SECY-96-007

January 4, 1996

FOR:	The Commissioners
FROM:	James M. Taylor Executive Director for Operations
SUBJECT:	STATUS OF ACTIVITIES RELATED TO REVISIONS TO 10 CFR PART 70, "DOMESTIC LICENSING OF SPECIAL NUCLEAR MATERIAL"

PURPOSE:

To provide the Commission with a status report on (1) the continued dialogue with all major interested parties regarding improvements to Part 70 of Title 10 of the Code of Federal Regulations (10 CFR Part 70), "Domestic Licensing of Special Nuclear Material," and (2) the Westinghouse Electric Corporation's offer to evaluate the practicality of implementing the draft rewrite of Part 70 and accompanying draft staff guidance documents at the Columbia Fuel Fabrication Facility in Columbia, South Carolina. This update was requested in a staff requirements memorandum (SRM) dated June 29, 1995.

BACKGROUND:

By the SRM dated June 29, 1995, the Commission directed the staff to continue an open dialogue with the fuel cycle licensees and other interested parties to develop a better understanding concerning the objectives of the Part 70 rulemaking, to gather applicable information, and to discuss alternative approaches to upgrade the regulatory base. In the interim, at the direction of the Commission, the Part 70 rulemaking was placed on hold pending the outcome of these efforts. The staff was also directed to pursue the offer by Westinghouse to implement the draft revision of Part 70 and the associated draft guidance documents.

DISCUSSION:

In response to the Commission's approval of the recommended course of action in SECY-95-151, "Alternative Approaches for Fuel Cycle Facility Regulation," an NRC-sponsored workshop was held on November 30-December 1, 1995.

The purpose of the workshop was to continue the dialogue with the fuel cycle licensees and other affected parties to develop a better understanding of the objectives of the proposed Part 70 rulemaking and to gather information that would assist the staff in refining the regulatory approach. Attachment 1 is the workshop agenda.

Workshop discussions were conducted by a meeting facilitator in the form of a round-table discussion among invited parties. Representatives from the NRC and the nuclear fuel cycle industry served as panel members, along with representatives from the U.S. Environmental Protection Agency, the U.S. Department of Energy, the Defense Nuclear Facilities Safety Board, the Tennessee Division of Radiological Health, the Tennessee Valley Energy Reform Coalition, and a consultant interested in the licensing of new facilities. In addition, attendees who were not serving as panel members were provided opportunities to present issues or to provide comments on the topics discussed during the workshop. This diversified forum contributed to ensuring that the concerns and views expressed included those of all interested parties.

To focus the discussions, the staff prepared and distributed before the workshop an overview paper that provided substantial background information

(Attachment 2). The paper discussed the staff's goals and objectives for improving the safety of operations and the basic issues to be explored in meeting these objectives. Although no attempt was made to reach consensus, the following issues were addressed in the course of the workshop discussions.

1. *Does the record of operations at fuel cycle facilities indicate a need for regulatory change?*
2. *Does the lack of grading of requirements according to risk in the current Part 70 indicate a need for revising the rule?*
3. *Are changes to the existing Part 70 format needed to improve clarity?*
4. *Rather than modifying the current rule, could an alternative approach be used to achieve NRC objectives?*
5. *Are changes needed in licensee safety programs to provide adequate confidence of safety?*
6. *Is the identification of items relied on for safety, through the performance of an integrated safety analysis (hazards analysis), a critical element in effective and efficient regulation of fuel cycle facilities?*
7. *How can the NRC obtain reasonable assurance of availability and reliability of the items relied on for safety?*
8. *Is the concept of using defined levels of risk for the graded application of controls reasonable?*
9. *Should all changes to the safety program be subject to prior NRC approval?*
10. *Should the license documentation be promptly updated when changes are made to the facility?*
11. *How should the NRC implement a "performance-based" regulation?*
12. *Assuming new requirements are adopted, how long should licensees be given to implement these requirements?*

The workshop provided an opportunity for interested parties to express their views concerning the need for improving NRC's regulation of special nuclear material and for the staff to describe the goals and objectives for improving these safety regulations and the proposed regulatory approach. The staff is continuing to review the information provided during the discussions, including requests for additional public workshops on such topics as integrated safety analysis and performance-based rules. In addition, the utility of the present regulations for licensing new facilities and technologies will also be considered in developing recommendations on what future course of action should be taken.

Westinghouse Electric Corporation's Implementation of Draft Revisions to Part 70

In parallel with the conduct of the public workshop, the staff pursued the Westinghouse Electric Corporation's offer to evaluate the practicality of implementing the draft rewrite of Part 70 and associated draft guidance documents at their facility in Columbia, South Carolina. On November 3, 1995, the NRC issued a license renewal in response to Westinghouse's revised application. (The revised application was submitted to the NRC on April 27, 1995.)

In preparing modifications to its license application, Westinghouse utilized the draft revision to Part 70 and the draft Standard Review Plan (SRP). In addition to programs already required by the current regulation, the provisions of the draft rule and the criteria in the draft SRP were applied where possible. The information gathered from this joint effort will be used to supplement industry's input and to support the staff's resolution of the proposed rule's content and format and accompanying guidance documents.

The revised application includes a commitment to perform an integrated safety analysis. Also included in the revised application is a commitment to implement elements of fire safety, chemical process safety, configuration management, maintenance, and quality assurance(1) programs that were not included in Westinghouse's original application, which was submitted to the NRC in April 1990. These programs, although not required by the present

Part 70 and not included in the original application, were considered important by Westinghouse and have been in existence at the facility for some time. Westinghouse did not incorporate provisions of the draft rule that would have put them at an economic competitive disadvantage with other licensees not making similar commitments.

NEXT STEPS

The staff is reviewing the results of the workshop discussions and the written comments received, as well as the results of Westinghouse's renewal experience. The staff is also considering the requests for additional public meetings. On the basis of these reviews, in March 1996 staff will provide the Commission with recommendations for a future course of action that would best meet the Commission's directive to establish a firm regulatory base for fuel cycle facility licensing activities.

COORDINATION:

The Office of the General Counsel has reviewed this paper and has no legal objection to its contents.

James M. Taylor
Executive Director for Operations

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Attachments: 1. Workshop Agenda
2. Improving the Regulation of Fuel Cycle Facilities: Overview

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1. Although aspects of the quality assurance program are in place at this time, full implementation will coincide with implementation of an integrated safety analysis.

NRC Public Workshop on
Improving NRC'S Regulation of Fuel Cycle Facilities
November 30, 1995 9 a.m. - 5 p.m.
December 1, 1995 8:30 a.m. - 12:30 p.m.

U.S. NRC Headquarters
Two White Flint North
11545 Rockville Pike
Rockville, Maryland

<u>November 30, 1995</u>

9:00 a.m.	Opening Remarks	NRC
9:15 a.m.	Introductions Review of Workshop Agenda Format for Discussions	Chip Cameron, Facilitator
9:45 a.m.	Overview	Elizabeth Q. Ten Eyck, Director, Division of Fuel Cycle Safety & Safeguards
10:15 a.m.	BREAK	
10:30 a.m.	*<u>Participant Discussion</u>: Are there problems with the regulatory base?	 Chip Cameron, Facilitator
12 Noon	LUNCH	
1:30 p.m.	*<u>Participant Discussion</u>: Alternatives for Achieving NRC Objectives	Chip Cameron, Facilitator
3:00 p.m.	BREAK	
3:15 p.m.	*<u>Participant Discussion</u>: Identification of Hazards, and Systems, Structures, and Components Relied Upon for Safety	Chip Cameron, Facilitator
5:00 p.m.	Meeting Adjourned	

**At the end of each topic discussion, time will be allotted for public comment.*

NRC Public Workshop on
Improving NRC'S Regulation of Fuel Cycle Facilities

U.S. NRC Headquarters
Two White Flint North
11545 Rockville Pike
Rockville, Maryland

<u>December 1, 1995</u>

8:30 a.m.	Introductions Highlights from November 30 Discussions	Chip Cameron, Facilitator
8:45 a.m.	*<u>Participant Discussion</u>: Implementing a Safety Program	Chip Cameron, Facilitator
10:00 a.m.	BREAK	
10:15 a.m.	*<u>Participant Discussion</u>: Other Issues	Chip Cameron, Facilitator
11:30 a.m.	Future Plans	Elizabeth Q. Ten Eyck, Director, Division of Fuel Cycle Safety and Safeguards
12:30 p.m.	MEETING ADJOURNED	

**At the end of each topic discussion, time will be allotted for public comment.*

IMPROVING THE REGULATION OF FUEL CYCLE FACILITIES: OVERVIEW

1.0 Introduction

Fuel cycle facilities are involved in the processing of uranium ore, the enrichment of uranium, or the fabrication of special nuclear material (enriched uranium or plutonium) into nuclear reactor fuel. All commercial fuel cycle facilities in the United States are licensed by the Nuclear Regulatory Commission (NRC). These currently include eight uranium fuel fabrication plants and one uranium hexafluoride production plant. The NRC also is currently reviewing an application to construct and operate the nation's first privately owned uranium enrichment plant in Homer, Louisiana. In addition, the Energy Policy Act of 1992 has designated the NRC as the regulatory body responsible for regulating two gaseous diffusion uranium enrichment plants (GDPs) operated by the United States Enrichment Corporation (USEC). Except for the uranium hexafluoride production plant and the mills that process uranium ore, which are licensed under Part 40 of Title 10 of the Code of Federal Regulations (10 CFR 40), and the GDPs, which are subject to certification under 10 CFR 76, the remaining operating facilities are licensed under 10 CFR 70.

The occurrence of serious incidents at fuel cycle facilities led the NRC to conclude that improvements in the regulation of these facilities were needed. As a result of this need, the NRC's Office of Nuclear Material Safety and Safeguards (NMSS) was directed by the Commission in 1991 to make changes in its operations and to improve its basis for regulating fuel cycle facilities. Because the majority of operating fuel cycle facilities are licensed under 10 CFR Part 70, "Domestic Licensing of Special Nuclear Material," improving the regulation of these facilities was given the highest priority.

2.0 The Basis for Regulatory Improvements

The recommendation to improve the basis for regulating fuel cycle facilities originated from studies following serious incidents at such facilities. Most Part 70 fuel fabrication facilities begin their processing of uranium fuel by heating a uranium hexafluoride (UF_6) cylinder to transfer the UF_6 into their process stream. This heating operation is similar to one conducted at the Sequoyah Fuels conversion facility (regulated under 10 CFR Part 40) where, in January 1986, an accident occurred involving the release of UF_6 to the atmosphere. In that accident, as a result of exposure to UF_6 and its reaction products, one worker died, and 41 other onsite workers and approximately 100 members of the public went to hospitals and doctors for observation and/or treatment. In June 1987, the House Committee on Government Operations issued a report about this accident titled "NRC'S Regulation of Fuel Cycle Facilities: A Paper Tiger." The House Committee criticized NRC's regulatory basis as being too narrowly focused on radiological safety and essentially ignoring other hazards, such as hazardous chemicals. It also recommended amending the regulation "that allows existing licensees to operate facilities indefinitely until NRC approves a renewal" because of its potential to "allow some licensees to operate in an unsafe manner if there are serious deficiencies in the renewal application."

The effectiveness of the regulatory system was again questioned as a result of the potential criticality event on May 29, 1991, at the General Electric (GE) plant near Wilmington, North Carolina. The ensuing investigation found that the event had its roots in a number of deficiencies that were systemic. These deficiencies related both to the operation of the licensed facility and to NRC's regulation of the facility. With respect to regulatory deficiencies, an NRC Incident Investigation Team reported in NUREG-1450, "Potential Criticality Accident at the General Electric Nuclear Fuel and Component Manufacturing Facility, May 29, 1991," that the terms of the license did not clearly identify the controls that needed to be maintained to ensure safety, nor did it prohibit the modification of criticality safety controls without prior licensee management review of safety implications. A February 1992 report by an NRC task force, "Proposed Method for Regulating Major Materials Licensees" (NUREG-1324), further identified a broad range of regulatory and operational weaknesses including: (1) failure to perform comprehensive hazards analyses to identify potential failures, potential accidents, and the items relied upon for safety; (2) lack of management analysis and control of changes to the process; (3) insufficient quality control in sampling and measurements relied upon for safe process management; (4) lack of comprehensive Standard Review Plans (SRP) containing acceptance criteria, to ensure thorough and consistent review by NRC staff; (5) insufficient NRC inspection and enforcement basis, partially due to incorporating by reference license conditions that are vague, uninspectable, or unenforceable; and, (6) automatic indefinite extension of a license, once in timely renewal, allowing disagreements over safety related questions and license conditions to delay NRC approval of the renewed license.

In October 1991, partly as a result of concern raised by the GE incident, the NRC issued Bulletin 91-01, which requested voluntary prompt evaluation and reporting of loss of criticality safety controls. Until this time, licensees did not generally report to the NRC the loss of such controls. In response, some licensees began to evaluate and identify controls and systematically evaluate the safety impact of their loss so as to be able to report as specified in the Bulletin. As a result of reports received, the staff became aware of precursor events occurring at the fuel cycle facilities. Analysis of these events identified certain regulatory and management practices as contributing factors and reinforced the views of staff that the precursor events resulted from generic weaknesses in the regulation of the industry, and were not limited to particular facilities, i.e., not limited to only the GE and Sequoyah Fuels plants. The precursor events also provided indications that operators were not always suitably trained to recognize and address signs of recurring problems, nor did management always demonstrate adequate attention to safety.

In addition to the 91-01 events, other events illustrated the lack of specific commitments not only to criticality safety, but to chemical process safety, and fire safety.

Aside from the treatment of fuel cycle safety issues, NRC staff has determined that the structure and content of the current Part 70 regulation needs improvement. Part 70 has evolved over the years by prescribing a set of narrow requirements to address each new need or problem as it arose. It has been repeatedly amended and patched since the late 1960s. Although operating fuel cycle licensees may have a good understanding of the current Part 70, it nonetheless contains redundant requirements presented in a rather illogical and disjointed format. The requirements are often prescriptive, and, in general, not graded according to risk (See Enclosure 1). It would be very difficult for a new applicant to determine which requirements would apply and how the NRC staff would interpret those requirements (See Enclosure 2).

3.0 Goals and Objectives

To address the deficiencies described above, the NRC staff has identified primary goals and objectives to improve the safety of operations of fuel cycle facilities, and to improve NRC regulation of those facilities.

With respect to the safety of operations of fuel cycle facilities, the NRC staff's objectives are :

1. To assure that licensees operate their facilities safely and thus reduce the frequency of precursor events and their potential for accidents.

2. To more clearly establish that licensees have a good understanding and control of the safety of operations at each fuel cycle facility. This objective may be achieved if:

a. Licensees establish and clearly articulate the safety basis for each fuel cycle facility.
  - Facility hazards and associated risks are identified, and controls are established commensurate with the risks.
  - The safety basis is focused on those items relied on for safety[2].

b. The safety basis is well maintained and current.

c. Operations are carried out in accordance with the documented safety basis.

d. Safety measures, graded according to risk, are in place to assure that items relied on for safety are available and reliable.

With respect to the NRC regulation of fuel cycle facilities, the NRC staff's objectives are:

1. To provide the NRC staff greater confidence that each fuel cycle facility is, and will continue to be, operated safely. This objective may be achieved if:

a. NRC staff has a clear and current understanding of the safety of operations at each fuel cycle facility.

b. The license application review process is comprehensive, uniformly applied to each licensee, and focused on safety issues graded according to risk.

c. The license application review process obtains commitments that provide adequate inspectability and enforceability of items relied on for safety.

2. To utilize NRC licensing, inspection, and enforcement resources more efficiently. This objective may be achieved if:

a. The licensee identifies the hazards and risks of the facility, and the associated items relied on for safety.

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[2] Site features, systems, structures, equipment, components, and human actions relied on for safety.

b. The staff has the information, i.e., the characterization of the risks associated with items relied on for safety, needed to prioritize the inspection and licensing review effort.
c. A more user-friendly Part 70 regulation is developed, including modification of its language and structure, to facilitate its use by current and new licensees.
d. The effort and time consumed in license renewal application reviews is reduced.

3. To reduce unnecessary burden on fuel cycle licensees. This objective may be achieved if:

a. The licensee focuses its resources on items relied on for safety.
b. The licensee prioritizes its efforts on those items with greater risk significance.

4.0 Suggested Regulatory Improvements

The Commission recommended, in January 1993, that to achieve the NRC staff's goal of improved safety, the highest priority should be given to upgrading the regulatory basis for determining the adequacy of licensee safety performance. In responding to the Commission's direction, the NRC staff proposed to revise Part 70 to contain new requirements for fuel cycle facilities (and other applicable materials licensees) that address the following areas to meet the objectives described above:

1) Integrated Safety Analysis (ISA) - An analysis that identifies hazards and their potential for initiating event sequences, the potential event sequences and their consequences, and the site, structures, systems, equipment, components, and activities of personnel that are relied on for safety.

2) Safety goals for accidents - Goals that licensees would be required to provide reasonable assurance of meeting, by prevention or mitigation of accidents;

3) To ensure that items relied on for safety are available and reliable to perform their intended functions, programs in the following areas would be required:

(i) fire protection

(ii) chemical process safety

(iii) criticality safety

(iv) management controls

(v) configuration management

(vi) quality assurance

(vii) maintenance

(viii) performance-based training

4) Description of safety activities - a discussion that is made part of the license, but providing authorization, similar to 10 CFR 50.59, for licensees to make changes in their license commitments without prior NRC authorization, provided that the ISA shows that such changes (1) do not increase the likelihood or consequences of an accident previously evaluated or (2) introduce an unreviewed safety issue; and,

5) Extended scope for reporting criticality events.

In addition to addressing new and revised safety requirements, the NRC staff also proposed, and received the Commission's concurrence, to address administrative and organizational deficiencies in the current rule. In particular, to make Part 70 more user-friendly, the staff proposed to simplify some of the language and reorganize the requirements for ease of understanding. According to these changes, Part 70 licenses would be categorized, according to the activities they conduct, into 6 groups, A through F. Based on the risks posed by each group, a different set of requirements would be applicable. Thus, for existing licensees, the new requirements described above would apply only if they belonged to Groups C, D, or E. For consistency with other materials-licensing parts of Title 10 and to minimize burden on other groups of licensees (A, B, and F) and Agreement States, the NRC staff proposed to retain most material that is already in current Part 70, albeit in a restructured format.

5.0 Workshop Discussions/Regulatory Issues

As part of its effort to ensure a sound framework for regulating fuel cycle facilities, the NRC has solicited the views of industry and other interested parties regarding possible changes to the existing regulatory structure. The November 30 workshop is part of this continuing effort. The NRC is hopeful that these discussions will provide information that is useful in meeting the objectives identified in Section 3.0 in an effective and efficient manner. Related to these objectives and the means of achieving them are a number of issues that NRC would like to explore. These issues include:

1. Does the record of operations at fuel cycle facilities show a need for regulatory change?

NRC staff analysis of serious incidents at fuel cycle facilities indicates that a significant fraction of those events resulted from systemic deficiencies in licensee safety programs. In addition, analysis of events reported under Bulletin 91-01 indicate that such deficiencies are not isolated but widespread (see Enclosure 3). The staff believes that the frequency and nature of events and incidents at fuel cycle facilities demonstrate deficiencies in licensees' existing safety programs that can be addressed by changes to Part 70. Such changes would help meet NRC's goal of improving safety.

Does this record support a need for regulatory change?

2. Does the lack of grading of requirements according to risk in the current Part 70 indicate a need for revising the rule?

The current Part 70 does not require that licensees (1) perform a systematic hazard analysis to identify items relied on for safety, (2) determine the quality and number of items commensurate with risk, and (3) assure the availability and reliability of those items. In addition, the current rule does not adequately address areas (e.g., chemical safety) known to have high risks (Enclosure 1). Instead, the current rule often contains detailed discussion of issues that are not of significant safety concern. This disproportionate attention to low-risk, mostly administrative, concerns may divert licensee attention from more significant issues.

Are changes needed in the regulation to help focus NRC and licensee attention on safety significant issues? Assuming it can be accomplished without imposing burdens on Agreement States, should unnecessary or unnecessarily prescriptive requirements in the existing rule be modified or eliminated?

3. Are changes to the existing Part 70 format needed to improve clarity?

As a result of a patchwork of amendments since Part 70 was first promulgated, the current regulation contains redundant and sometimes disproportionate requirements placed in a rather illogical and disjointed format (see Enclosure 2).

4. Rather than modifying the current rule, could an alternative approach be used to achieve NRC objectives?

For power reactors, the NRC invoked its authority to require additional information from licensees to obtain Individual Plant Examinations (IPEs). This approach might be used to obtain information produced by an ISA, including information about the items relied on for safety. Could the IPE approach also be used to ensure the establishment of safety programs needed to guarantee the availability and reliability of those items?

Another method for accomplishing NRC objectives is to define needed requirements and incorporate them as conditions in the license. Is this a viable approach?

5. Are changes needed in licensee safety programs to provide adequate confidence of safety?

NRC staff analyses indicate that the following improvements in safety programs would help correct the systemic deficiencies that have been identified. They include:

1. performance of an ISA
2. increased attention to chemical safety hazards
3. increased attention to fire protection
4. increased attention to criticality safety hazards
5. effective configuration management
6. performance-based safety training
7. effective maintenance of safety features
8. effective management control system
9. effective quality assurance for safety features

Are improvements in all these areas needed? Are there other areas where improvements are needed?

6. Is the identification of items relied on for safety, through the performance of an ISA (hazards analysis), a critical element in effective and efficient regulation of fuel cycle facilities?

To meet its goals for (1) effective and efficient expenditure of its licensing, inspection and enforcement resources, and (2) reduction of unnecessary burden on fuel cycle licensees, NRC would like to focus on those aspects of facility operations relied on for assuring the safety of licensed processes. Corresponding increased licensee attention to these safety related items will have a positive impact on safe operations, another goal of NRC. To identify the items relied on for safety, staff proposes that each fuel cycle licensee perform a comprehensive analysis (Integrated Safety Analysis) that identifies hazards and potential accidents, and through analysis of these, identifies the items relied on for safety.

Should there be a requirement for NRC licensees to perform an Integrated Safety Analysis? Are there any other approaches that could be used to meet NRC objectives?

7. How can the NRC obtain reasonable assurance of availability and reliability of the items relied on for safety?

The draft revision of Part 70 would require licensees to assure the availability and reliability of all items relied on for safety through the establishment of certain programs, e.g., quality assurance, maintenance, training, configuration management, etc. These programs, which are described in more detail in the draft SRP, are intended to provide the requisite assurance in a manner commensurate with the level of risk present at each facility. Thus, facilities with low overall risk might expect to implement simple and relatively less burdensome programs, while higher risk facilities might need to implement more rigorous programs. This approach is consistent with NRC's goals to (1) concentrate on items relied on for safety and (2) grade regulatory requirements so as to reduce the regulatory burden on licensees to the extent practicable.

Is the approach taken by NRC reasonable? Are there any other approaches that should be considered?

8. Is the concept of using defined levels of risk for the graded application of controls reasonable?

In the revised Part 70, NRC would specify limits (e.g, exposure to 5 rem) that the licensee must provide "reasonable assurance" will not be exceeded for any individual offsite, under accident conditions identified by the ISA.

The SRP provides specific criteria for judging whether the number and quality of the licensee's safety controls provide such "reasonable assurance."

Are there alternative concepts that should be considered?

9. Should all changes to the safety program be subject to prior NRC approval?

As in the case for fuel cycle facility Material Control and Accounting, and Physical Security Plans, the draft revised Part 70 proposes that prior approval for certain changes would not be required if those changes did not reduce the effectiveness of the safety program.

10. Should the license documentation be promptly updated when changes are made to the facility?

The NRC staff proposes to include in the Part 70 revision a requirement for prompt updating of the license documentation and notification to NRC when changes are made to facility operations that impact the safety program. Documentation of all other changes would be made in annual updates. The prompt reporting of all changes to the safety basis provides NRC with an increased level of confidence in the licensee's ability to operate the facility safely. This satisfies one of NRC's primary goals. In addition, by maintaining a "living license," the need for a license renewal process may be obviated. This could result in considerable cost savings for the fuel cycle industry.

Is the proposed approach reasonable? Are there any alternatives that NRC should consider?

11. How should the NRC implement a "performance-based" regulation?

NRC favors the development and implementation of "performance-based" regulations. This approach generally involves (1) the establishment of general performance objectives in the regulation and (2) the description of acceptable approaches for meeting those objectives in the SRP or other guidance. Are there alternative approaches that should be considered?

12. Assuming new requirements are adopted, how long should licensees be given to implement these requirements?

The draft revision to Part 70 proposes to allow twelve months for implementation of all new requirements.

Enclosure 1: Current Part 70 Requirements and the Risks They Address

Enclosure 2: Difficulties with Interpreting Current Part 70

Enclosure 3: Regulatory Concerns From Precursor Events at Fuel Cycle Facilities

THE REQUIREMENTS IN PART 70 AND THE RISKS THEY ADDRESS

One of the purposes for revising 10 CFR 70 is to refine the regulation so that requirements are commensurate with the risk that those requirements address. Disparities in the risk vs. rule content in the current regulation can be divided into three categories: high risk activities receiving relatively little regulatory attention, low risk activities receiving large amounts of detailed discussion, and moderate risk activities which receive more attention than high risk activities. One of the goals of the draft revised Part 70 is to modify the existing requirements so that the set of requirements more accurately reflects NRC's concerns regarding the risk involved in the regulated activities.

The most recognized high-risk hazard involving facilities which possess and use special nuclear material (SNM) is the unintentional criticality. The regulations in the existing 10 CFR 70 (Sections 70.22 through 70.24) include a reasonably detailed description of an acceptable program for the detection of and response to such an event. However, the existing regulations are much less descriptive in requiring such a program as part of the license application and on the <u>prevention</u> of a criticality excursion. New regulations detailing an acceptable criticality prevention program would provide a more complete coverage of this hazard. The draft revised 10 CFR Part 70 (Paragraph 70.70(b)) includes a requirement, at facilities where a criticality could occur, for the implementation of a safety program that provides reasonable assurance, through a formalized analysis process, that unintended criticalities are avoided.

Although usually less recognized as a high-risk hazard than is a criticality in a nuclear facility, chemical hazards in fuel cycle facilities cause more injuries to workers, more destruction of property, and more unintentional radiological releases to the environment than criticality events. Material processing at fuel cycle facilities typically involves direct contact of the SNM with explosive gases, flammable liquids, strong acids and oxidizers, and high temperatures. The oversight of these chemical hazards when they affect radiological safety or when they are present for the processing of licensed nuclear materials is the jurisdiction of the NRC (see e.g., the Memorandum Of Understanding with OSHA). The regulations in existing 10 CFR Part 70 only mention hazardous chemicals in conjunction with the requirements of a fuel cycle facility's emergency plan (paragraph 70.22(i)(3)(xiii)), and that mention is brief and does not specify the desired safety performance. Additional requirements for controlling chemical safety hazards are warranted in light of the risk level associated with these hazards. The safety program requirements in draft paragraph 70.70(b)) address the protection of workers, the public and the environment from the unintended release of radiation, of radioactive material, and of hazardous chemicals that could affect radiological safety or that could be generated by the release and/or reactions of radioactive compounds.

In a similar vein, one of the possible causes of a significant radiological release to the public involves the occurrence of a major fire at a fuel cycle facility. The processing of SNM provides a unique scenario whereby ordinary fire prevention and mitigation techniques may be ineffective or detrimental to the establishment of an adequate fire safety program. Even a small fire at a fuel cycle facility could compromise confinement of radioactive materials and criticality control features, thus compounding the risk associated with the possession of SNM. The treatment of fire hazards in the existing 10 CFR Part 70 is mostly limited to reporting requirements (Section 70.50). To correct this deficiency, the prevention of fires at larger fuel cycle facilities is addressed as part of the safety program which would be required by the draft revised rule per paragraph 70.70(f). This paragraph states that each application for a Group C or D license shall contain a description of the fire protection program to ensure, in the event of a fire, the availability of the safety and safeguards functions for structures, systems, equipment, components, and human actions relied on for safety and safeguards.

Many of the hazardous situations which have occurred at fuel cycle facilities have been traced to insufficient maintenance and testing of equipment, incomplete documentation of process changes, or inadequate training of personnel in the operational safety systems. These issues are paramount to the safe operation of a hazardous chemical process but are not significantly addressed in the existing version of the rule. In order to further ensure that a licensed operation is adequate to protect health and to minimize danger to life or property, safety system requirements including surveillance, testing, calibration, maintenance, configuration control, and qualification and training of personnel have been included in the draft revised Part 70. Paragraph 70.70(g) indicates that each application for a license should include a description of the maintenance program which ensures that the structures, systems, equipment, and components relied on for safety perform their function correctly when needed. Paragraph 70.70(h) requires each application for a license to include a description of the configuration management program that will ensure that modifications to the site, structures, systems, equipment, components, staffing, procedures and computer programs result in adequate safety and safeguards. Paragraph 70.70 (k) requires that each application for a license include a description of the program for qualification and training of personnel relied on for safety to provide reasonable assurance that they will reliably perform functions necessary for adequate safety and safeguards. Each of these requirements is applied to an extent that is commensurate with the risk at the individual licensed facility.

Many of the activities covered by 10 CFR Part 70 which involve relatively little risk have been given a reduced amount of detail in the revised rule. The detailed requirements for filing an application for a Part 70 license in existing sections 70.21 through 70.23 have been condensed by half in the revised rule. Some of the detail has been reallocated to the sections of the rule dealing with specific groups of licensees in order to make the regulations more readable. Other details have been eliminated because they are unnecessary. This should help the application process be more understandable. It also allows for more attention to be focused on requirements for the higher risk activities addressed by the regulations. Similarly, sections of the rule detailing the provisions for authorized usage and transfer of SNM (Sections 70.41 and 70.42) have been merged with the general licensing requirements so as to reduce the regulatory content as these topics deal mainly with administrative matters which involve little or no risk.

Another area where 10 CFR Part 70 can be streamlined is in the regulation of nuclear material control and accounting (MC&A). The existing Part 70 contains MC&A requirements for those facilities that use or manufacture SNM of moderate strategic significance as well as some general requirements for other types of licensees. In the proposed revision of the rule, the sections on material balances and inventory control (70.51), material status reports (70.53), material transfer reports (70.54), measurement controls (70.57), and FNMC plans (70.58) would be removed from Part 70 and transferred to Part 74. As a result, essentially all MC&A requirements, regardless of the type of licensee, would then be consolidated in one part of the regulations. This would leave 10 CFR Part 70 to focus more on the high safety risk subjects unique to fuel cycle facilities.

Overall, the draft revised version of 10 CFR Part 70 is a leaner, more focused set of regulations for domestic licensing of SNM. The draft revised document has been reduced by one-third from the volume of the existing rule, and the attention given to licensing activities is more commensurate with the risks involved in each area. These improvements coupled with the reorganization of the document into a more logical pattern with more emphasis being placed on the prevention of safety problems should promote a more efficient and effective rule. Notwithstanding, modifications to this draft potentially could make the rule even more efficient and effective.

DIFFICULTIES FOR NEW LICENSEES WITH EXISTING PART 70

The organization of the existing 10 CFR Part 70 is so deficient that a new license applicant might have difficulty determining what is required for its particular situation. The piecemeal format which has developed through years of patchwork additions to the rule has resulted in a document that lacks clarity and focus. The existing part 70 contains non-chronological patterns, requirements for particular situations dispersed throughout much of the text, and duplications. All of these deficiencies result in a document that is more burdensome to comprehend and use than is necessary.

One of the most obvious problems with the format of the existing 10 CFR Part 70 is the non-sequential order of its regulations. Entire sections of Part 70 are seemingly out of place. For example, sections dealing with the contents of license applications are placed before and after sections dealing with the NRC approval of the applications. The sections dealing with application approval are also placed before and after requirements for persons already holding an approved license. The general topics discussed in the sections of Part 70 pertaining to specific licenses are presented in Table 1. It can be seen from this list of topics that the structure of the document is fragmented, repetitive and non-sequential.

The requirements in many of the paragraphs within certain sections of 10 CFR 70 are very specialized. That is, they are relevant to different applicants depending on whether such applicants possess or use a certain type of material, quantity of material, type of facility or equipment, or undertake certain activities. Unfortunately, the paragraphs are not logically arranged so that their applicability can be easily determined. A good example of this situation in the existing Part 70 is §70.22, "Contents of applications", as seen in Table 2. This example shows that with the exception of paragraphs 70.22(d) and (e), no two consecutive paragraphs within §70.22 are necessarily applicable to the same group of license applicants. Therefore, in order to become cognizant of the current requirements, a new license applicant would have to meander back and forth through the regulations to understand what is required and what is not. The revised 10 CFR 70 has been restructured so that most of this fragmentation is avoided and a table is provided that shows clearly which paragraphs are applicable to each type of applicant.

Reducing the amount of duplicative text within the existing 10 CFR 70 would also help make the regulations to be less confusing and easier to follow. The duplications within Part 70 are not verbatim statements, but rephrasings of requirements already established elsewhere. This may to cause a new applicant/licensee to compare the multiple phrasings to try and determine if they are equivalent. The result is the current regulation is very burdensome to anyone attempting to understand it. One example of the duplicative nature of Part 70 is the portions of the rule dealing with the various programs for safety and safeguards. First, section 70.22 requires programs for material control, safety assessments, physical protection of SNM, physical security, emergency plans, and safeguards contingency plans to be part of certain license applications. Next, section 70.23 explains that license applications will be approved if the application satisfies certain conditions, including most of the programs listed in section 70.22, with each program discussed individually and contained within its own paragraph. Once an application is approved, section 70.32 requires that the contents of each applicable license contain certain license conditions, which address the same safety or safeguard requirements, again individually discussed within their own paragraphs. This repeated discussion of the same requirements is largely eliminated in the revised version of the rule. Instead, a simple reference is included where necessary to include all pertinent programs.

Another way in which the existing 10 CFR Part 70 is seen as being difficult to interpret is in conjunction with the requirements of other parts of 10 CFR. This is particularly true with respect to the physical protection and material control and accounting requirements in 10 CFR Parts 73 and 74. Part 70 contains some of the requirements for these programs, and the remaining details are listed in Parts 73 and 74, thus possibly causing confusion. The revision of Part 70 proposes moving the details of these requirements to Parts 73 and 74 and incorporating them by reference. This should help streamline the review and analysis of the regulations for special nuclear material licensees.

In sum, the disorganization and repetitiveness of the existing 10 CFR 70 make it difficult to follow and understand. The revised 10 CFR 70 has been structured to make the requirements less confusing and more orderly. The revised rule also eliminates several pages of duplicative details which are now incorporated by reference. This revised structure should promote a more readable and less confusing set of requirements when Parts 70, 73 and 74 are viewed as a total package.

TABLE 1 - SEQUENCE OF SELECTED TOPICS IN 10 CFR 70

§70.21 - Information on filing a license application.

§70.22 - License application contents.

§70.23 - License application approval.

§70.24 - Requirements for persons with an approved license.

§70.25 - Additional submissions required for certain license applicants which are not included in the section on the contents of an application.

§70.31 - License application approval and issuance of a license.

§70.32 through 70.38 - Lists more requirements for persons with an approved license.

§70.39(a) - More license application approval criteria.

§70.39(b) through 70.44 - More requirements for persons with an approved license.

§70.50 - Licensee reporting requirements.

§70.51 - More requirements for persons with an approved license.

§70.52 through 70.54 - More reporting requirements.

§70.58 - Details on the FNMC plan requirements which must be included in certain license applications.

TABLE 2 - EXAMPLE OF PARAGRAPH SPECIALIZATION

The portions of §70.22 are applicable to specific licensees as follows:

§70.22(a) - General instructions applicable to all part 70 licensees.

§70.22(b) - Applies to license applications for possession of SNM, possession of equipment capable of enriching uranium, operating an enrichment facility, or to possess and use SNM in a quantity exceeding one effective kilogram. However, this section does not apply to SNM used in sealed sources, or for those uses involved in the operation of a power reactor, or when involved in a waste disposal operation.

§70.22(d) and (e) - General instructions applicable to all part 70 licensees.

§70.22(f) - Applies to license applications for possessing and using SNM in a plutonium processing and fuel fabrication facility.

§70.22(g) - Contains application instructions for a license authorizing the transport (or delivery to a carrier for transport) of formula quantities of SNM, plus additional instructions for transport of 10 kg or more of SNM of low strategic significance.

§70.22(h) - Applies to license applications for possessing or using formula quantities of strategic SNM, except when in conjunction with the operation of a nuclear reactor.

§70.22(i) - Applies to license applications for possessing over 700 grams of U-235, 520 grams U-233, 450 grams plutonium, 1,500 grams U-235 if contained in materials enriched to no more than 4%, 450 grams of any combination of the above materials, half of the above material quantities if massive moderators or reflectors may be present, uranium hexafluoride in excess of 50 kg in a single container, uranium hexafluoride in excess of 1000 kg in multiple containers, or in excess of 2 curies of plutonium in unsealed form or on foils or plated sources.

§70.22(j) - Applies to license applications for possessing or using formula quantities of strategic SNM, except when in conjunction with the operation of a nuclear reactor.

§70.22(k) - Applies to license applications for possessing or using SNM of moderate strategic significance or 10 kg or more of SNM of low strategic significance, except when in conjunction with the operation of a nuclear reactor.

§70.22(l) - Applies to license applications to possess, use, transport, or deliver to a carrier for transport, formula quantities of stategic SNM.

§70.22(m) - Applies to license applications to possess equipment capable of enriching uranium or to operate an enrichment facility, or to produce, posses, or use more than one effective kilogram of SNM.

§70.22(n) - Applies only to license applications that involve the use of SNM in a uranium enrichment facility.

ENCLOSURE 3

REGULATORY CONCERNS FROM PRECURSOR EVENTS AT FUEL CYCLE FACILITIES

CONTENTS

I. SUMMARY AND CONCLUSIONS

The NRC staff has reviewed the causes of a considerable number of serious incidents and precursor events at nuclear fuel cycle facilities. Serious incidents are those involving harm or serious risk of harm to persons; while precursors are events which place a facility at increased risk of such a serious incident.

The purpose of the staff review was to determine whether the causes for serious incidents and precursors were random failures or reflect important and systemic deficiencies in safety programs.

The NRC staff review was conducted in two phases. In Phase One a detailed analysis of eight events was conducted. In Phase Two a larger number of events were reviewed, but in less detail. This approach was used because detailed analysis provides a deeper understanding of systemic causes; while the review of more events can indicate whether these causes are truly characteristic of the industry.

The NRC staff conclusions and observations based on this review are:

1) There is a set of systemic program deficiencies at fuel cycle licensees (see Table 1) that are consistent causes of serious incidents and precursors.

2) These deficiencies are neither rare nor isolated in the industry.

3) A list of corrective safety programs has been identified that, if required, would specifically address these deficiencies.

4) These corrective programs have been found consistent with the requirements proposed in the draft Part 70 revision.

The Phase One review analyzed eight events which the NRC staff had previously identified as particularly serious or as illustrating factors that cause serious incidents. Each event was treated as an individual case study. The interest was not in the events per se, but in which types of systemic program deficiencies cause or contribute to such incidents. By "systemic" is meant causes which are not individual random failures, but those in which a basic safety program was deficient, or was not being observed. The primary result of this Phase One review was a list of eleven systemic program deficiencies that were consistently implicated in causing or contributing to the events. These are shown in column one of Table 1. Typical examples of deficiencies on this list are inadequacies in "Configuration Management" and "Accident Identification".

The Phase Two review examined the 64 criticality safety event reports in the NRC Bulletin 91-01 Event Tracking System as of March 1995. The objective was to determine whether the deficiencies identified in the eight events of Phase One were also characteristic of this larger set of events, and were characteristic of the industry in general.

Review of these 64 events showed that they were not isolated to one or two facilities. The statistics were that 5 of 7 reporting licensees had 7 or more events. An assessment of the first 43 events (through August 1993) showed that 32 were true precursors, not just documentation or other minor problems. In six cases, one more failure could have caused a criticality. Finally, an analysis of the causes of the 10 most serious precursors implicated the same set of programmatic deficiencies as found in the Phase One study. In addition, occurrence of 32 criticality precursors in just 22 months also raises the question of whether the frequency of failures affecting criticality control is too high. Considering the nature of the causes of these 32 events, there is reason to question whether all potential criticalities have been identified, and whether the controls on those that have been identified are adequate.

Having identified a set of systemic deficiencies of concern, a corresponding set of corrective actions was developed. These corrective actions are shown in column two of Table 1. The corrective actions consist of the establishment of safety program elements like an effective Configuration Management Program or an Integrated Safety Analysis. The proposed requirements of the draft Part 70 revision were compared to this list of specific corrective actions, and were found to be consistent with it.

II. PHASE 1: ANALYSIS OF EIGHT SERIOUS INCIDENTS AND PRECURSORS

The eight events selected for this phase one review are listed in Table 2 of Section V. Certain of these events were selected because they were instances of death or injury, others because they came close to causing such harm, and some because they illustrate significant causes. In this document, the phrase, "serious incident", refers to events involving actual harm to persons or severe risk of harm. For example, under this definition, a serious incident could be any of the following: a) an inadvertent nuclear criticality, b) acute exposure to excess radiation or releases of hazardous licensed material, or c) releases, explosions, or other events with a high potential for affecting regulated operations. A precursor is defined as an event which places a system in a state of substantially enhanced risk of such serious incidents. The term, "event", is used generically to refer to any of the events studied. These definitions are strictly for use in the context of this analysis.

The analysis to follow contains a narrative of each serious incident or precursor event. This is followed by a description of deficiencies causing the event. This format has been followed to provide the reader the opportunity to assess the deficiencies and the relevance of each event.

Not all causal factors are included, only those that were judged to be systemic deficiencies in the licensee's safety programs. By "systemic" is meant causes which are not individual random failures, but those in which a basic safety program was deficient, or was not being observed. In other words, a systemic deficiency is not just one of the few failures one expects in a good safety program, but one that is indicative of more general problems. Due to limited information, determining whether a deficiency was systematic is sometimes a matter of judgement. On the other hand, the investigative reports often reveal quite clearly the systemic nature of the deficiencies, usually through interviews concerning operating practices.

Event descriptions and, for the most part, assignment of causes are based on licensee Bulletin 91-01 reports, NRC investigative reports, and associated NUREGS.

In order to show how the assignment of deficiencies described below are the same as given in Table 1, the numbers and abbreviations for the corresponding deficiencies from Table 1 are shown in parentheses.

Event A: Transfer to Unsafe Geometry Tank

This event occurred at a low enriched uranium fuel fabrication plant. The initial problem was a malfunctioning interface level control valve in a solvent extraction column. As a result of the malfunction, and actions in response to it, the uranium-bearing feed material was carried through the column to safe geometry quarantine tanks. While attempting to keep the process operating despite the faulty control valve, personnel several times transferred the contents of the quarantine tanks to unfavorable geometry waste tanks. In order to prevent transfer of solutions containing too high a concentration of uranium to these unfavorable geometry tanks, criticality safety procedures required that the solution be sampled, and the concentration of uranium measured, prior to transfer. For some of the transfers no sampling was done. For other transfers it was done, but in an improper manner. As a result, high concentration uranium solution was transferred to the unfavorable geometry tank. Eventually this high uranium concentration was detected and the operation was shut down. Nuclear criticality conditions in the unfavorable geometry tanks were mitigated by active sparging to prevent settling, and by the fortuitous presence of contaminants.

This tank transfer process, including sampling and the transfer itself, had originally been under highly automated control to ensure criticality safety. When the automatic sampling aspect of this system was eliminated, the formal change to the criticality safety program was not reviewed by the NRC.

Systemic Deficiencies:

NUREG-1450 documented an investigation of this incident, which occurred at a low enriched uranium (LEU) fuel facility in 1991. In its final section NUREG-1450 listed the deficiencies which had caused the incident. Among them were many of the systemic deficiencies shown in Table 1. The numbers of the corresponding deficiencies from Table 1 are shown here in parentheses. The deficiencies contributing to this event include 7 out of the 11 listed in Table 1. The deficiencies, as stated in NUREG-1450, were:

1) Job specific training on criticality safety was lacking. Reliance was entirely on on-the-job training. There was no QA of operator performance. There was no documentation system for operations that would permit such QA. (from Table 1: 1. Personnel)

2) There was no QA audit program for criticality controls that consisted of sampling and measurement. (from Table 1: 7. Measurement)

3) Nuclear criticality safety QA audits were inadequate in that they did not focus on process controls, but on hardware changes. That is, changes of major hardware were audited, but procedural or process changes were not. (9. Criticality)

4) Criticality control for transfers to the unsafe geometry tank was inadequate. There was only one control, not double contingency, the standard acceptable practice. Secondly the reliability of this one control, even when properly followed, was inadequate. The type of sampling and measurement procedure that was being used as a criticality control was unreliable, had not been tested, and had no QA. Its inadequacy constitutes a deficient criticality safety review of the elimination of the automatic sampling system. (4.Controls, 5.Criticality, 6.Configuration Management)

5) There was no distinction made between safety control alarms and process alarms in the automatic control system. Hence, violation of a safety limit had no special identifying characteristic. (2.Safety Labeling)

6) Configuration control of the automatic control system was inadequate. The various changes that degraded criticality control occurred without adequate review and approval of their impacts. (6.Configuration Management)

7) There was no assessment of the safety impact of the process change that directed additional waste streams to the quarantine tanks. This made frequent emptying of the tanks necessary to keep the production flow up. This frequency put pressure on the operators to cut corners on the sampling procedures. The operational and safety impacts of this seemingly innocuous process change had not been evaluated, as it would have been in an effective configuration management program. (6.Configuration Management)

8) Management attention to safety was noted as deficient in that there was too little management time available, and there was a lack of ownership of specific facilities. That is, there was no specific manager in charge of the unit that had the problem. (5.Management)

9) A lack of any system for management of engineering or maintenance impact on criticality controls was noted (6.Configuration Management, 11.Maintenance)

Event B: Rupture of an Over-filled UF_6 Cylinder.

This event occurred in January of 1986 at a UF_6 conversion plant. This facility was not regulated under Part 70. However, the fact that this was a serious accident involving a UF_6 cylinder, an item handled by most other fuel cycle facilities, should permit the identification of the type of deficiencies that could lead to such an event elsewhere.

The sequence of events began when a UF_6 cylinder was grossly over-filled due to an erroneous weight indication, lower than the correct value, on the scale used to monitor the amount of UF_6 in the cylinder during filling. This error occurred because the cylinder was mispositioned on the scale. A factor in this mispositioning was the fact that the scale had been designed for 10 ton cylinders, while the one being weighed was a longer, 14 ton, design. Once the over-filled condition was recognized, it was not possible to obtain an accurate estimate of the amount of the over-fill. This was again because the scale was not designed for 14 tons. To remove the contents, the cylinder was heated in a steam chest, a violation of standard procedures for UF_6. There were no special procedures or checklists for this process. There was no automatic over-pressure monitoring and alarm system. There was no over-pressure relief. Expansion of the UF_6 upon phase change from solid to liquid ruptured the cylinder. A large release of gaseous UF_6 occurred, killing one person by the effect of chemical toxicity.

Systemic Deficiencies:

This event revealed an absence of several elements of a program for safe handling of UF_6. One cause of these deficiencies may have been the lack of an explicit regulatory requirement for chemical safety. However, this is an indirect deficiency. The more substantive safety elements missing were: formal hazard identification, hazard evaluation, management controls, and configuration management.

The following specific deficiencies were noted:

1) The special hazards of overfilling and the unloading of an overfilled cylinder had not been adequately identified as elements of any safety program. (2. Safety Label)

1) Personnel should have been trained in safe procedures for unloading an over-filled cylinder because this event had occurred before. (1. Personnel)

3) Configuration change control was inadequate. When the scale for controlling amount of UF_6 in cylinders began to be used for 14 ton cylinders instead of the design basis 10 ton, a formal engineering change should have been conducted. (6. Configuration Management)

4) There was no QA program for this weighing process; hence, its inadequacies were not detected. (5. Management, 7. Measurement QA)

5) Considering the hazard of over-filling, controls on the filling process were inadequate. Investigators recommended two independent weighing devices, both capable of measuring a 14 ton overfill. (4. Controls)

6) The fact that chemical toxicity, not radiological, was the acute hazard for this event amounted to a regulatory gap between two agencies. In any case, hazardous chemical activities were not being adequately addressed by the licensee. (10. Chemical safety)

Event C: NOX Release

This incident occurred at a conversion plant in November of 1992. Acid was erroneously added to a tank already filled with uranium yellowcake, a reversal of the normal sequence. This produced a rate of nitrous oxide (NOX) generation so large as to overwhelm the off-gas system. The result was a large release of toxic NOX gases. Mitigation of the release was reduced because the capacity of the off-gas system had been severely degraded due to lack of maintenance. Although off-site consequences occurred, the regulatory concerns of the NRC with this event are the toxic effects on workers from a process involving regulated material, including the fact that this release could have forced an immediate evacuation with loss of control over other regulated processes.

Systemic Deficiencies:

1) This accident scenario was not adequately identified and evaluated as a major toxic release hazard. (10: Chemical Safety, 3: Accident ID)

2) The lack of formal NRC cognizance of chemical safety involving or affecting regulated material meant that there was no NRC-regulated chemical safety program. Hence, controls in place for this process were inadequate. (4: Controls)

3) Lack of management attention to safety features like the off-gas system contributed to the event. (5: Management)

4) Poor maintenance of a system that should have been relied on for safety led to its unavailability when needed. (11: Maintenance)

Event D: Perchlorate Explosion and Fire

This event occurred in an HEU fuel plant in 1992. In this case, a chemical accident caused a radiological problem with licensed material. Cylinders intended for a waste precipitation operation were erroneously selected for an evaporation and concentration operation. Incorrect cylinders, containing perchlorate solution, were selected for this process, which was conducted in an evaporator tray. The first step of the process involved boil-down of solution. Flames were observed from the evaporator tray. These flames were noted as unusual, and extinguished. However, the boil-down was continued. An explosion occurred starting a small fire in adjacent equipment containing uranium bearing materials. HEU contamination occurred.

Systemic Deficiencies:

This event is an example of the need to consider chemical hazards due to their potential to affect licensed material. Perchlorate-bearing solutions had not been formally identified as a special hazard. Nor had the scenario of misdirecting containers to the evaporator tray been identified as a potentially hazardous scenario. Hence, specific controls were not established to make the event sufficiently unlikely. The misrouting of cylinders is a good example of the type of unusual, hence unanticipated, mistakes that might be identified in an Integrated Safety Analysis. Had such misrouting been recognized as having large potential consequences, methods for preventing misrouting could have been devised. (3:Accident ID, 4:Controls, 10:Chemical Safety)

Event E: Uranium Solution Sent along Wrong Path:

This event occurred in the UF_6 hydrolysis process at the front end of an LEU fuel plant in October 1992. Due to a cracked dip tube, a hydrolysis tank level control indicator malfunctioned causing overfilling of the tank. The tank lacked an overflow line; therefore, the contents backed up into the off-gas system and flowed into an unsafe geometry vaporization chest. In subsequent reports it was noted that analysis of off-normal flow paths had not been conducted for this and certain other plant areas.

Systemic Deficiencies:

The lack of an overflow is an inadequate safety control. The fact that off-normal flow paths had not been analyzed for this tank and similar locations was an inadequacy of the nuclear criticality safety program. This particular accident path had not been formally identified. (3:Accident ID, 4:Controls, 9:Criticality)

Event F: Uranium accumulation in ducts

This event occurred at an HEU fuel plant several times over the period 1994-95. Process operators were unaware of the accumulation of a uranium compound dust in the ducts of a system for ventilating a liquid process. The accumulation reached an amount exceeding the criticality safety limits. Liquid aerosols from the process had been entrained in the air pulled into the ducts. The duct drain for liquids was plugged; hence, the liquid remained until it evaporated leaving the dust. The liquid drain trap was, by procedure, supposed to be emptied regularly. Operators had noted very intermittent behavior as far as the presence or absence of liquid in this trap. This problem of excessive accumulations had occurred at least 4 times in the past.

Systemic Deficiencies:

1) Recurrence of these accumulations four times shows a lack of management attention to a potential safety problem. In the case of these precursors, it is the recurrence that is the indicator that the problems are systemic. (5. Management)

2) Monitoring of the drain trap was not adequately indicated to operators as a safety control. (2. Safety Label)

3) Operating personnel were not sufficiently trained about the potential and danger of accumulation, hence did not recognize the problem. (1. Personnel training)

4) The control of accumulations in the duct was inadequate. The process and ducts ideally should have been designed to minimize such accumulations. In addition, procedural controls were needed for monitoring the status of the drain and of any accumulations. There was a lack of ability to adequately measure the materials in the ducts as a second control. (7. Measurement QA, 4. Controls)

Event G: Sampler plugged

This event occurred in May of 1993 at an LEU fuel plant. In the Integrated Dry Route (IDR) conversion process line, the sampler for the UO_2 section was found to be plugged. The result was that the samples being taken by operators had not been representative for some period of time.

Systemic Deficiencies:

QA for this measurement step may have been inadequate. There was no redundancy nor QA check mentioned for verifying that the sample was representative. The plugging mentioned presumably interfered with the dynamics of the aerosol flow so that the stream being sampled was not a current well-mixed extract of the process stream. (7. Measurement QA)

Event H: UO_2 spill

This event occurred in an LEU fuel plant in February 1993. A 124 Kg accumulation of 4.6 % enriched UO_2 powder occurred when the discharge hose from a UO_2 blender came loose. The UO_2 powder is fed out of the blender by an accurate screw drive feeder. When the hose came loose, the feed should have been shut off by an automatic limit switch, but this had been taped over to prevent false cut-offs. The limit switches had been installed as an interim fix after a spill in a different piece of equipment. However, this change had not gone through the formal Engineering Change Notice nor the Acceptance Test Procedures. Hence, the limit switches had not been established as a formal criticality control, nor had the operators been trained as to their purpose. As a permanent fix for this problem, an engineering project was underway to alter the discharges so as to prevent spills in the first place.

Systemic Deficiencies:

1) Configuration management was not followed and no Engineering Change Notice (ECN) was filed for installing the limit switches. False cut-offs during operation might have been revealed by acceptance testing if an ECN had been followed. (6. Configuration Management)

2) The limit switch should have been identified as a criticality control and labeled as such. (2. Safety Label)

3) The accident scenario of the blender discharge hose coming loose should have been identified as a formal criticality accident, and formal controls applied. (3. Accident ID)

4) The selection and use of this limit switch was inadequate as a criticality control due to excessive false actuation. The Accident Investigation Team also concluded that measures to enforce the moderation control area established around the blender were inadequate. (4. Controls)

5) Despite the fact that the limit switches did not go through ECN, they were present for a safety reason. Therefore, the operators should have been trained as to the safety significance of the switches. (1.Personnel)

III. PHASE TWO: REVIEW OF BULLETIN 91-01 EVENTS

Bulletin 91-01 requests reporting by fuel cycle licensees of loss or substantial degradation of a criticality safety control. It also requests reporting of conditions with a possible criticality hazard which have not been analyzed. Licensees have been submitting such reports since November of 1991. Brief synopses and analysis of these reports have been assembled into a database called BETS, Bulletin 91-01 Event Tracking System. As of August 1995, this database contained 64 events reported over a period of 41 months. All 64 events were reviewed, but only the first 43 received more detailed analysis, due to time limitations. This rate of occurrence, 64 events in 41 months, is not the primary concern of this analysis; the primary concern is what they indicate about the generic causes of such events. Out of the first 43 events, only 5 were minor events, such as unanalyzed conditions that later were evaluated as acceptable. The other 37 reported events involved, at a minimum, substantial degradation of a safety control.

The facilities at which all 64 events occurred were tabulated. They were found to occur at most fuel cycle licensees, not just one or two. The 64 events were distributed among 7 major licensees as follows, in order of frequency: 26, 13, 8, 7, 7, 2, 1. Since 5 out of 7 licensees had 7 or more events, such events are not isolated.

The first 43 events reported have been categorized in two ways, by degree of seriousness, and by cause. Seriousness here refers to the extent to which likelihood of criticality is affected. The purpose of determining the seriousness of the events is to identify those events that came closest to a criticality so that their causes may be studied. The presumption is that the causes of the more serious events should be of greater regulatory significance. The second categorization, by cause, was then done only for these more serious events. This categorization of causes related these events to the same deficiencies as identified in the Phase One study.

It should be noted that, although the database consulted was oriented toward criticality precursors, inadvertent criticality is not the only adverse consequence that can result from loss of control over licensed material. Radiological contamination and worker harm also may occur.

SERIOUSNESS

Almost by definition, any event reported under Bulletin 91-01 criteria is sufficiently serious to qualify as a precursor. This is because the Bulletin requires reports on "substantial degradation of a criticality control"; and such degradation would mean a state of increased likelihood of an accident. This was, in fact, found to be the case. Only a few of the incidents were truly minor. These were typically reports of an unanalyzed condition that was subsequently analyzed and found to be acceptable.

In reviewing the events, five categories were established in order of seriousness, from Category 1, the most serious, to Category 5, the least. None of the events was an actual criticality.

A distinction is made in this analysis between failure of a criticality control, and exceeding the criticality safety limit on the controlled parameter. For instance, the controlled parameter may be mass of U-235 in a certain location. The control may consist of barriers keeping it out of the location. If the barrier fails, the control has failed. However, the mass of U-235 that actually enters the controlled location may not exceed the mass limit established as subcritical by analysis.

Category 1 events are those where the criticality safety limit was actually exceeded. In most cases, this consisted of a potentially critical mass of U-235 accumulating at a location. Category 2 events are cases where the control has failed, but the criticality safety limit has not been exceeded. These are serious failures in that control has been lost over fissile material. The fact that the mass of fissile material that accumulated did not exceed the safety limit was often fortuitous.

The database has a total of 64 reported events from November 1991 through March 1995. The first 43 of these were reviewed. They were categorized with the following result:

BULLETIN 91-01 CRITICALITY SAFETY EVENTS

CATEGORY	NUMBER OF EVENTS
1. 1 control failed & limit exceeded	10
2. 1 control failed, limit not exceeded	22
3. degradation of 1 control	5
4. degradation of criticality alarm	1
5. minor or unknown condition, later found OK	5
TOTAL	43

Category 1 consists of 10 events where a criticality safety limit was exceeded. The most common safety limit involved was mass of U-235 in a location. For six of these ten events, the reported masses and enrichments indicate that safety limits were exceeded by an amount sufficient that one more event could have caused a criticality. Based on the reports, this occurred 6 times out of the 43 events examined. The one additional event that could have caused a criticality was typically ingress of water. Thus, for these six cases, the likelihood of a criticality depended on the quality of the single remaining criticality control, moderation.

Many processes at these facilities have established two criticality safety controls as a way of implementing the ANSI/ANS double contingency principle. For events in categories 1 and 2 above, one of these criticality controls has been lost. Presumably, in these cases, one other criticality control remains. Criticality controls are established over parameters like mass, moderation, or geometry that affect criticality. The term "limit" in the table refers to the criticality safety limit on the parameter being controlled. In the table, out of 43 reports, there were 32 cases of total failure of one control. In 10 of these 32 cases the criticality safety limit was exceeded, in 22 it was not.

The typical case of loss of a single control was a UO_2 powder spill outside of controlled geometry. Such a spill is clearly loss of control, but the amount spilled may or may not have exceeded the established criticality safety limit.

Category 3, "degradation of one control", means that both of the double contingency controls are still being maintained, but one of them has been weakened. The typical event was failure of one out of two redundant process monitors used as part of a single control on mass. When one monitor fails, mass control is still maintained, but at a lower level of reliability.

Category 4 differs from the others in that likelihood of criticality itself is not affected. The one Category 4 event was loss of power to the criticality alarm system. This is not a threat of criticality itself, but loss of a mitigation capability.

The 5 other events, Category 5, were minor events. These events typically involved discovery of an unanalyzed condition. The condition was then later shown not to be hazardous. Technically, such an event is loss of control, but they have been tabulated separately here to show that the other 32 losses of control were true failures.

CAUSES

Tables 3 and 4, on pages 19 and 20, show the causes of the ten most serious events (Category 1 above). The deficiencies identified in Table 3 are the same as those of Table 1. The conclusion is that most of these deficiencies are contributors to the criticality precursors of Bulletin 91-01, just as they were to the selected events analyzed in Section II.

IV. TABLES

Tables 1 and 2 below display the results of the Phase One study in tabular form. The two tables are the reverse of each other. Table 1 lists the events associated with each of the eleven deficiencies. Table 2 lists the deficiencies for each of the eight events. Tables 3 and 4 are a similar display of the ten most serious criticality precursors from the Phase Two study.

Table 1:

Column one of Table 1 lists eleven deficiencies using just a single word identifier. These identifiers are then followed by a brief descriptive phrase. These single-word identifiers are used in referring to the eleven deficiencies elsewhere in this document. More extended definitions of each of the deficiencies are given following the table. Column two lists safety program elements that could address the deficiency. Column three lists all the events where that deficiency was a causal factor.

Table 2:

Table 2 displays the eight events of the Phase One study and lists the systemic program deficiencies that contributed to them. The events listed in Table 2 were serious incidents or were precursor events. By "serious incident" is meant any of the following: a) an inadvertent criticality, b) an acute radiation exposure beyond permissible limits, or c) a release of licensed material or of hazardous material of regulatory concern to the NRC. A precursor is an event which places a system in a state of substantially enhanced risk of one of these incidents.

Table 3:

Table 3 has the same format as Table 1, but covers the ten most serious criticality precursor events from the Phase Two study.

Table 4:

Table 4 is analogous to Table 2 in that it is a list identifying the ten criticality precursor events used in Table 3. An extended description of each of these ten events is given in the text following the table.

Table 1: Systemic Fuel Cycle Safety Deficiencies & Precursors

Systemic Program Deficiency	Corrective Program	Precursors (Table 2) Caused by Deficiency
1. Personnel: safety knowledge inadequate	performance based safety training	A:Transfer to Unsafe, B:Cyl.Rupt., F:Dust in Duct, H:UO_2 spill
2. Safety Label: safety features not identified as such	Integrated Safety Analysis, Configuration Management Program	A:Transfer to Unsafe, F:Dust in Duct, H:UO_2 spill
3. Accident ID: hazard not analyzed, accident not identified	Integrated Safety Analysis	C:NOX, D:P.Expl., H:UO_2 spill, E:U sol'n wrong path
4. Controls: inadequate or unreliable safety controls	Integr. Safety Analysis, Configuration Management Program	A:Transfer to Unsafe, C:NOX, D:P.Expl., H:UO_2 spill, E:U path
5.Management: management attention to safety insufficient	Management Systems	A:Transfer to Unsafe, B:Cyl.Rupt., C:NOX, F:Dust in Duct
6. Configuration Management: poor control of changes impacting safety	Configuration Management Program, Safety Maintenance Program	B:Cyl. Rupt., A:Transfer to Unsafe, H:UO_2 spill
7. Measurement: poor measurement & sample QA	QA Program	F:Dust in Duct, G:Sampler Plug.

8. Fire: defective fire safety program	Integr. Safety Anal., integrated fire program	D:Perch.Explos.
9. Criticality: deficient NCS program	Integr. Safety An., Standard NCS Program	A:Transfer to Unsafe, E:U sol'n. wrong path
10. Chemical: deficient chemical safety program	Integr. Safety An., off-site chemical exposure criteria, Chem. Safety	B:Cyl. Rupt., C:NOX
11. Maintenance: inadequate safety maintenance program	Safety Maintenance Program	A:Transfer to Unsafe Tank, C: NOX Release

DEFINITIONS OF SAFETY DEFICIENCIES

The definitions below give more detail as to the significance of these generic deficiencies. In general, the deficiency may be in a licensee's safety program itself, or in its implementation. The deficiencies counted here are features that directly affect safety, not simply a program inefficiency or a failure to provide required documentation.

Definitions:

1. Personnel safety knowledge inadequate:
This is a situation where specific information is lacking to avoid a serious incident. This deficiency is indicated if the reason for violating a procedure was either lack of familiarity with, or knowledge of, the procedure. Personnel also need a certain understanding of the hazards and of the reasons for safety controls in order to respond appropriately to off-normal conditions. An example of this deficiency was the fact that the personnel involved in the UF_6 cylinder rupture did not sufficiently appreciate why heating an overfilled cylinder was hazardous.

2. Safety Label, items relied on for safety not identified as such:
This deficiency is the lack of a program to adequately identify and label items relied on for safety. This safety labeling process should follow identification of the feature in an ISA or other formal hazards control system. It consists of having a formal labeling program with signs, classifying equipment and procedures as "relied on for safety". A key aspect is "adequacy" of the labeling. A label may exist, but be insufficiently obvious to operators. For example, safety systems and replacement parts should have a special, very obvious, type of label to distinguish them from non-safety items. Operating procedures that have a criticality safety significance should be marked on the procedures checklist with a special symbol.

3. Accident ID, hazard not analyzed or accident not identified:
This deficiency consists in failure to identify all hazards and all potential accident scenarios. Formal identification within the plant's formal safety program is required. The fact that some persons at a plant might informally be aware of a hazard is not sufficient to constitute "identification".

4. Controls, inadequate or unreliable safety controls:
This is a situation where items relied on for safety, such as procedures, features of hardware, measurements, etc., either do not exist where needed or

are inadequate. For safety procedures, this deficiency is not simply a failure to observe a correct procedure, but the fact that the procedure itself is missing or inadequate. Normally deficiency number 3, "Accident Identification", and this deficiency number 4 do not appear together for the same event. This is because failure to identify a hazard will usually result in no controls being established to protect against it. Thus such a fault is really a case of a potential accident not being identified. Occasionally both deficiencies may occur together. For instance, an accident could be caused by a combination of an inadequate control on one hazard together with another unidentified hazard. The perchlorate explosion, Event D, is an example.

5. Management attention to safety insufficient:
This includes events such as: a) ignoring a recurring problem that comes to management's attention, b) tolerating recurring violations or degradations of an established safety procedure, c) lack of a safety analysis or control for a process, or d) a needed management system (e.g. a particular QA program) that is weak or absent, e) insufficient staffing, f) allowing safety maintenance schedules to stretch too far.

6. Configuration Management, poor control of changes impacting safety:
This deficiency is the lack of a comprehensive Safety Configuration Management Program that ensures that all processes, and all changes that might impact safety are adequately managed. This management of change requires a system that uses firm procedures or hardware to ensure that all required actions are performed. These required actions include changes to hardware drawings, operating and maintenance procedures, safety analysis and controls, training, qualifications, etc..

7. Measurement, poor measurement and sampling QA:
Sampling and measurement are two steps in determining the value of a process variable. The measurements of concern here are those used as safety controls. One common source of this deficiency is the difficulty of obtaining representative samples. Another form of this deficiency consists of using measurement devices or methods that are not sufficiently reliable. A third form of this deficiency is lack of independent QA audits of the measurement methods.

8. Fire, deficient fire safety program:
Lack or inadequacy of a fire safety program that addresses criticality safety or other interactions with licensed material.

9. Criticality, deficient Nuclear Criticality Safety Program:
This deficiency is a nuclear criticality safety (NCS) program that has systemic deficiencies. The program should conform to ANSI/ANS NCS Standards endorsed by NRC Regulatory Guides. There is a difference between this and other criticality safety deficiencies like 3 and 4, accident identification and inadequate controls. These others are very specific deficiencies. This deficiency covers more general aspects of the program. The typical instances in the cases reviewed were a failure to apply required evaluations or audits to all processes in the plant. Such failures thus precede and cause deficiencies like inadequate controls.

10. Chemical, deficient chemical safety program:
This consists of lack or inadequacy of a chemical safety program to address the potential impact of chemical incidents on licensed materials. This program needs to address 1) the chemical affects on workers and public from licensed materials, and 2) the fact that accidents with hazardous chemicals can affect the nuclear safety of other parts of the operation.

11. Maintenance, inadequate safety maintenance program:
There are two aspects to this: 1) planned maintenance of a quality that is graded according to the safety significance of the system, and 2) adequacy of engineering controls for unplanned maintenance to ensure that safety impacts are determined and accommodated. This latter function may be considered part of the Configuration Management System for major maintenance actions, but for quick repairs it may not be.

Table 2 gives identifying information about the eight events which have been reviewed. An identifying letter (A - H) and "Abbreviated Name" for each event are given in column 1. These letters and abbreviated names are the ones used to refer to these events in Table 1. Table 1 assigns the events to specific deficiencies. A longer name for the event is given in column 2 of Table 2. The last column of Table 2 lists the generic safety deficiencies which contributed to each event. These deficiencies in column 3 of Table 2 are identified by the same digit and one word descriptions used in column 1 of Table 1 for the eleven systemic program deficiencies.

Table 2: Serious Fuel Cycle Incidents and Precursors Events

Abbreviated Name	Event Description	Facility Type & Date	Systemic Program Deficiency
A: Transfer to Unsafe	solvent extract. upset, uranium sol'n. transfer to unsafe geometry tank	LEU fuel, 5/91	1:Pers, 2:Safety Label, 4:Controls, 5:Management, 6:Config. Management, 7:Measurement, 11:Maintenance
B: Cyl.Rupt.	overfill & rupture of UF_6 cylinder	conversion plant, 1/86	1:Pers, 2:Label, 4:Controls, 5:Management, 6:Config. Manag., 7:Measurement, 10:Chemical
C: NOX	NOX release from digestion tank	conversion plant, 11/92	3:Accident ID, 4:Controls, 5:Management, 10:Chemical, 11:Maintenance
D: P. Expl.	Perchlorate explosion & fire at HEU plant	HEU fuel, 9/92	3:Accident ID, 4:Controls
E: U Path	U solution took wrong path	LEU fuel, 10/92	3:Accident ID, 4:Controls, 9:Criticality
F: Dust in Duct	uranium dust accumulation in Ducts	HEU fuel, 3/95 2/95, 9/94, 83	1:Pers, 2:Safety Label, 4:Controls, 5:Management, 7:Measurement
G: Sampler Plug.	IDR UO_2 section sampler plugged	LEU fuel, 5/93	7:Measurement

H: UO_2 Spill	limit switch taped, hose came loose, UO_2 powder spilled	LEU fuel, 2/93	1: Pers, 2:Safety Label, 3:Accident ID, 4:Controls, 6:Config. Management

Table 3: Safety Deficiencies & Criticality Precursors

Systemic Program Deficiencies	Corrective Program	Abbreviated Precursor Names from Table 4
1. Personnel: personnel unfamiliar with safety controls	performance based safety training	flowmeter, limit switch, hood mass limit, Pu drums
2. Safety Label: safety features not identified as such	Integrated Safety Analysis (ISA), Configuration Management Program	limit switch, wrong cart
3. Accident ID: hazard or accident not identified	ISA	limit switch, flowmeter
4. Controls: inadequate or unreliable safety controls	ISA, Configuration Management Program	flowmeter, limit switch, Incinerator mass, tank sludge, ADU spill
5.Management: management attention to safety insufficient	Management Systems	
6. Configuration Management: poor control of changes impacting safety	Config. Managm. Prog., Safety Maintenance Program	limit switch
7. Measurement: poor measurement & sample QA	QA Program	Incinerator mass, flowmeter
8. Fire: defective fire safety program	ISA, integrated fire safety program	

9. Criticality: deficient NCS program	ISA, NCS Program	flowmeter, Incin. mass, tank sludge, Pu drums
10. Chemical: deficient chemical safety program	ISA, Chemical Safety Program	
11. Maintenance: inadequate safety maintenance program	Safety Maintenance Program	ADU spill, 2 gaskets

Table 4: Criticality Precursor Events

(criticality safety limit exceeded for 1 control)

	Type of Plant	Date	Abbrev.	Event Description
1	LEU fuel	10/27/92	Wrong Cart	Nat. U pellet cart used for enriched.
2	LEU fuel	2/7/93	Limit Switch	Limit switch taped, outlet tube came loose, UO_2 spill
3	LEU fuel	4/27/93	Incin.Mass	no mass measurements of I/O
4	HEU fuel	5/10/93	Pu Drums	mass limit exceeded
5	HEU fuel	5/20/93	Tank sludge	mass limit, annual cleaning
6	HEU fuel	6/2/93	2 bottles in hood	hood mass limit
7	LEU fuel	7/20/93	ADU spill	leak in pellet press intake
8	LEU fuel	8/13/93	2 gaskets	leak from UO_2 mill output gasket, error: 2 gaskets instead of 1
9	LEU fuel	6/10/92	flowmeter	flowmeter failed, overconcentration of U from stripper to tank
10	HEU fuel	11/04/92	HEU tank concentr.	conc. limit in storage tank measured too high

CRITICALITY PRECURSORS

The ten events shown in Table 4 above are cases where a criticality safety limit was exceeded. This means that, not only did a criticality control fail, but the result caused the controlled parameter to exceed established safety limits. In most cases, the limit exceeded was a limit on mass or concentration of fissile isotope. In a majority of the ten cases, the limits were exceeded by such a substantial amount that it is likely that ingress of water could have resulted in criticality. This is strictly a preliminary judgement in the absence of specific criticality analysis of the situation. However, the masses in these cases were sufficient for that enrichment and chemical form to be critical, given adequate moderation and reflection. Continued safety was thus being assured by moderation control alone.

The paragraphs below provide a short description of each of these ten serious events.

1. Wrong Cart:
This event consisted of a cart designed for uranium pellets other than enriched being left behind in a process area after the operations were concluded. Operations with enriched U commenced. The cart was then loaded with enriched uranium pellets in an amount exceeding safety limits. The safety label on the cart was not sufficiently obvious to alert the operators that it was not to be used for enriched uranium.

2. Limit Switch:
This event is Event H of the Phase One study. Limit switches had been installed to cut off UO_2 powder flow in case the outlet tubing from a hopper came loose. The tubing did come loose, and a large UO_2 spill built up, because the limit switch had apparently been taped over. The likely reason for the taping was a high false alarm rate impeding production. The normal configuration control procedure (ECN with testing) was not followed for installation of the limit switches. For this reason the operators appeared to be insufficiently aware of the safety function of the switches, since they did not inform management when the switches developed a high false actuation rate. The limit switches had no special safety labeling, and had not been formally tested. Such testing might have revealed the high false actuation rate.

3. Incinerator Mass:
This event involves an incinerator used to burn trash contaminated with fissile material. After burning most of the ash would be removed from the incinerator for disposal, but there would always be some residual ash remaining in the incinerator. This residual ash would contain some fissile material. The amount of fissile material remaining in residual ash had been measured the first few times the incinerator was operated. Thereafter, it was assumed, without verifying measurement, that the residual mass of fissile material remaining in the incinerator was at a constant equilibrium. An actual measurement was eventually made. It showed an accumulation of fissile isotopes exceeding the equipment's criticality safety mass limit.

4. Pu Drums:
Six old drums were discovered holding clay soil containing plutonium in amounts exceeding posted safety limits for such drums.

5. Tank Sludge:
During annual tank cleaning a waste tank was found to contain 570 grams of highly enriched uranium exceeding its criticality safety limit of 350 grams. The uranium was in a layer of sludge which had accumulated to a depth of 1/4 inch on the flat bottom of the tank. A one inch layer would have been required to be critical in this flat geometry. The proposed fix was to replace the tank with one that has a conical bottom permitting more effective wash-out of sludge.

6. Two bottles in hood:
A hood for HEU processing had a posted limit on total fissile mass. This was exceeded by the presence of two bottles. Each was capable of holding close to the limit. One was half-full and the other more than half.

7. ADU Spill:
A powder leak occurred at the gasket in the outlet from an ADU Bulk Container which feeds a pellet press. An amount accumulated that would be more than a critical mass, if moderated. Poor maintenance was a factor.

8. Two Gaskets:
A UO_2 leak occurred at the outlet of the UO_2 milling step after calcining. The cause was accidental installation of 2 gaskets, where only one was required.

9. Flowmeter:
A flowmeter controlling water feed to a solvent extraction stripper malfunctioned causing a 2/3 reduction in water flow. This produced a concentration in the output stream that was higher than normal. The high concentration stream eventually accumulated in a favorable geometry tank at 20 g/liter. This exceeded the allowed concentration limit of 15 g/liter.

10. HEU Tank Concentration:
A sample taken from an UNH storage tank showed a concentration of 440 g U-235 /liter, exceeding the safety limit of 400 g/l. This was in the uranium recovery area of an HEU plant. This was believed to be a spurious event caused by a bad sample. No deficiencies were attributed to this event in Table 3. It is included here for completeness in reviewing cases where limits have been reported as exceeded.