2.4).
- k. In the Occupational Protection Program, priority attention should be given to better control of radionuclide production, movement, deposition, and removal within nuclear power plants. In particular, stronger efforts need to be made to determine

how lower occupational doses have been achieved in certain foreign nuclear power plants and whether similar approaches could be applied in the United States. Such efforts should be closely coordinated with the related research being conducted by the DOE and EPRI (Section 2.5).

1. The NRC Staff should evaluate the sabotage protective measures employed by other countries. This evaluation should then be used in considering design or other criteria related to sabotage protection on standard plants (Section 2.6).

3. THERMAL HYDRAULIC TRANSIENTS

3.1 Introduction

The focus of research on thermal-hydraulic transients is on the development of experimental data and analytical methods to assess nuclear plant behavior during complex system transients and small-break loss-of-coolant accidents (LOCAs).

3.2 General Comments

The research program in this area reflects the fact that safety concerns have undergone a realistic evolution in which large-break accidents have correctly received reduced emphasis. Small breaks also are viewed more properly as part of the spectrum of reactor transients. This research will provide an improved technical basis for NRC regulatory activities concerning operator training and plant procedures.

3.3 Semiscale and Babcock & Wilcox (B&W) Simulation

Semiscale continues to provide useful information in a cost-effective manner for the understanding of thermal-hydraulic behavior of pressurized water reactors (PWRs) under LOCA and transient conditions. The Semiscale configuration (MOD-2A) simulating Westinghouse Upper Head Injection plant has been upgraded to MOD-2B with the addition of both new and improved equipment. We continue to support the work of this facility.

We note with approval progress on the Full Integral Systems Test (FIST) Facility and program. FIST is a joint industry-NRC effort that parallels the work at Semiscale for BWRs.

For some time the NRC Staff has identified, and the ACRS has endorsed, a need for experimental data relating to phenomena specific to B&W reactor systems and for the assessment of analytical calculations of B&W plant response to LOCA-related transients and accidents. The NRC and B&W Owners Group have been negotiating details of a cooperative test program using industry facilities. The progress of this effort has been unacceptable to date. This program should be pursued vigorously in order that NRC can make use of B&W accident analyses with increased confidence.

We have commented in past reports (Refs. 1, 6) that a facility with typical B&W plant geometry is needed in a timely manner to provide an acceptable level of confidence in the analytical models that have been developed to predict the phenomena associated with LOCA-related transients and accidents. We note that funding for upgrading the GERDA Facility has been included in the FY 1984 and 1985 budgets. The NRC Staff has concluded that this approach will provide an adequate experimental base and will be more cost effective than a Semiscale MOD-5. We accept this conclusion, but believe that special attention will be needed to provide appropriate analytical support for the experimental program.

In addition, we believe that a well-developed program of separate effects tests is needed in support of the GERDA program. As with any integral-effects test facility, the GERDA design will require inevitable compromises with scaling and the degree of fidelity to which all important phenomena can be modeled. In order that these compromises will not result in invalid analyses and mathematical models of operating plants, we believe that a comprehensive program of separate-effects tests and analyses is a necessary adjunct to GERDA.

3.4 Separate Effects

Research in this area includes experiments designed to provide detailed understanding of specific phenomena during a transient, or a specific component of a plant system. Results of these studies are utilized in the analysis development program to improve and/or help verify computer codes.

NRC has begun a new program to investigate primary to secondary system heat transfer and fluid dynamics under transient conditions within steam generators. NRC has secured the use of a nearly full-scale PWR steam generator for these tests. We believe that this program will provide useful information and is worthy of support, provided that the NRC maintains close management control so that overall program costs do not exceed those currently estimated. Since a large-scale test program such as this often encounters budgetary scheduling difficulties, it clearly requires not only close management but also careful scheduling. We note also that the experimental results will apply directly to Westinghouse plants, and may be extrapolated to those of Combustion Engineering, but will probably not apply to B&W plants.

3.5 Transient Models and Codes

This work is centered on the development of "best-estimate" analytical models and computer codes to improve capabilities for

predicting plant behavior during accidents and transients. Development of PWR and BWR plant analyzers designed to aid NRC in understanding and evaluating procedure development and operator training for accidents is also included.

Two programs deserve mention; the Code Assessment and the Plant Analyzer Programs. While we support the Code Assessment Program at its current funding level, it appears that the assessment effort is not properly aligned with code applications. We recommend that the focus of effort shift more towards assessment of plant transients with a corresponding reduction in the large-break LOCA assessment program.

The Plant Analyzer Program is rapidly becoming a major focus of effort and funding in the program on Transient Models and Codes. As such, it deserves careful scrutiny. This program is divided among three National Laboratories (BNL, INEL, LANL) and a private firm (Technology Data of California) and includes efforts to develop high speed versions of the TRAC and RELAP codes, a parallel processor, and a plant data bank. This is an ambitious project which has the potential of providing a significant contribution to accident analyses for improved procedure development and operator training. It is essential that NRC take an active and aggressive role in planning and coordinating the Plant Analyzer Program to assure its usefulness to NRC.

3.6 Recommendations.

3.6.1 Overall Budget Recommendations

The currently planned budget for FY 1984 is \$27.7 million, a substantial increase over the FY 1983 level. We believe that this level of effort is appropriate.

3.6.2 Summary of Specific Recommendations

- a. The NRC/B&W Owners Group cooperative test program should be pursued vigorously in order that NRC can make use of B&W accident analyses with increased confidence (Section 3.3).
- b. Special attention should be given to developing an effective analytical support effort for the B&W test program. A comprehensive program of separate-effects tests and associated analyses is a necessary adjunct to this test program (Section 3.3).
- c. The program to investigate the primary to secondary system heat transfer and fluid dynamics under transient conditions within

steam generators is worthy of support, provided the NRC maintains close management control so that overall program costs do not exceed those currently estimated (Section 3.4).

- d. The focus of the code assessment effort should be shifted more towards assessment of plant transients, with a corresponding reduction in the large-break LOCA assessment program (Section 3.5).
- e. NRC should take an active and aggressive role in planning and coordinating the Plant Analyzer Program to assure its usefulness to NRC (Section 3.5).

4. SITING AND HEALTH

4.1 Introduction

The Siting and Health Program includes studies of the Earth Sciences (i.e., seismology, geology, meteorology, and hydrology), Site and Environment, and Health Effects. This program addresses the environmental aspects of the siting of nuclear facilities and the protection of the public from harmful effects of radioactivity released from licensed nuclear facilities, in order to develop the technical bases needed for supporting NRC's regulatory requirements and standards-setting activities.

4.2 General Comments

The programs covered by this Decision Unit relate closely to ongoing research in other Decision Units as well as in other Federal agencies and private organizations. For this reason, we recommend that the NRC Staff coordinate their efforts with these groups.

4.3 Earth Sciences

4.3.1 Meteorology and Hydrology

The purpose of the Meteorology research program is to reduce uncertainties in existing methods for predicting the movement of effluent plumes, to extend the distance over which existing models are applicable, and to reduce the uncertainties in predictions of the spatial and temporal characteristics of severe weather phenomena. The Hydrology research includes projects to evaluate groundwater transport and interdiction methods for containing releases resulting from postulated core-melt accidents.

Based on information available during our assessment of the ongoing and proposed research projects in these two areas, we concur with the deferment of the proposed experimental program on Atmospheric Dispersion in order to provide funding for higher priority research.

4.3.2 Geology and Seismology

Research in the Geology and Seismology area is devoted primarily to developing a better understanding of relevant factors in several important regions of the United States. Major emphasis is being

placed on the Eastern United States. An improved knowledge of seismology, geology, and geophysics is important in obtaining an improved capability for estimating the likelihood of occurrence of severe earthquake-induced motion at a reactor site. We support the proposed level of effort and are in general agreement with the research program outlined. However, we recommend that the NRC Staff evaluate further the potential for gaining information significant to the estimation of earthquakes having a recurrence frequency equal to or less than one in ten thousand per year, and that the program be modified to give this matter increased emphasis if worthwhile studies can be defined.

4.4 Site and Environment

This program originally included research to improve methods for evaluating alternative sites for nuclear facilities; to obtain additional information on the relationships of population density, land-use patterns, and siting alternatives for incorporation into the site-selection process; to provide validated technical bases for the development of siting criteria; and to develop methodologies and dosimetric information bases for improved protection of the public and workers from adverse effects of ionizing radiation.

In response to reductions in the research budget, the NRC Staff proposes to defer this program beyond FY 1983 and will not be able to complete the previously planned studies of the impact on safety of increased population densities in the areas near operating nuclear plants. Under the circumstances, we concur.

4.5 Health Effects

The objectives of this program are to improve understanding of the relationship between radiation exposure and the magnitude of the biological effects; to obtain additional information on the metabolism of inhaled and ingested compounds containing radio-nuclides; to improve the methodology for predicting morbidity and mortality resulting from radiation exposures; to evaluate the effectiveness of protective actions and radiation monitoring instruments; and to develop radiation protection standards as needed.

Research in this program continues to show progress and the work appears to be well coordinated with related efforts in other Federal agencies. We are encouraged to note that the NRC has, in response to our earlier comments, provided increased support for the projects on Gastrointestinal Absorption of Actinides and on Relative Biological Effectiveness of Fission Neutrons at Occupational Exposure Levels. With respect to the latter project, we

understand that the NRC Staff has made an initial effort to communicate with the DOE. We recommend that the NRC Staff explore further the possibility of gaining useful information through an examination of the records of the DOE relative to neutron exposures of workers in plutonium facilities.

4.6 Recommendations

4.6.1 Overall Budget Recommendations

We endorse the proposed funding level of \$8.6 million for this Decision Unit in FY 1984.

4.6.2 Summary of Specific Recommendations

- a. Research in this Decision Unit should be closely coordinated with related research being conducted in other Decision Units as well as in other Federal agencies and private organizations (Section 4.2).
- b. The NRC Staff should evaluate further the potential for gaining information significant to the estimation of earthquakes having a recurrence frequency equal to or less than one in ten thousand per year, and the Geology and Seismology Program should be modified to give this matter increased emphasis if worthwhile studies can be defined (Section 4.3.2).
- c. The NRC Staff should explore further the possibility of gaining useful information through an examination of the records of the DOE relative to neutron exposures of workers in plutonium facilities (Section 4.5).

5. RISK ANALYSIS

5.1 Introduction

This Decision Unit contains research programs directed toward the development of risk assessment methodology and methods for risk reduction, the assessment of the risk presented by existing and planned nuclear power plants, and the evaluation of transportation and materials risk.

5.2 General Comments

We have generally supported the research program on Risk Analysis in our previous reports to the Congress (Refs. 1, 2), usually recommending some augmentation in funding support. This recommended augmentation, however, was strongly tied to specific safety matters about which we believed the proposed program was seriously inadequate. For example, in our 1982 report to the Congress (Ref. 1), we recommended that the following receive significantly greater priority and support:

- Development of methodology for incorporating risk contributors such as seismic events, design errors, operator errors of commission, sabotage, and systems interactions into PRAs.
- Augmentation and improvement of the ongoing programs on core damage and core melt preventive and mitigative features.
- Establishment of a program to examine work relating to LWR safety approaches in other countries.

Few of these recommendations have been adopted by the NRC Staff in its FY 1983 program. Recently, NRR provided a fairly detailed statement of needs for improved methodology in PRA, and RES is developing a modified research program which seems to be moderately responsive to NRR needs. The NRC, however, is not giving enough emphasis, priority, and funding support to these matters to make up for the time which has been lost. We believe that research to fill the gaps in the state-of-the-art PRA methodology and research to provide direct support of a Severe Accident Policy should be greatly accelerated and funds reallocated as necessary within this Decision Unit.

5.3 Design Against Sabotage

We have repeatedly recommended (Refs. 1, 6) increased research efforts with regard to design measures to reduce the risk arising from internal or external saboteurs. RES has provided only modest support in prior years to research to reduce the risk from sabotage and seems to feel that a very long-term resolution of this matter is acceptable. We observe that several other countries have taken the matter sufficiently seriously to require extensive measures beyond access control specifically to reduce the vulnerability to sabotage. In a relatively turbulent world, in which it is difficult to predict actions by terrorist groups, we believe that it would be prudent to incorporate design measures to further reduce vulnerability to sabotage as part of the original design of new plants, and to search for practical improvements which can be implemented on existing plants. The NRC research program has generated several useful reports. We believe that these reports contain information that could form part of the basis for deciding whether the NRC should have a policy concerning design measures to protect against sabotage and, if so, what that policy should be. We believe that the evaluation and synthesis of the available information, the generation of additional information as may be needed, and the development of options, cost-benefit analyses, and trade-offs should be accomplished as part of the research program, with active input by the regulatory staff.

Part of the reason for the slow pace and lack of focus on the issue of sabotage by the NRC appears to have arisen from a lack of commitment by upper management to its resolution, and the absence of a clear designation of responsibility for this matter within the NRC. Recent discussions with representatives of RES suggest that the Division of Risk Analysis may be a suitable lead group for the long term, although clearly other parts of the NRC Staff must be involved in an integrated program.

We recommend that funds be specifically authorized to provide such resources as are necessary and can meaningfully be used to provide that information needed for timely policy decision making concerning design measures to deal with sabotage for both new and existing plants.

5.4 Reactor Risk Analysis

We have repeatedly recommended (Refs. 1, 2, 6) a high priority and greater funding support for research intended to provide information vital to decision making with regard to a Severe Accident Policy. However, these recommendations have been largely ignored,

and work that could and should have been performed concurrently continues to be done sequentially. As a result, the currently available NRC studies do not include all important accident initiators, do not adequately treat uncertainties, and do not include all reactor/containment combinations of interest. The FY 1983 budget includes no significant increase in funds for such research and, worse yet, a marked reduction is proposed for FY 1984.

We recommend that the Congress single out the matter of Severe Accident Policy and authorize the NRC to apply all necessary resources, as can meaningfully be used, in FY 1983 and FY 1984 to provide that information which appears to be relevant to timely policy decision making.

We recommend that about \$2 million be reallocated from other programs in this Decision Unit in FY 1984 to fund the work in support of a Severe Accident Policy. In particular, the \$2 million proposed in FY 1984 for development of the MELCOR Code can be cut at least in half by stretching out its development or making its development more efficient.

5.5 Risk Methodology and Regulatory Analysis

The use of PRA methodology in regulatory decision making is already growing very rapidly and will increase with the publication of a final NRC Safety Goal Policy. However, NRC-supported PRA studies performed to date have not included many important potential accident initiators and contributing failures, even though fire and earthquakes have been modeled in recent industry-sponsored PRAs. As a result of these large gaps in methodology, NRC decision making on individual generic topics, as well as on the complex issues related to Severe Accident Policy, may be severely hampered and perhaps not soundly founded. The Systematic Evaluation Program also suffers from the unavailability of such methodology.

The Division of Risk Analysis appears to be planning the initiation or expansion of efforts directed at some of these weaknesses in methodology. The proposed pace, however, is far from adequate. We recommend that this work be accelerated and that first priority in this program be given to the early development of practical risk models to treat the following issues in near-term PRAs:

- seismic events
- externally induced floods
- fire
- systems interactions
- operator errors of commission
- design and construction errors

Models to analyze accidents initiated by wind and by internally induced floods also should be improved as necessary.

There also exists a major need for research that would provide the bases by which the NRC should make decisions in the face of the very large uncertainties that must be expected for PRA results. Such information is particularly important for decisions in instances where a nuclear power plant may be estimated to be at or near the threshold of acceptability for continued operation.

With regard to the issue of externally caused floods, we recommend pursuit of a short-and-long term research approach which includes the following:

- A detailed summary of the currently available knowledge including the applicability and limitations of each method. These methods should include various probabilistic models for the estimation of floods with long return periods; an examination of different procedures for estimation of the probable maximum precipitation and probable maximum flood; and methods to use data from similar basins.
- The development of improved methods for examining climatic and hydrologic phenomena probabilistically.

We recommend that the major share of funding in this Decision Unit in FY 1984 be allocated to these matters and those discussed in Sections 5.3 and 5.4, and that other proposed programs that represent small refinements in methodology, detailed additions to the data bank, etc., be slowed up or deferred.

5.6 Transportation and Materials Risk

We agree with the reduction in funding proposed by the NRC for research on Transportation and Materials Risk.

5.7 Recommendations

5.7.1 Overall Budget Recommendations

We endorse the proposed funding level of \$17.7 million for this Decision Unit in FY 1984. However, we recommend a major reallocation of funding within this Decision Unit.

5.7.2 Summary of Specific Recommendations

- a. The research to fill gaps in the state-of-the-art PRA methodology and the research to provide direct support of a Severe

Accident Policy should be greatly accelerated and funds reallocated as necessary within this Decision Unit (Section 5.2).

- b. The evaluation and synthesis of the available information on design measures against sabotage, the generation of additional information as may be needed, and the development of options, cost-benefit analyses, and trade-offs should be accomplished as part of the research program, with active input by the regulatory staff (Section 5.3).
- c. Funds should be specifically authorized to provide such resources as are necessary to provide that information needed for timely policy decision making concerning design measures to deal with sabotage for both new and existing plants (Section 5.3).
- d. The Congress should single out the matter of Severe Accident Policy and authorize the NRC to apply all necessary resources as can meaningfully be used in FY 1983 and FY 1984 to provide that information which appears to be relevant to timely policy decision making on the matter of severe accidents (Section 5.4).
- e. The NRC should reallocate about \$2 million in FY 1984 for the work being conducted in support of a Severe Accident Policy, to be obtained partly from other programs within this Decision Unit, and partly by reducing by one-half the \$2 million proposed for the development of the MELCOR Code in FY 1984 (Section 5.4).
- f. The NRC should give first priority within the Risk Methodology and Regulatory Analysis Program to the early development of practical risk models to treat the following issues in near-term PRAs:
 - seismic events
 - externally induced floods
 - fire
 - systems interactions
 - operator errors of commission
 - design and construction errors

Models to analyze accidents initiated by wind and by internally induced floods also should be improved, as necessary (Section 5.5).

- g. The NRC should undertake research that will provide the basis by which the NRC can make decisions in the face of the very large uncertainties and difference of expert opinions which must be expected for the state-of-the-art PRA results (Section 5.5).
- h. Research on the issue of externally caused floods should include the development of the following (Section 5.5):
 - A detailed summary of the currently available knowledge including the applicability and limitations of each method.
 - The development of improved probabilistic methods for examining climatic and hydrologic phenomena probabilistically.
- i. The NRC should allocate the major share of the funding in this Decision Unit to the research described in Items a, b, f and g above, and other proposed programs which represent refinements in methodology or narrow additions to the data bank, etc., should be slowed up or deferred (Section 5.5).

6. ACCIDENT EVALUATION AND MITIGATION

6.1 Introduction

The proposed research in this Decision Unit is intended to provide the technical bases for decisions to be made by the Commission in the course of arriving at a policy for dealing with severe reactor accidents. Since this policy is closely related to the Commission's policy on safety goals and its policy on siting, the development of these policies and of the associated research must be carefully coordinated, and must have a well-defined and common objective. It is especially important that considerable effort go into an initial definition of these policies in order that the associated research can be designed to produce results needed to refine the policies and their implementation.

The proposed research program is said to fall into the categories of preliminary research that is needed to arrive at a policy on severe accidents, and of confirmatory research designed to confirm an initial policy decision and to decrease uncertainties that may be associated with the initial approach.

Research being proposed includes severe accident analysis, studies of damage progression in severely degraded cores, efforts to improve the modeling of partial and total core melts and their consequences, prediction of containment loading as a result of severe accidents, improved definition of the radioactive materials available in containment for release during a severe accident, and studies of systems for mitigating the consequences of severe accidents.

The NRC Staff is following work being done in this area by EPRI, by an industry group in the Industry Degraded Core Rulemaking (IDCOR) Program, and by the DOE.

There is also participation in the International Atomic Energy Agency activities in safety analysis, and in code and standards development. Information exchange with several foreign groups and activities is achieved through a number of bilateral agreements.

6.2 General Comments

In our report to the Commission on the NRC Safety Research Program for FY 1984 and 1985 (Ref. 6) we commented:

We have recommended repeatedly in our reports to the Commission and to the Congress that the research in the Accident Evaluation and Mitigation Decision Unit be structured to answer questions arising in connection with reactor regulation and licensing. In our recent reports, specific attention was called to the need for organizing the research under this Decision Unit to answer questions likely to arise in connection with the Commission's stated intention to modify the licensing process to take specific account of accidents more serious than those generally identified as Design Basis Accidents.

In that report we commented on the lack of a defined approach for dealing with severe accidents, and pointed out the difficulty of evaluating a research program without knowing more about the questions it is intended to answer. Since that time, we have reviewed additional materials provided by the NRC Staff and have conferred with them on several occasions. It is our judgment that there still does not exist a workable coherent approach to dealing with severe accidents. We find it difficult to comment on a research program to support an as yet undefined approach. Our further comments are made in that context.

6.3 Severe Accident Analysis

This program is designed to provide additional information concerning a variety of postulated sequences of equipment malfunctions and operator errors with a goal of developing a strategy to prevent or mitigate severe accidents. The approach emphasizes code development and the use of these codes for detailed analysis of accident sequences suggested by the TMI-2 accident, and by the possibility of PTS.

We doubt that the detailed deterministic codes being developed, even if compared with information available from experiments, can describe in a useful way the multiplicity of possibilities associated with severe core damage. We suggest less emphasis on codes which, because of their elaborateness and complexity, may give the appearance of validity, but which may produce results that are either of little use or misleading. We recommend more emphasis on efforts to identify accident initiators and sequences not yet encountered in operating reactors.

We support some research that examines a variety of hypothesized sequences and looks for the impact of various actions by a licensee during the course of an accident involving severe core damage. We urge, however, that such work be more closely related to possible regulatory requirements than appears to be the case for the work proposed.

6.4 Damaged Fuel

The proposed research in this area is intended to provide the NRC with modeling capabilities to assess consequences of severe accidents. The programs proposed are said to be designed to improve:

- The ability of current risk codes, by benchmarking and validation.
- The accuracy with which the fission product source term produced by severe accidents can be described. (Data are to be gathered under degraded core conditions in a test reactor.)
- The description of the hydrogen production under accident conditions. (Better information on both quantity and time of release is said to be needed.)
- The description of containment loading produced by severe fuel damage.
- Understanding and applications of the TMI-2 core examination.

The NRC plans to complete Phase I of the Power Burst Facility (PBF) tests on early melt progression in FY 1984. PBF test results will be incorporated into the Severe Core Damage Analysis Package (SCDAP), the Severe Accident Sequence Analysis (SASA) Program, the fission product source term program, the hydrogen program, and the MELCOR Code development and assessment program. The NRC also plans follow-on tests (Phase II) at the PBF using previously irradiated fuel and reaching significantly higher temperatures (near 5000°F) than the previous tests. Current efforts are said to be aimed at a better "understanding", but the processes being studied are extremely complex and the research is very expensive. We believe that the experimental research should be preceded by a better definition of the questions to be answered. We have previously questioned the amount of detail that it is possible or desirable to define in an actual accident. Additional attention should be given to this problem in order to focus the research to produce useful

results. With this in mind, we do not recommend the work planned in the Atomic Energy of Canada Ltd. Test Reactor (NRU), or that in the Annular Core Research Reactor (ACRR). At this time, we do not recommend Phase II experiments in PBF.

The expenditures associated with the Damaged Fuel Program make up a large fraction of the funding of this Decision Unit. The proposed research is complex and difficult. It is imperative that some initial strategy for dealing with severe fuel damage accidents be developed before planning of this research program is completed.

6.5 Containment Loading

The proposed research in this area is expected to yield information on containment loading due to deflagration of hydrogen and other combustible gases, on effects of rapid quenching of hot core materials (steam overpressure and missiles), and on basemat melt-through processes.

We recommend that additional effort be given to defining the containment behavior needed to meet licensing objectives in order that the research program can eliminate uncertainties in current licensing capabilities. Since this problem is being examined also in the Damaged Fuel Program, we recommend that any unneeded duplication between this program and that on Damaged Fuel be eliminated.

6.6 Fission Product Source Term

Work under this program appears to be well managed, and funding for FY 1984 and 1985 seems adequate. We urge that continuing attention be given to the information needed for licensing and regulatory decisions. A significant part of the funds requested are for development of a variety of codes, and experimental work is justified partly as being needed for validation of these codes. Careful early planning must ensure that these codes are likely to contribute the information needed for regulatory decision making and do not simply become ends in themselves. We believe that the peer review process being used will help to prevent this. The related research on better definition of the source terms for accidents in LWR fuel cycle facilities and in facilities using radioactive materials should be subjected to similar planning and review, and should be better coordinated with the work pertaining to nuclear power plants.

One important area, previously accorded little study in this program, is the role of radiation chemistry in the source term. Radiolytic chemical processes may affect, for example, hydrogen gas

production in water and/or steam, aerosol behavior, and the deposition of various chemical species on surfaces. We recommend that such studies be initiated as soon as possible.

6.7 Improved Safety Systems

For almost two decades, the ACRS has urged that analytical evaluations and supporting experiments be conducted to determine the feasibility and utility of features for severe accident mitigation. Filtered vented containment systems, core retention devices, and containment heat removal systems are among those that have been suggested. We are dismayed that no investigations of this type are being proposed in this program for FY 1984. We recommend that at least \$2 million be allocated to this work; it can be taken from the Damaged Fuel Program.

We urge also that the NRC Staff make use of work on improved safety systems being done in other countries. Although there are reasons for different approaches by different groups, we need to understand whether what is being proposed by others may represent a significant improvement.

6.8 Recommendations

6.8.1 Overall Budget Recommendations

We endorse the proposed funding level of \$43.9 million for this Decision Unit in FY 1984. However, we recommend a shift of \$2 million from the Damaged Fuel Program to the Program on Improved Safety Systems.

6.8.2 Summary of Specific Recommendations

- a. Less emphasis should be given to the development of codes which, because of their elaborateness and complexity, may give the appearance of validity, but which may produce results that are either of little use or misleading; more emphasis should be placed on efforts to identify accident initiators and sequences not yet encountered in operating reactors (Section 6.3).
- b. We support some research that examines a variety of hypothesized sequences and looks for the impact of various actions by a licensee during the course of an accident involving severe core damage. We urge, however, that such work be more closely related to possible regulatory requirements than appears to be the case in the work proposed (Section 6.3).

- c. We do not recommend the work planned in NRU or that in ACRR. At this time, we do not recommend Phase II experiments in PBF (Section 6.4).
- d. Additional effort should be given to defining the containment behavior needed to meet licensing objectives in order that the research program can eliminate uncertainties in current licensing capabilities. Any unneeded duplication between the research in the Containment Loading Program and that on the Damaged Fuel should be eliminated (Section 6.5).
- e. In the program related to the Fission Product Source Term, continuing attention should be given to the information needed for licensing and regulatory decisions (Section 6.6).
- f. Studies should be initiated as soon as possible to look at the role of radiation chemistry in the source term (Section 6.6).
- g. At least \$2 million should be reallocated from the Damaged Fuel Program to support the Program on Improved Safety Systems (Section 6.7).
- h. The NRC Staff should make use of work being done in other countries in the Improved Safety Systems area (Section 6.7).

7. LOSS OF COOLANT ACCIDENTS

7.1 Introduction

Research in this Decision Unit is intended to provide experimental data and analytical methods to assess plant behavior during a LOCA. Also included is the testing of models of reactor systems and components to better understand plant behavior during accidents. The resulting test data will be incorporated into codes to improve predictions of plant behavior during a LOCA.

7.2 General Comments

The proposed budget includes items requiring a large financial commitment over a long period of time. In many cases, costs for portions of the program begun in earlier years have peaked and are declining. Other programs have been reoriented as the NRC perceptions of needed research have changed since the TMI-2 accident. As discussed in Chapter 3, small breaks and transients that may lead to inadequate core cooling are now receiving the attention they need. We believe that these changes in program emphasis have been appropriate.

7.3 2D/3D Program

This is an international program involving Japan, the Federal Republic of Germany (FRG), and the United States. It was begun when LWR safety research was preoccupied with large-break LOCAs. At present, the major project in this program is the construction of the Upper Plenum Test Facility (UPTF) which has been initiated by the FRG. The UPTF will require long-term expenditures by the NRC to support analyses and instrumentation. The estimated cost of the UPTF has risen to such an extent that there is even greater concern with the benefit, which is rather small for a very large expenditure. One concern is that the UPTF is representative only of a Westinghouse-type PWR and that it has as a major objective the study of hot-leg injection, which is a feature special to the FRG-type PWR.

A second part of the 2D/3D Program involves work at two experimental facilities in Japan, the Cylindrical Core Test Facility (CCTF) and the Slab Core Test Facility (SCTF). We believe that useful results are being obtained from these facilities in a cost-effective manner.

We understand that the current international agreement governing the 2D/3D Program expires in April 1985 and must be renegotiated if the full complement of planned tests is to be run. Given the above comments, we recommend that the NRC carefully consider renegotiation of an agreement for international cooperation in LOCA experimental and analytical work to assure cost-effective results that are applicable to the designs in the United States.

7.4 Computer Simulation Scaling

This program includes experimental work on thermal-hydraulic separate effects to provide data to benchmark and improve computer models. Some of this work involves small projects conducted under contract with university laboratories. We believe that these programs are useful and cost effective. NRC should consider extension of such university programs to the extent consistent with prudent overall program management.

7.5 Recommendations

7.5.1 Overall Budget Recommendations

We endorse the proposed funding level of \$11.0 million for this Decision Unit in FY 1984.

7.5.2 Summary of Specific Recommendations

- a. The NRC should carefully consider renegotiation of any new agreement related to the 2D/3D Program to assure cost-effective results that are applicable to the designs in the United States, upon expiration of the international agreement governing this program (Section 7.3).
- b. We support the use of university laboratories for the Computer Simulation Scaling Program and recommend the extension of such use of university facilities to the extent consistent with prudent overall program management (Section 7.4).

8. LOFT

8.1 LOFT Consortium

An international Consortium has recently been formed to conduct a three-year program of tests at the LOFT Facility. In the recent past, we have not supported the LOFT Program because it was not seen as cost effective. We now understand that the NRC plans to cancel its future contribution to the LOFT Consortium at the behest of the Office of Management and Budget.

8.2 Recommendation

We support termination of the NRC funding for this Program.

9. ADVANCED REACTORS

9.1 Introduction

This Decision Unit consists of research on Liquid Metal Fast Breeder Reactors (LMFBRs) and High Temperature Gas Cooled Reactors (HTGRs). The current LMFBR research program is devoted solely to supporting the licensing needs of the NRC in connection with the Clinch River Breeder Reactor (CRBR).

9.2 LMFBR Research

The proposed budget includes \$7.3 million for LMFBR safety research in FY 1984, with \$6.3 million being devoted primarily to meeting CRBR licensing needs and the remaining \$1.0 million being devoted to establishing a regulatory position for post-CRBR LMFBRs. The latter expenditure follows a recommendation made by the ACRS in its last report to the Congress (Ref. 1).

The proposed funding to support the CRBR licensing appears adequate. However, we recommend that the technical scope of the program be modified to incorporate a probabilistic risk assessment of CRBR. We believe that the background and experience gained by such a study is needed for a proper evaluation of the PRA being performed by the CRBR Project Staff as well as to provide long-term guidance for research on larger LMFBRs. Furthermore, we are concerned that the program may not devote adequate attention to defining a source term suitable for evaluation of postulated CRBR accidents and wish to emphasize the importance of such work.

Current guidance by the NRC calls for maintenance of a program to provide a technical base for licensing LMFBRs, in addition to CRBR, consistent with the projected plans of the Executive Branch and the Congress. We strongly support this thrust, but we believe that it is inadequate. For example, we believe that the NRC should be prepared to offer safety advice during the early design stages of any post-CRBR LMFBR as well as during the construction permit review stage. The NRC was not prepared to offer such design-stage advice for either the CRBR or the Conceptual Design Study which was submitted to the Congress in March 1981.

We welcome the \$1.0 million program mentioned above to establish a regulatory position. We understand that the primary thrust of the expenditure will be in support of a cooperative study with industry

and DOE to perform a PRA on a large-size commercial prototype plant, and such an effort should be fruitful. We believe, however, that a PRA is only one step toward developing a regulatory position which will require continuing efforts to develop design criteria, to define safety research needs, and to define an appropriate NRC generic safety research program on LMFBRs.

Current NRC planning calls for a generic LMFBR research program in the range of \$4.0 to \$5.0 million per year as the CRBR licensing effort is phased out. Such a program could support a minimal cadre of people knowledgeable on LMFBR safety problems which would be available to the NRC when called upon. This level of activity would involve primarily analytical research with little or no experimental effort; it would almost represent placing the NRC LMFBR safety research program on a standby basis. We have recommended in the past (Ref. 2) that a level in the range of \$20 million per year would be reasonable and suitable if the Congress continues to support a large LMFBR base technology program as it has in the past (\$325 million for FY 1983) or if it expects the Nation to move forward with a commercial prototype size unit within a few years. We recommended \$11.5 million for FY 1983 (Ref. 1). We accept political realities that an \$11.5 or \$20 million level is unlikely for FY 1984, but we believe strongly that a funding level at least equivalent to that proposed for FY 1984 should be retained for generic work as CRBR needs are fulfilled.

9.3 HTGR Research

The research programs related chiefly to support of the Fort St. Vrain reactor will be completed for the most part in FY 1983. The research proposed for FY 1984 and 1985 recognizes an intent of the nuclear industry to develop a lead-plant conceptual HTGR suitable for siting in or near an industrial complex, and is aimed at developing an appropriate basis for the safety review and licensing of such a plant. If indeed it is likely that a license application for such a plant can be expected within the next few years, it is appropriate for the NRC to continue a suitable program of research on HTGRs. In such an event, however, the \$2.6 million proposed for such research is probably inadequate. If the likelihood of a license application is more remote, the proposed expenditures should be reallocated in FY 1984 to support other more urgent safety research programs in other Decision Units.

9.4 Recommendations

9.4.1 Overall Budget Recommendations

We support the proposed budget of \$7.3 million for CRBR-LMFBR research in FY 1984 and recommend that at least an equivalent funding level

be retained in subsequent years for generic LMFBR work as CRBR needs are met.

We support the proposed budget of \$2.6 million for HTGR research only if there is reasonable likelihood of a construction permit application being received within the next few years. If not, we recommend that these funds be reallocated to support other more urgent safety research programs in other Decision Units.

9.4.2 Summary of Specific Recommendations

- a. The NRC should include a PRA of CRBR in the LMFBR research program (Section 9.2).
- b. NRC should assure that the LMFBR research program devotes adequate attention to defining a suitable source term for evaluation of postulated CRBR accidents (Section 9.2).
- c. The NRC should be prepared to offer safety advice during the early design stages of any post-CRBR LMFBR as well as during the construction permit review stage (Section 9.2).
- d. The NRC efforts to develop a regulatory position for post-CRBR LMFBRs should include efforts to develop design criteria, to define safety research needs, and to define an appropriate NRC generic safety research program on LMFBRs (Section 9.2).

10. WASTE MANAGEMENT

10.1 Introduction

The Waste Management research program is directed to the health and safety problems that result from the handling and ultimate disposal of high- and low-level radioactive wastes and uranium mill tailings. The safe disposal of such wastes continues to be a significant public concern.

10.2 General Comments

In our previous report to the Congress (Ref. 1), we noted that the coordination and direction of the NRC waste management research program had undergone significant improvement. Our latest review shows that this trend continues. It is not clear, however, that all of the proposed studies are truly "research". Some of the work appears to involve primarily literature reviews. A clear statement of what is involved in each of the NRC waste management research projects would be useful.

Another general comment applies to the selection of projects for NRC support. Although we agree that the NRC Staff must develop a capability to verify independently the licensing applications they receive (for example, the ability to model the long-term behavior of a proposed high-level radioactive waste repository), such a capability is not necessary in all aspects of waste management. We recommend that specific efforts be directed to the development of a protocol for determining where the capability for independent verification is required, and where it is not.

We also recommend that consideration be given to assuring that the data being obtained in various environmental studies of potential waste management facilities are adequate for verifying the computer models that have been developed for determining compliance. In terms of the models themselves, there are two areas of need: model validation, and model simplification. The NRC Staff should assure that these major areas of need are being addressed in their research program.

Closely coupled with the verification of environmental transport models is the need for the NRC Staff to move promptly to develop criteria for assuring proper operation of waste disposal facilities. As far as practical, it is important that the criteria be

developed first, followed by the development of the models for determining compliance with the criteria.

10.3 High-Level Waste (HLW)

The objectives of this program are to identify failure mechanisms that could affect waste isolation capability; to identify the technical requirements needed for mitigating the consequences of accidental or unplanned movements of radionuclides; to define the technical requirements for developing regulations and standards for the construction, operation, and decommissioning of waste disposal facilities; and to delineate the uncertainties or confidence levels in the associated analytical methodologies.

In the HLW research, one of the greatest concerns lies in assessing the long-term performance potential of both the natural and the engineered components of the planned geologic repositories. There are at present three major impediments to a well-coordinated research program in this area: (1) the prolonged debate over reprocessing, which has delayed the critical decision on what form the waste will take (spent fuel or reprocessed waste); (2) the lack, in the past, of Congressional guidance as to the management and funding of the National HLW disposal program; and (3) the absence of the provision by the EPA of repository environmental release standards.

In the absence of EPA guidelines, the HLW technical criteria proposed by the NRC are not at present based on a release standard for the total system. Rather, they place specific constraints on each component of the waste disposal system, including both the engineered and the geologic barriers. Such conservatism may ultimately be found to be necessary. But considering the present lack of detailed knowledge of both engineered and geologic system performance under repository conditions, increased research emphasis needs to be given to the development of methods for determining the barrier properties of the entire waste system, including individual assessments of the waste form, canister, overpack, backfill, and geologic medium. Care should be taken to make such assessments under conditions that closely simulate the repository environment. The absence of standard methods for laboratory experiments on waste form and package properties severely limits the usefulness of some of the research that has thus far been conducted. Standard methods should be developed as soon as possible.

The highest priority for research in this area should be given to studies of the barrier properties of the repository geologic

medium. The conservatism of the currently proposed NRC policy for HLW disposal lies in its emphasis upon a high-integrity, long-lived waste package for isolation of the radioactive material. A corresponding under-emphasis is placed upon the radionuclide retardant properties of the geologic media surrounding the repository. This policy necessarily drives the waste package cost upward, significantly affecting the cost of the total repository. If the geologic/hydrologic barriers were better understood, it is possible that the requirements for the engineered barriers could be lowered, thus reducing costs without compromising public safety.

One avenue of research that should be further explored in this regard is the use of natural uranium ore bodies as analogs for a HLW repository, and as devices for validation of the various radionuclide transport codes that have been developed. Sites such as Oklo in Gabon have been used in the past and should continue to be used in learning about radionuclide release and transport in natural geologic systems.

Once the repository geologic environment is better understood, it will be worthwhile to devote some research effort towards a different mode of safety analysis for the repository. Rather than developing a separate criterion for each barrier, research should be conducted to determine what level of performance would be sufficient for each of the barriers, given specific limits for radionuclide releases to the accessible environment. In this way, excessive research into the integrity and licensability of various types of canisters and waste forms can be minimized.

10.4 Low-Level Waste (LLW)

This program is designed to investigate the means for safe disposal of low-level radioactive wastes containing source, special nuclear, and by-product materials. Such wastes are usually placed in the near surface (upper 15 m to 20 m) of the earth. More than 90 percent of the volume of radioactive waste presently being generated is LLW. A number of existing LLW burial sites have been shut down or are accepting waste only on a curtailed basis. New sites must be identified in the very near future.

Decommissioning of nuclear power plants as well as our proposed increase in emphasis on the reduction of occupational exposures (which may, in part, involve increased decontamination of nuclear power plant cooling systems) both depend for their success on the ready availability of facilities for the disposal of the resulting large volumes of LLW. Recently, the NRC has developed and published regulations for the disposal of LLW. The availability of the

criteria included in these regulations should help in screening, selecting and approving additional sites that are needed.

The NRC Staff originally proposed studies of alternatives to near-surface disposal of LLW. Owing to lack of resources, these have been postponed indefinitely. We recommend that these studies be initiated in FY 1984 to seek alternative disposal methods.

In assessing the research that has been conducted on LLW disposal, we find that too much emphasis has been given to the mistakes of the past (such as at Maxey Flats) rather than to the successes (such as at Barnwell). A reorientation to determine what has made the operation of certain sites successful would be more productive than seeking solely to determine why the operations at other sites failed. The NRC research program particularly needs to address the problems associated with LLW segregation, stabilization and volume reduction.

In another area, NRC recently found it possible, after careful evaluation, to permit certain animal tissues and liquid scintillation wastes, containing ^{14}C and ^3H , to be disposed of without regard to their radioactivity. We would encourage the NRC Staff to support research to develop criteria for the exemption of other types of LLW from current disposal restrictions. EPA has proposed developing standards for radioactive wastes whose radioactive concentrations are "below regulatory concern". To the extent that the NRC staff can develop and provide data to support this work, we would encourage them to do so.

Lastly, as mentioned earlier, we believe that there is a need to consider problems related to the cleanup and restoration of damaged nuclear plants, such as TMI-2. Priority should be given to the development of criteria governing the environmental release or disposal of waste waters generated in the cleanup process.

10.5 Uranium Recovery

The disposal of uranium mill tailings that result from uranium recovery and concentration operations has long been a public concern. We support the work to develop criteria for dealing satisfactorily with the large number of existing uranium mill tailing piles and to provide early guidance for licensing and regulating new mills. One area that should be emphasized in this work is the evaluation of possible alternatives to current disposal methods.

10.6 Recommendations

10.6.1 Overall Budget Recommendations

We endorse the proposed funding level of \$9.3 million for this Decision Unit in FY 1984.

Overall, it is our conclusion that the pace of the NRC program on the management of radioactive wastes (particularly LLW) is far too slow. If the NRC Staff is to conduct the research necessary to maintain regulatory surveillance of the developmental programs in this subject area, they must continue to mount a vigorous program relevant to these needs. We recommend that studies on alternatives to near-surface disposal of LLW be initiated in FY 1984.

10.6.2 Summary of Specific Recommendations

- a. A clear statement should be made as to what is involved in each of the proposed NRC waste management research projects (Section 10.2).
- b. A protocol should be developed for determining in which cases it is necessary to have the capability for independent verification of data submitted by licensees, and in which cases it is not (Section 10.2).
- c. Consideration should be given to assuring that the data being obtained in various environmental studies of potential waste management facilities will be adequate for verifying the computer models that have been developed for determining compliance (Section 10.2).
- d. Criteria should be developed for assuring proper operation of waste disposal facilities, prior to the development and verification of environmental transport models (Section 10.2).
- e. For HLW repositories, increased emphasis should be given to the development of methods for determining the barrier properties of the entire waste system, including individual assessments of the waste form, canister, overpack, backfill, and geologic medium under conditions that closely simulate the repository environment (Section 10.3).
- f. Standard methods for laboratory experiments on HLW form and package properties should be developed as soon as possible (Section 10.3).

- g. In the HLW area, the highest priority for research should be given to studies designed to obtain a detailed understanding of radionuclide transport and retardation in the various geologic media under consideration (Section 10.3).
- h. The NRC Staff should further pursue the use of natural uranium ore bodies as analogs for HLW repositories and as devices for validation of the various radionuclide transport codes that have been developed (Section 10.3).
- i. Rather than developing a separate criterion for each barrier, research should be conducted to determine what level of performance would be sufficient for each of the barriers within the HLW repository system, given specific limits for radionuclide releases to the accessible environment (Section 10.3).
- j. For LLW, an effort should be made to determine what qualities have contributed to the success of operations at certain disposal sites, rather than focusing on the problems at sites that have failed (Section 10.4).
- k. Problems associated with LLW segregation, stabilization and volume reduction should be addressed in the research program (Section 10.4).
- l. Criteria should be developed for exempting from current disposal restrictions additional types of LLW, similar to the action taken with respect to certain animal tissues and liquid scintillation wastes (Section 10.4).
- m. Priority should be given to the development of criteria governing the environmental release or disposal of waste waters generated in the cleanup process of damaged nuclear plants, such as TMI-2 (Section 10.4).
- n. Evaluation should be made of possible alternatives to current uranium mill tailings disposal methods (Section 10.5).

APPENDIXES

APPENDIX A

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APPENDIX B

GLOSSARY

ACRR	Annular Core Research Reactor
ACRS	Advisory Committee on Reactor Safeguards
ALARA	As Low As Reasonably Achievable
ASME	American Society of Mechanical Engineers
BNL	Brookhaven National Laboratory
B&W	Babcock and Wilcox
BWR	Boiling Water Reactor
CCTF	Cylindrical Core Test Facility
CRBR	Clinch River Breeder Reactor
DOE	Department of Energy
DOT	Department of Transportation
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
FDA	Food and Drug Administration
FEMA	Federal Emergency Management Agency
FIST	Full Integral Systems Test
FRG	Federal Republic of Germany
FY	Fiscal Year
GERDA	A Semiscale Integral-Test Facility Built for the Use of a FRG B&W Plant Licensee
HLW	High-Level Waste
HTGR	High Temperature Gas Cooled Reactor

IDCOR	Industry Degraded Core Rulemaking
INEL	Idaho Nuclear Engineering Laboratory
LANL	Los Alamos National Laboratory
LER	Licensee Event Report
LLW	Low-Level Waste
LMFBR	Liquid Metal Fast Breeder Reactor
LOCA	Loss-of-Coolant Accident
LOFT	Loss of Fluid Test
LWR	Light-Water Reactor
MELCOR	Methods for Estimating Leakage from Containment of Radionuclides
NPRDS	Nuclear Plant Reliability Data System
NRC	Nuclear Regulatory Commission
NRU	Atomic Energy of Canada Ltd. Test Reactor
NRR	Office of Nuclear Reactor Regulation
OSHA	Occupational Safety and Health Administration
PBF	Power Burst Facility
PRA	Probabilistic Risk Assessment
PTS	Pressurized Thermal Shock
PWR	Pressurized Water Reactor
QA	Quality Assurance
RELAP	Advanced System Code used to model Loss-of-Coolant Accidents
RES	Office of Nuclear Regulatory Research
SASA	Severe Accident Sequence Analysis

SCDAP	Severe Core Damage Analysis Package
SCTF	Slab Core Test Facility
SNUPPS	Standardized Nuclear Unit Power Plant System
SSMRP	Seismic Safety Margins Research Program
TMI-2	Three Mile Island Unit 2
TRAC	Transient Reactor Analysis Code
UPTF	Upper Plenum Test Facility
USI	Unresolved Safety Issue
UT	Ultrasonic Testing

APPENDIX C

THE ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

The Advisory Committee on Reactor Safeguards was established as a statutory Committee in 1957 by revision of the Atomic Energy Act. The ACRS was charged with the responsibility for review of safety studies and facility license applications submitted to it, and to make reports thereon, advising the Commission with regard to the hazards of proposed or existing reactor facilities and the adequacy of proposed reactor safety standards, and to perform such other duties as the Commission might request. Section 182b of the Atomic Energy Act requires ACRS review of the construction permit and operating license applications for power and testing reactors and spent fuel reprocessing facilities licensed under Section 103, 104b or 104c of the Atomic Energy Act; any application for a research, developmental or medical facility licensed under Section 104a or c of the Act and which is specifically referred to it by the Commission; and any request for an amendment to a construction permit or operating license under Sections 103 or 104a, b, or c which is specifically referred to it by the Commission. The Energy Reorganization Act of 1974 transferred operation of the ACRS from the Atomic Energy Commission to the Nuclear Regulatory Commission.

In 1977, Public Law 95-209 added to its other duties a requirement for the ACRS to undertake a study of reactor safety research and to prepare and submit annually to the United States Congress a report containing the results of this study. The first of these reports was submitted to the Congress in December of 1977.

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2. Facility Operations	Human Factors Electrical Systems Reactor Radiological Effects Safeguards and Security
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4. Siting and Health	Site Evaluation Reactor Radiological Effects Extreme External Phenomena
5. Risk Analysis	Reliability and Probabilistic Assessment Fuel Cycle
6. Accident Evaluation and Mitigation	Class 9 Accidents Reactor Fuel Reactor Radiological Effects
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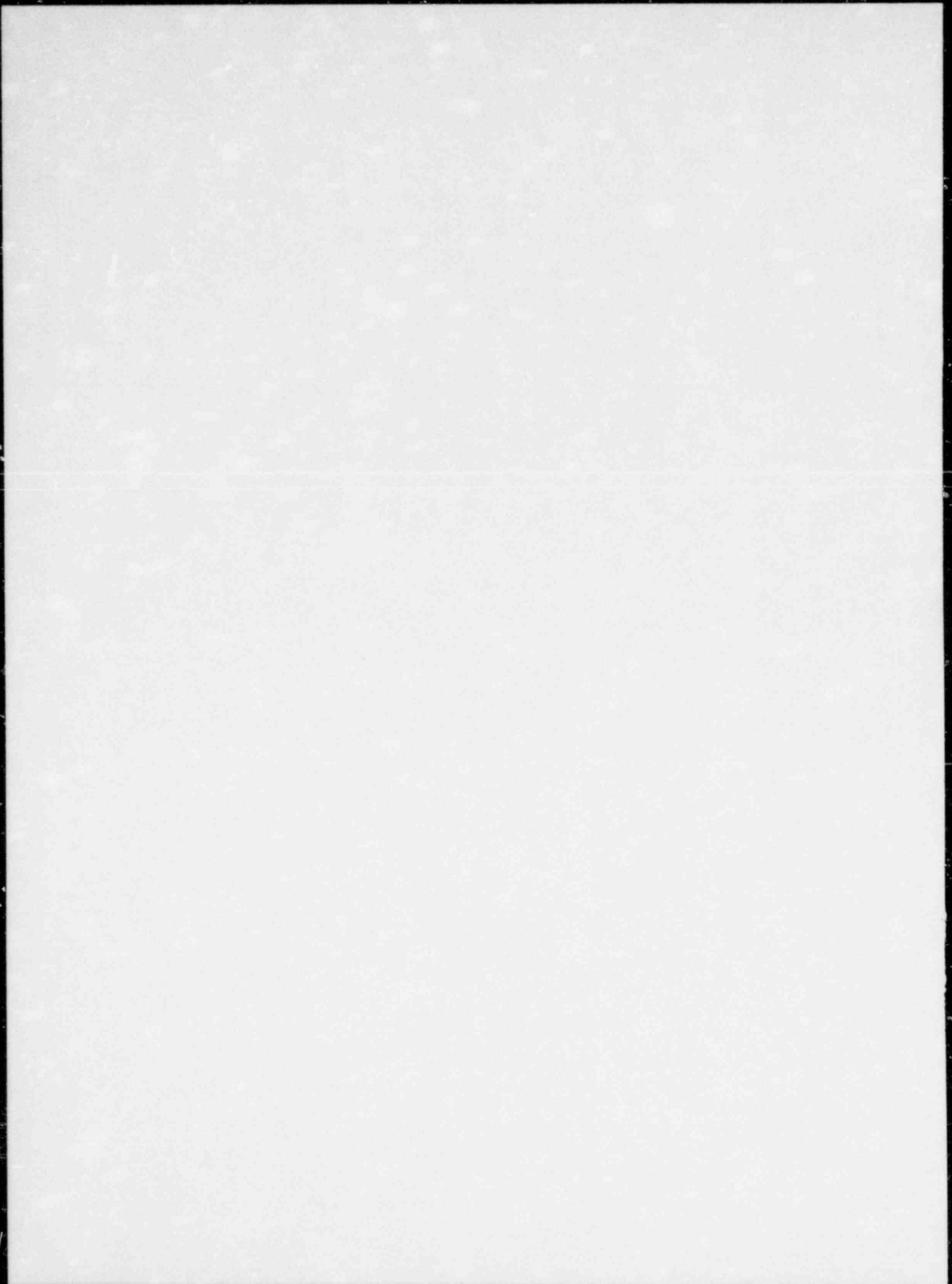
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