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**AN ASSESSMENT OF
CRITICALITY
SAFETY**

AT THE DEPARTMENT OF ENERGY

ROCKY FLATS PLANT
Golden, Colorado

July-September 1989

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Team Leader
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September, 1989

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ABSTRACT

This is a report on the 1989 independent Criticality Safety Assessment of the Rocky Flats Plant, primarily in response to public concerns that nuclear criticality accidents involving plutonium may have occurred at this nuclear weapon component fabrication and processing plant. The report evaluates environmental issues, fissile material storage practices, ventilation system problem areas, and criticality safety practices. While no evidence of a criticality accident was found, several recommendations are made for criticality safety improvements.

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**AN ASSESSMENT OF CRITICALITY SAFETY
AT THE DEPARTMENT OF ENERGY
ROCKY FLATS PLANT**

EXECUTIVE SUMMARY

A criticality accident at the Rocky Flats Plant could produce a potentially lethal dose of neutron and gamma radiation to workers at close range, could generate heat and fission products, and, in extreme but low probability circumstances, could result in the release of radioactive material to the environment. Where fissionable materials such as plutonium-239 and uranium-235 are present at the plant in sufficient quantity, a criticality accident can occur either by adding more fissionable material, removing non-fissionable material that would otherwise help avoid or terminate a criticality, or by adding certain non-fissionable materials such as water that could contribute to producing a criticality.

A criticality accident could cause steam to form and increase pressure if the fissile material was contained in a fluid system, eventually resulting in an explosion or rupture which would stop the criticality, or it could release heat more slowly with the possibility of causing recurring or more severe criticalities. Although the absence of chemical high explosives (such as TNT) at Rocky Flats Plant and the presence of controls and physical constraints make a nuclear bomb type of explosion impossible, criticality accidents are a real possibility. The engineering design of criticality safety features and the physical limits and procedures used at the plant are crucial factors in protecting the workers from such an event and in ensuring public safety. Further details on the nature of nuclear criticality events and the history of criticality accidents at other facilities are provided in Appendix H.

This report describes an independent assessment conducted by SCIENTECH, Inc. and funded by the Department of Energy (DOE). It addresses a wide range of concerns involving criticality safety features, limits and procedures implemented at the Rocky Flats Plant. The eleven member Criticality Safety Assessment Team selected by SCIENTECH found no indication that a criticality accident ever occurred at the Rocky Flats Plant; however, several inadequate conditions and practices were identified. Recommendations for corrective actions are included in this report.

In developing its recommendations, the Team investigated the technical details of criticality safety concerns that had been raised by others or that the Team members themselves could identify. The Team was not constrained or restricted in any way in its efforts to assess the status of criticality safety at the Rocky Flats Plant. Its conclusions and recommendations are probably more favorable to the plant than some of its detractors would have expected, but they are certainly more negative than anticipated by Rocky Flats Plant managers.

For example, the Team looked for and discovered several kilograms of plutonium in a pipe that serves as an exhaust ventilation duct for some of the gloveboxes in Building 771 (not the incinerator). The plutonium was *downstream* of the high

efficiency particulate air (HEPA) prefilters relied upon to keep plutonium in the gloveboxes. Thus, this plutonium was outside the normal envelope used to control fissile material inventory. This plutonium was in the form of a slurry, and the quantity found was more than enough fissile material for a criticality accident if consolidated geometrically and if a neutron "reflector" such as water or a human body were present in certain configurations. This location is *upstream* of the final exhaust system HEPA filters, so plutonium was not being released to the environment. Thus, the plutonium that was found by the Team posed no immediate danger to public or worker safety.

Previous to this study, plant managers had insisted that this type of plutonium holdup (accumulation) was not happening at the plant, even though exhaust ducts had been specifically suggested by a former employee and ventilation system designer of plant contractor Rockwell International, Mr. James Stone, as a probable location for dangerous quantities of plutonium to collect. The Team found indications that there may be holdup of significant quantities of plutonium in several other exhaust ducts in the plant. The Team also found evidence that fissile materials had been found in ventilation systems in several buildings at Rocky Flats Plant during past renovations.

A comprehensive program of routine nondestructive assay (NDA) using gamma spectrometry should be undertaken to identify other locations where this type of plutonium holdup is occurring and for Rocky Flats Plant management to monitor and correct this problem in the future. This is the same NDA technology used by the Team in its investigation, and this technology is commonly used at other nuclear facilities to identify and correct the problem of fissile material holdup in ventilation systems. The capability to perform NDA is already in place at the Rocky Flats Plant, but NDA has been previously neglected or avoided for the types of surveys suggested by the Criticality Safety Assessment Team.

Another weakness at the plant is its approach to the nuclear safety philosophy of defense in depth, a concept that is specifically referred to in DOE nuclear criticality safety guidelines as the "double contingency" principle. According to this principle, there must be two independent barriers or impediments between a normal operating condition and a criticality accident. This concept is roughly equivalent to the "single failure" criterion widely used in other nuclear facilities. Implementation of this concept at Rocky Flats Plant is inadequate in that one of the two contingencies used at the plant in criticality safety practice is a procedural limit and the other is sometimes only conservatism in the calculations that are applied to that limit, rather than an *independent* physical or administrative barrier. It is common in the rest of the nuclear industry to assume that such conservatism has already been lost at the time a single failure occurs. Department of Energy criticality safety guidance in this area should be clarified. Other weaknesses in the Criticality Safety Program at Rocky Flats Plant are described in the report.

The Team has raised several concerns about the storage of fissile waste materials and fissile material residues in some locations at Rocky Flats Plant for which evidence could not be found of detailed studies of the effects of either flooding or earthquakes on criticality safety. In the basement of Building 776, where about 300

55-gallon drums of plutonium residue are stored, the Team found that the sump pump was inoperable. The pump was not tagged, so it would not be apparent to anyone relying on the pump to remove water from the room that the pump might not be effective. Also, the criticality safety analysis for the flooding of this storeroom could not be found, so it was not clear whether a criticality accident would occur if the room was inadvertently flooded. This room had previously collected water from the room above. Some of the drums in this room had rusted, and water marks and mineral deposits from external ground water were found on the inside walls by the Team during its inspection. In addition, there are no water level or radiation alarms in this basement storage area. While no imminent danger was found, such a combination of factors is unacceptable.

The Team is also concerned about the storage of residue drums in Building 371 in a vertical arrangement that makes the drums susceptible to falling together during an earthquake. While this and other buildings are themselves reportedly designed to withstand an earthquake, the arrangement of vertical shelving and the presence of only partially restrained drums on the shelves are considered by the Team to be inadequate to protect against the effects of an earthquake. The drums could fall off of their shelves and might create the potential for a criticality accident by piling up on the floor of the building in a configuration for which criticality safety has not been evaluated.

In searching for evidence of a past criticality accident at Rocky Flats Plant, the Team examined a wide variety of records. These records documented:

1. exposures of workers to radiation,
2. infractions of criticality safety procedures,
3. environmental measurements of fission products,
4. serious incidents such as fires that have occurred at the plant,
5. photographs of significant events at the plant,
6. renovations of buildings and systems at the plant, and
7. results of nuclear material accountability programs.

No evidence was found of an accidental criticality ever having occurred at Rocky Flats Plant.

The Team examined records of personnel at Rocky Flats Plant who had the highest levels of exposure to radiation. The radiation exposure records go back to the earliest days of Rocky Flats Plant operations. No exposures were found that would indicate even a minor accidental criticality ever occurred at Rocky Flats Plant. While one could argue that a very minor criticality accident might have occurred and remain undetected, none have been identified to date. Also, if such an accident went undetected by personnel dosimeters, it would not have been detectable in the environment and could not have caused harm to workers or to the public.

The Team reviewed the history of the more than 600 procedural infractions recorded by the criticality safety program at Rocky Flats Plant since 1962 to search for evidence of past criticality accidents. The Team also studied the root causes of

the procedural infractions. Although no evidence was found of past accidental criticalities, the Team found a high incidence of root causes involving personnel error in the procedural infractions, judged to be primarily due to complacency or poor communication on safety matters. Many of these infractions were of a minor but recurring nature, involving violations of limits on mass, separation distance, or the volume of fissile material containers. These infractions are generally unlikely to cause an accident by themselves since they involve the violation of only one of the two barriers required by the double contingency principle. Nevertheless, since 1962, there have been about eight serious criticality safety procedural infractions involving kilogram quantities of fissile materials in such a manner that the remaining safety margin to a criticality accident was unacceptable.

Since no evidence of actual criticality accidents was discovered by the Team in the records of criticality safety procedural infractions, it is possible that rumors or allegations of "frequent criticalities" result from informal language at the plant by the workers themselves. The words "criticality infraction" (or even "criticality" alone) are occasionally used by some workers to describe a violation of the procedures or limits established by the Criticality Safety Program. These are the criticality safety procedural infractions discussed above. This language may cause less experienced workers or persons who supply support services to conclude that a criticality accident, as discussed during employee indoctrination training, has occurred when it actually has not. Recommendations have been made by the Team to address this kind of misinterpretation by improvements in safety training.

The Criticality Safety Assessment Team determined that if there had been a moderate criticality accident at the plant in the past, the radioactive fission products cesium and strontium generated from such an accident would be indistinguishable from background levels of fission products already present in the environment. These background levels of fission products occur throughout the world as a result of fallout from atmospheric testing of nuclear weapons and from reactor accidents. These fallout levels would mask any radioactive evidence of a small or moderate accidental criticality if any such event had occurred at Rocky Flats Plant in the past. The criticality accident used in the Team's calculations that prove this point was typical of accidental criticalities that have occurred at other facilities. A more severe criticality accident would produce other effects that would be impossible to conceal.

In some of its contacts with DOE and contractor personnel at Rocky Flats Plant, the Team detected an absence of healthy inquisitiveness into safety matters. For example, the Team could find no engineering managers who had inquired about the root causes or the long term safety implications resulting from the several building renovations during which potentially hazardous plutonium or uranium accumulations had been discovered in ductwork. The history of such discoveries was not part of a program of "lessons learned." Accumulations of fissile material are also assumed by plant managers to be health physics concerns or material control concerns long before they are recognized as criticality concerns. This is an inappropriate safety philosophy since the accumulations of plutonium that were found in an exhaust duct by this Team are considered already to be a significant criticality safety concern, and neither of these other programs had prevented it.

The lack of inquisitiveness about safety at Rocky Flats Plant is also indicated by the number of people who came to the Team with anonymous tips as to where to look for problems. These people were apparently *afraid to raise their concerns* to their own supervisors. Neither the DOE nor the contractor place a high enough value on people who raise safety questions or otherwise surface bad news. More aggressive actions should be taken to encourage feedback on safety issues from plant workers and to demonstrate management's commitment in this area.

In summary, the Team has found no evidence that a criticality accident ever occurred at the Rocky Flats Plant. The Team, however, is not satisfied with criticality safety practices or with the understanding of nuclear safety standards by the workers at the plant. A number of recommendations for improvements are made in this report. Some of these recommendations address issues raised by the public in the news media, and others arise from observations made by the Team. In the aggregate, the recommendations are meant to suggest to the Department of Energy and to Rocky Flats Plant managers that much remains to be done. Until safety is given appropriate priority relative to production and until DOE instills a healthy, questioning attitude about nuclear safety in all of the people who work there, Rocky Flats Plant will not operate as safely as it can and should.

1. Introduction

As agreed by the Department of Energy (DOE) and the Governor of Colorado, an independent Team of experts was assembled by SCIENTECH and has assessed safety issues related to the potential for a criticality accident of (a) any plutonium accumulation in ventilation systems and (b) plutonium in residues or wastes that are stored in containers at the Rocky Flats Plant. The Team concentrated on questions relating to protection of health and safety from a criticality accident at the plant.

The Team's effort included an independent verification of methods used to measure the *quantity* and *location* of plutonium in ventilation duct work and in storage containers, and to control materials and residues within the plant to avoid conditions that could lead to a criticality accident.

In particular, the Criticality Safety Assessment Team assessed the potential for a criticality accident arising from:

1. possible accumulation of plutonium in various exhaust ventilation systems that support the process systems used at Rocky Flats Plant;
2. possible accumulation of plutonium in the exhaust system of the incinerator located in Building 771; and
3. the geometric configuration and content of containers of special nuclear material (SNM) residues stored at the facility.

The scope of the Team's evaluation included:

1. a review of measures implemented at the plant to prevent a criticality accident, especially in ventilation ducts, including ducts associated with the incineration process for concentrating residues, to determine if there is an adequate implementation of the "defense in depth" policy for criticality safety;
2. a review of plant operating experience for lessons learned and corrective actions implemented, including:
 - a. records of criticality safety procedural infractions,
 - b. results of offsite environmental monitoring,
 - c. records of personnel radiation exposures,

- d. results of nuclear material accountability programs, and
 - e. records of building renovations;
3. a verification of estimates made by the operating contractor of plate-out of plutonium in the filters, pipes, valves, and components of the ventilation systems;
 4. a criticality safety evaluation of the stored plutonium residue containers to determine the potential for accidental criticalities and to assess the measures taken to prevent such accidents.

The first week of the team's effort was spent at Rocky Flats Plant, primarily for orientation. The Team received a number of briefings and tours during that week. The second week was spent offsite to allow for preparations and planning and to allow the plant managers an opportunity to start assembling information required by the Team.

The Team then spent two weeks onsite for the formal assessment. This period included studies of 30 separate topics; inquiries into 30 other areas involving interviews with various plant managers, workers, and former employees; several surveys and measurements to search for and identify plutonium holdup in ventilation ducting; independent measurements of plutonium residues; and inspections of various buildings and process systems used to process SNM.

This report is divided into sections which organize by general subjects the many details that were gathered during the assessment. Where some overlaps in subject matter are unavoidable, either the pertinent information is repeated or cross references are provided to aid the reader. Thus, while some mention is made of ventilation system holdup in Section 2 in discussing public concerns, the details of the ventilation system (which are needed in order for the reader to comprehend the Team's conclusions) will be found in Section 3 and Appendix F. Similarly, Section 4 provides details about storage of plutonium residues at the plant.

Section 5 provides the Team's assessment of the criticality safety program currently implemented at Rocky Flats Plant. This section describes the program and provides an evaluation of its features relative to generally accepted practices in the nuclear industry.

Sections 2 through 5 also include the Team's recommendations and suggestions for improvements. To assist the reader in finding the recommendations and suggestions, they are printed in **bold type**. Section 6 provides a *consolidated* list of all of these recommendations and suggestions that some readers will find useful. The recommendations provided in Section 6 should to be viewed as actions that must be taken in order to ensure that the Rocky Flats Plant can operate at a level of safety appropriate to a nuclear facility. The *suggestions* are somewhat less mandatory in that alternatives may exist which could address satisfactorily the issues identified.

The Appendices contain detailed information about the Team and the assessment. Appendix A is a complete copy of the charter for the Team. It was written in advance of the assessment to describe the scope of the Team's task. The charter also summarizes the experience of the Team members. Appendix B provides a more structured biography and the Team assignments for each member.

Appendix C provides information on the various process buildings at Rocky Flats Plant which the Team visited and inspected. Appendix D gives the data collected by the Team in assessing the problem of plutonium accumulation in some of the ventilation systems. Appendix E discusses personnel exposure records, and Appendix F describes the various ventilation systems at the plant and reviews renovation records. Personnel radiation exposure records and ventilation renovation records were both important in the Team's search for the alleged criticality accidents or the potential for such accidents.

Appendix G provides the database of criticality safety procedural infractions which the Team used to assess root causes of the violations of safety limits by Rocky Flats Plant workers. This listing should provide readers with a much better understanding of the "incidents" which are the subject of much of the media attention that has been focused on the plant.

Appendix H provides a number of important definitions and explanations of terminology for those who may not be experts on nuclear facility inspections. Many readers may benefit from reading Appendix H first.

Appendices I and J list the names of plant personnel contacted by the Team and the "keywords" used to search the Rocky Flats Plant Library database for historical documents.

Appendix K describes the rather crucial but technical computer codes used at Rocky Flats Plant to evaluate the geometry of fissile materials for criticality concerns.

Appendix L is a review of the formally-documented employee concerns which pertain to criticality safety issues.

Appendix M is a listing of the references used by the Team or which may be useful to readers that are interested in particular details.

Finally, Appendix N provides a list of acronyms and abbreviations used in this report.

Perhaps readers who are concerned about the thoroughness of the assessment should read the Appendices in detail. The Team is interested in knowing where improvements could be made. Those who have criticisms are invited to raise them with the Team. You may write to the Criticality Safety Assessment Team Leader at: SCIENTECH, Inc., 11821 Parklawn Drive, Rockville, MD 20852.

2. Public Concerns Regarding Criticality Accidents

A criticality accident at the Rocky Flats Plant could produce a potentially lethal dose of neutron and gamma radiation to workers at close range, could generate heat and fission products, and, in extreme but low probability circumstances, could result in the release of radioactive material to the environment. Where fissionable materials such as plutonium-239 and uranium-235 are present at the plant in sufficient quantity, this type of accident can occur either by adding more fissionable material, removing non-fissionable material that would otherwise help avoid or terminate a criticality, or by adding certain non-fissionable materials such as water that could contribute to producing a criticality.

A criticality accident could cause steam to form and increase pressure if the fissile material was contained in a fluid system, eventually resulting in an explosion or rupture which would stop the criticality, or it could release heat more slowly with the possibility of causing recurring or more severe criticalities. Although the absence of chemical high explosives (such as TNT) at Rocky Flats Plant and the presence of controls and physical constraints make a nuclear bomb type of explosion impossible, criticality accidents are a real possibility. The engineering design of criticality safety features and the physical limits and procedures used at the plant are crucial factors in protecting the workers from such an event and in ensuring public safety. Further details on the nature of nuclear criticality events and the history of criticality accidents at other facilities are provided in Appendix H.

This is a report on an independent assessment funded by the Department of Energy that addressed nuclear criticality safety features, limits and procedures implemented at the Rocky Flats Plant.

2.1 Background and Definition of Terms

In an article in the Denver Post on June 15, 1989, it was stated that suspicions of a possible nuclear reaction at Rocky Flats Plant were first raised in the late 1970s by Dr. Carl Johnson, the former Jefferson County Health Director who died earlier this year. Dr. Johnson allegedly found relatively high levels of radioactive cesium in soil samples east and west of the plant.¹ It was also noted that a 1987 study of groundwater at Rocky Flats Plant by plant personnel reported high levels of strontium near Building 881. In addition, Nat Muillo, Rocky Flats Plant Project Director for EPA in Denver, was reported by the Post to have said that, "The levels are still extremely low and no data we have now indicate that such a reaction (inadvertent criticality) occurred." Mr. Muillo told the Post that there are other explanations for the measured strontium and cesium onsite in addition to the nuclear-reaction theory. The elements, he said, may have been used in the calibration of testing instruments, or faulty measurements may have resulted in false readings. Also, the Team notes that spontaneous fissions in the plutonium

¹ "Distribution of Cesium-137 in the Surface Dust in the Vicinity of Rocky Flats Plant: Final Report," by Carl Johnson; unpublished report to Jefferson County Health Department, April 18, 1978.

handled at Rocky Flats Plant also can lead to measurable quantities of both of these fission products. Spontaneous fissions are those which occasionally occur even without a chain reaction simply because of the instability of the nucleus of the atom. Rocky Flats Plant critics, as reported by the Post, believe that the levels of cesium and strontium are too high to be caused by fallout; they argue that more likely causes are a nuclear reaction or the illegal burial of spent nuclear fuel rods.

The Rocky Mountain News of June 16, 1989, carried a similar story and similar statements by the EPA; in this case, the EPA spokesmen were Martin Hestmark, Milton Lammering, and Rich Lathrop.

Before addressing in Section 2.2 (below) the issues raised by Dr. Johnson and commented upon by Mr. Muillo and his associates, it is appropriate to ensure that the readers understand such fundamental terms as *fission* and *criticality*. (A more detailed discussion is in Appendix H.)

The fission process can be imagined as starting with a large plutonium nucleus that *captures* an extra neutron. The resulting nucleus behaves like an oversized pulsating water drop that cannot be contained by the surface forces trying to hold it together. This unstable drop eventually breaks into several smaller drops called fission fragments or *fission products* and a few very tiny droplets, *neutrons*.

A fission product can be any atom smaller than plutonium. The fissioning of any two plutonium nuclei could produce two sets of entirely different fission products. However, there is generally a preference to form one large atom and one smaller atom. This still presents a large number of possibilities, and fission products actually include a wide range of different elements.

Frequently the fission products are radioactive. This means that the nuclei of these atoms are themselves unstable and will ultimately become stable by emitting radiation such as beta particles or gamma rays. The time it takes for radioactive fission products to decay is associated with the half-life of the specific nucleus. The half-life can range from a few seconds to over thirty years. The half-life is the amount of time that it takes the activity to decrease by one half, or from one half of the original amount to one quarter of the original amount, etc. Thus, some of the radioactive fission products decay to a stable condition rapidly, while others remain for many decades as they gradually decay to smaller and smaller activity levels.

Cesium-137 and strontium-90 are two fission products that are produced by the fissioning of plutonium. Each has a half life of 30 years, and each is produced at about the same rate (5 to 10 percent of the fission products) in the fissioning of plutonium. These two radioactive fission products do not generally occur in nature; their presence is due almost exclusively to the fission processes developed by man. Scientists have, however, identified a region in Africa where concentrations of natural uranium have accumulated due to natural causes, achieved spontaneous criticality, and produced many fissions. Residual amounts of "natural" fission products, consequently, can be found near these areas.

The current, world-wide distribution of fission products was caused by man. During the late 1940s and 1950s several countries were conducting above-ground tests of nuclear weapons. These explosions created large amounts of fission products that were dispersed into the upper atmosphere and eventually settled to earth (fallout). Cesium-137 and strontium-90 can generally be found anywhere in the environment because of this world-wide fallout. Nuclear power reactors are also a source of cesium-137 and strontium-90, but none is released in normal operation. Large quantities were released during the Chernobyl accident; little or no cesium and strontium were released in the accident at Three Mile Island.

The second term that must be fully understood by the reader is *criticality*. First, it is important to understand that the word criticality needs a modifying adjective, such as *controlled* or *accidental*. For example, nuclear power plants are controlled at some condition of criticality whenever they are operating. They become slightly *supercritical* when they increase power level. They become *subcritical* when power is reduced or the plant is shut down. When a nuclear plant is started up and prepared for operation, it actually becomes slightly supercritical long before it starts to generate any measurable heat. The condition of criticality in nuclear power plants is controlled by the design of the uranium fuel and the control rods. The enrichment of the fuel, design of the reactor, and strict operational controls ensure that the risk of an uncontrolled criticality of damaging consequences at a nuclear power plant is extremely low and, therefore, acceptable. Thus, a *controlled* criticality is *not* an unsafe condition.

A nuclear weapon is designed to get to an extreme state of supercriticality as fast as possible before the energy generated by the buildup of the chain reaction has a chance to shut down the chain reaction. This, too, is a controlled state of criticality which has to be designed into the nuclear weapon. Nuclear weapons are not assembled, disassembled or stored at Rocky Flats Plant, so the safety of the weapons themselves is not relevant to this study.

This report focuses on situations where fissile materials are unintentionally assembled under conditions of geometry, mass, concentration, etc., that would promote an uncontrolled or accidental criticality.

2.2 Environmental Cesium-137 as an Indicator of a Criticality Accident

It has been alleged that the measured levels of strontium-90 and cesium-137 in the soil and water near Rocky Flats Plant are an indication that a criticality accident has occurred at the plant. One objective of the Team was to determine if the measurements of cesium-137 and strontium-90 could confirm these allegations.

Dr. Carl Johnson asserted that there might be an association between environmental cesium-137 and strontium-90 and a criticality accident at Rocky Flats Plant. In 1978, he measured cesium-137 concentrations in respirable dust downwind from the plant that were 17 times greater than values previously reported for background.¹ His reported measurements for distances less than 10 km and greater than 10 km from the plant are summarized in Table 2-1.

The Colorado Department of Health (CDH) also has evaluated levels of cesium-137 in surface soil near the Rocky Flats Plant.² The results were much lower than Dr. Johnson's measurements in both magnitude and range of error. This initiated a controversy principally focused upon the differences in sample collection and preparation methods. Both the CDH and Dr. Johnson collected the top 3-5 mm of soil. However, Dr. Johnson then used an ultrasonic bath to destroy soil aggregates followed by an aqueous sedimentation process to obtain the fraction of soil particles that were less than 5 microns in diameter.

Table 2-1
Measurements of Cesium-137 Concentrations in Soil

<u>Author</u>	<u>Location</u>	<u>pCi/g</u>	<u>Depth</u>
C. Johnson	< 10 km from Rocky Flats Plant	37 ± 26	Top 3 mm, Particles < μm
C. Johnson	>10 km from Rocky Flats Plant	19 ± 21	Top 3 mm, Particles < 5 μm
Colorado Department of Health	Near Rocky Flats Plant	3 ± 2	Top 3 mm, Particles < 2 mm
Colorado Department of Health	Colorado	1 ± 0.3	Top 3 mm, Particles < 2 mm
EG&G Measurements, Inc.	30,000 acre flyover of Rocky Flats Plant	0.3 - 0.6	Averaged Over Top 6 cm
Colorado State University	Fort St. Vrain Monitoring Program	0.01-0.05	Averaged over Top 10 cm
Department of Energy	Rocky Flats Plant Measurements	0.5 - 2.6	Range of values in 4 m bore holes

An aerial radiological survey of Rocky Flats Plant was conducted in July 1989 by EG&G Measurements, Inc.³ This survey covered an area of 9.7 km x 12.8 km (~30,000 acres) at an altitude of 46 meters (150 feet) and produced over 75,000 data points. The data were analyzed for all man-made gamma emitting

² "Radioactive Soil Contamination(¹³⁷Cs and Pu) in the Environment near the Rocky Flats Nuclear Weapons Plant," by Colorado Department of Health, September 1977.

³ "An Aerial Radiological Survey of the United States Department of Energy's Rocky Flats Plant," EG&G, Inc., preliminary review, July 1989.

radionuclides with emphasis on cesium-137 and americium-241, the latter of which is a decay product (not a fission product) of plutonium-241. The cesium-137 activity was relatively uniform over the survey area in the range of 0.3-0.6 pCi/g (picocuries per gram of soil) averaged over a soil depth of 6 centimeters. These values are consistent with world-wide fallout levels measured by similar aerial surveys in the United States. There was no indication of cesium-137 deposition due to Rocky Flats Plant operations.

There has also been an environmental monitoring program associated with the Fort St. Vrain Nuclear Generating Station which, like Rocky Flats Plant, is near Denver, Colorado. Soil samples near that plant have been analyzed for cesium-137 since 1974. This sampling procedure consists of removing a core of soil 10 centimeters in diameter and 10 centimeters deep. The reported values represent the concentration averaged over this 10 centimeter depth since the samples were taken from agricultural land that has been routinely plowed and tilled.⁴

Finally, the Rocky Flats Plant operating contractor has measured cesium-137 in soil at various locations around the plant site. These measurements have primarily consisted of making bore holes down to a depth of 12 feet. The values reported are averages along each bore hole.⁵

The data compiled in Table 2-1 for the various cesium-137 concentrations measured in the soil in the vicinity of the Rocky Flats Plant and the rest of Colorado are confusing at best and misleading at worst. The picture would be even more complicated for strontium-90 since the laboratory analysis depends on an additional radiochemical separation that is not required for identification of cesium-137.

One important feature of the data in Table 2-1 is the *range* of values in each of the individual measurements. The information for locations away from Rocky Flats Plant represents the background levels above which any activity released due to a criticality accident would have to be identified. The detection limit for this additional activity depends on the range of uncertainty in this background. In order to unambiguously identify an excess of cesium-137 above these background levels, the additional concentration in the soil would have to be at least 1 pCi/g.

Thus, it is important to consider just how much cesium-137 could be released as the result of a criticality accident. An analysis of accidents that have taken place at other facilities indicates that the number of fissions occurring during such an event is in the range of 10^{15} to 10^{19} (see Appendix H). The larger values represent major accidents that are accompanied by other effects such as flashes of light, heat, high radiation doses, local contamination and neutron activation.

⁴ "Radiological Environmental Monitoring Program: Fort St. Vrain Nuclear Generating Station," report to Public Service company of Colorado from Department of Radiology and Radiation Biology, Colorado State University survey reports, 1973-1988.

⁵ "Remedial Investigation Report for High Priority Sites (881 Hillside Area)," Volumes VIII & IX, DOE Rocky Flats Plant, Golden, Colorado, March 1, 1988.

As an example, consider a moderate criticality accident producing 10^{17} fissions. The yield of cesium-137 atoms is approximately 0.06 per fission. Thus, the amount of cesium-137 activity produced would be:

$$\begin{aligned}
 &A = \lambda \cdot N \\
 \text{where } &\lambda = \text{decay constant for cesium-137 (1/yr)} \\
 &N = \text{number of cesium-137 atoms produced (atoms)} \\
 \text{then } &A = \frac{0.693}{30} \left(\frac{1}{\text{yr}} \right) \cdot 0.06 \left(\frac{\text{cesium-137 atoms}}{\text{fission}} \right) \cdot 10^{17} (\text{fissions}) \cdot \\
 &\quad \frac{1}{3.7 \times 10^{10}} \cdot \left(\frac{\text{curies}}{\text{dis/sec}} \right) \cdot \frac{1}{3.15 \times 10^7} \left(\frac{\text{yr}}{\text{sec}} \right)
 \end{aligned}$$

$$\text{or } A \approx 120 \text{ microcuries of cesium}$$

A worst case estimate would be that all of the radioactive cesium would escape from the building and become dispersed in the environment. If this amount of cesium were uniformly deposited over the plant site of 385 acres (1.5 square kilometers), and the deposition was limited to the top 0.5 cm of soil, the soil concentration of cesium-137 would be 0.01 pCi/gram. This value is too small to be observed no matter which measurement or sampling procedure in Table 2-1 is used.

In order to use cesium-137 concentrations in soil to identify a criticality accident, the following conditions must be satisfied:

- a) the total number of fissions would have to be much larger than 10^{17} , in which case there would be other more reliable indications that an accident had occurred; and
- b) the entire inventory of cesium-137 from 10^{17} fissions would have to be deposited in an area less than 4 acres in which case the excess levels of cesium-137 would be detected in the fly-over data.

Perhaps much of the confusion over this issue in the past has come from associating a criticality accident with a nuclear reactor accident. In the latter case, many fission products (millions of curies) are available to be released into the environment if the reactor containment fails. The large inventory of cesium-137 and strontium-90 released at Chernobyl in 1986 was the result of fission product accumulation during normal operations of the facility that involved prolonged fissioning in the reactor's fuel core at high power levels. In the case of a criticality

accident at Rocky Flats Plant, there would be no large accumulation of fission products because there are no operations that intentionally produce fissions over long periods of time. Also, a criticality accident would be of relatively short duration and not generate much fission product activity. As calculated above, the amounts of each fission product generated would be several microcuries. A microcurie is one millionth of a curie. For example, a typical household smoke detector contains about one microcurie of Americium-241. Thus, the identification of fission products in the environment near Rocky Flats Plant is not a very sensitive indicator for a criticality accident inside the plant, since the resulting activity could not be detected above already existing background levels.

Cesium-137 and strontium-90 were also identified in surface water and ground water wells at Rocky Flats Plant.⁵ Mr. Nat Muillo, Rocky Flats Plant coordinator for the EPA, expressed concerns about the reliability of the data and the explanations provided as to why fission products were observed in well water.

Surface waters in the State of Colorado do have measurable quantities of cesium-137. Samples taken upstream and downstream of the Fort St. Vrain Nuclear Generating Station, 35 miles northeast of Rocky Flats Plant, had concentrations of 4.5 ± 1 pCi/liter and 3.8 ± 0.5 pCi/liter respectively during the past five years.⁴ Well water from a ranch in Weld County averaged 5 ± 1 pCi/liter during the same period.⁴ This was a shallow well that is typical for this region. Values in the range 1 to 5 pCi/liter have also been measured in Colorado by the U. S. Geological Survey and Colorado State University.⁶

Surface water from Woman Creek just east of the plant has been measured to have concentrations of 0.2 to 0.8 pCi/liter dissolved and suspended cesium-137. Alluvial wells at Rocky Flats Plant have also been measured and range from 1 to 3 pCi/liter.⁵

Thus, the concentration of cesium-137 in surface and well waters near the Rocky Flats Plant is not substantially different from other regions in Colorado. For comparison, the EPA *drinking water limit* for cesium-137 is 160 pCi/liter (40CFR141).

An analysis, similar to the one described above, was found by the Team in the Rocky Flats Plant Library. In 1973, the Health Physics Research Department at Rocky Flats Plant published "An Assessment of the Radiation Hazard Associated with a Maximum Credible Accident at Rocky Flats."⁷ In that report, the maximum credible accident was assumed to be 1×10^{19} fissions, or *100 times more severe* than the 1×10^{17} fissions used in the above example. The report focuses on the *health effects* of such an accident rather than the *ability to detect* isotopes in the environment. The results, based on conservative (worst case) assumptions, were that the total dose to the public *at the plant boundary* would be well below the limits set by Federal Regulations for nuclear power plants (10CFR100).

⁶ Private Communication, Department of Radiology and Radiation Biology, Colorado State University.

⁷ R.L. Murti, HPR-317390-109, November 14, 1973, Rocky Flats Plant Library, file #A-1533.

The above discussions indicate that the *consequences* of a criticality accident are not likely to be indicated by measurements taken outside the plant. Actual experience confirms this point. Those nuclear facilities around the world which have experienced criticality accidents (Rocky Flats Plant is not one of them) reported limited physical damage, all of which was contained within the building where the accident occurred. Some of these criticality accidents produced lethal levels of radiation in the immediate vicinity; some even killed people working in the same room. Often, people in the vicinity of a criticality accident did not immediately realize that anything was wrong and had to rely on sensors and alarms to tell them that they had a problem.

Unlike a nuclear reactor, which has a long time to build up a large inventory of radioactive fission products such as those released to the atmosphere at Chernobyl, a criticality accident caused by bringing fissile materials together would produce a relatively small amount of fission products. If such an event were to occur at Rocky Flats Plant, the small amounts of fission products produced would be largely confined to the plant, although some could conceivably be dispersed to the environment. A criticality accident which would be large enough to damage equipment in a building at the plant could produce an amount of radioactive material so small that, even if it all escaped from the building, it would be lost in the background levels of radioactive materials from nature and from the fallout described above. Additional information regarding criticality accidents is provided in Appendix H.

Nevertheless, criticality accidents are dangerous to workers in the plant, and there is no guarantee that they will always be so small in terms of energy released. While it is not true that they are occurring frequently at the Rocky Flats Plant (as suggested by some people), the potential for criticality accidents must be taken very seriously by those who work in and manage the plant.

2.3 1957 and 1969 Fires

On June 15, 1989, the Denver Post reported that, "according to sources close to the investigation," the FBI may uncover evidence proving or disproving decade-old rumors of an accidental nuclear reaction at the facility. According to the Post, Rocky Flats Plant critics have long suspected that such a reaction happened during one or both of the fires at the plant in 1957 and 1969.

Over the years, the Rocky Flats Plant has had several fires, as have other manufacturing plants that handle large quantities of combustible materials. Most of the fires at Rocky Flats Plant have been relatively minor, localized events with little damage to equipment and materials and little radiation exposure to workers. Two fires, one on September 11, 1957, and one on May 11, 1969, were significantly more extensive. The Team has investigated the possibility that these fires were associated with a nuclear criticality event. The Team concludes that such an event *did not* occur in either fire. Moreover, the dispersal of plutonium in each fire was essentially confined to a single building, with very little contamination found outside of the building.

The concern for nuclear criticality in connection with a fire is due to the possibility that plutonium, which would be safe under normal conditions, could be assembled into a critical configuration in the unpredictable course of a fire, particularly if this configuration was flooded with the water used in fighting the fire. This concern strongly influenced the fire fighting procedures used for the 1957 and 1969 fires at Rocky Flats Plant, but the initial efforts to extinguish the fires without water were unsuccessful. The fire spread to other parts of the building and threatened the destruction of the building and subsequent dispersal of greater quantities of plutonium than were initially involved. Accordingly, decisions were made to extinguish these fires with water. These efforts were successful.

Health Physics personnel were on the scene for both fires almost immediately. They monitored both the interior of the building and the area surrounding the building, both during and immediately following the fire, and verified the safety of the fire fighters. The insignificant level of radioactive contamination found outside the building was easily attributable to material carried out on the feet of firemen and other personnel. The fire fighters and the employees involved in subsequent cleanup of the building all wore personal dosimetry badges. Health physics records for the months following the fires show no radiation exposures out of the ordinary. Radiation dosimeters mounted on building walls at the time of the 1969 fire were also evaluated by Dow Chemical Company, the plant's operating contractor at the time, and showed no evidence of dose levels that would have been associated with a criticality accident. The Team found no report that such dosimeters were in place or evaluated after the 1957 fire.

Records of the 1969 fire also state that some plutonium escaped to the roof of the building and to an adjacent roof due to a damaged filter, but that no plutonium was released outside the boundaries of the plant.

Several lessons were learned as a result of each of these fires (and other smaller fires as well). Reports were written at the time to document these lessons. The Team looked into these reports and interviewed people who were at the plant and involved in fighting these fires or cleaning up after them. Almost all of the lessons learned from these fires are important in reducing the probability of fire, reducing the magnitude and spread of a fire if it does occur, and reducing the radioactive contamination due to a fire. The lessons learned have no direct impact on nuclear criticality safety. A potential exception to this general statement, which the Rocky Flats Plant has guarded against, involves the installation of two inch high curbs along the perimeters of various processing rooms after the 1969 fire. These curbs can contain a considerable volume of water on the floor of the room. The curbs are designed to prevent the spread of potentially contaminated fire fighting water throughout the building. The height of the curbs and the amount of plutonium permitted in the room are limited on the basis of a criticality analysis, so the room remains safely subcritical even during emergency situations such as fires.

The Team concludes that a criticality accident did not cause and did not result from these fires.

2.4 Building 771 Incinerator Issues

Although no allegations have been found concerning the potential for criticality in the incinerator in Building 771, DOE and Rocky Flats Plant personnel told the Team that this incinerator may be an important source of public concern with criticality accidents. They urged the Team to address the criticality potential of this equipment because of public concerns for this equipment raised by unrelated charges that burning of plutonium residues in that incinerator violate environmental laws. There were allegations that the insulation bricks in the fire box of the incinerator have never been replaced and, further, that no fissile material balances have been performed in the operation of the incinerator.

The operations and records associated with the incinerator were examined by members of the Team. No evidence was found to indicate that a criticality accident had occurred during operations of the incinerator. The records examined included radiation exposures of workers, criticality safety procedural infraction reports, and minutes of the Nuclear Criticality Safety Committee. The Team inspected the incinerator and discussed its operation with management and operations personnel.

The Team determined that the incinerator components are cleaned out about once each week. The cleanup activities include the fire box, the heat exchangers, and the exhaust gas filters. The caustic wash solutions are filtered and sampled for fissile material content when transferred to the wet processing area of Building 771. The solutions are sampled and analyzed twice to verify contents. The exhaust gas lines are checked with radiation detection instruments for fissile deposits after every run. The insulation fire bricks in the fire box of the incinerator are replaced every three years. Because the incinerator is started and shut down frequently, the thermal cycling causes the bricks to spall. The spalling constantly removes deposited fissile materials which are then removed with the ash residue produced by the incinerator.

Discussions with the Nuclear Materials Accountability personnel indicated that material balances are performed on the incinerator operations on a batch basis. That is, the amount of fissile material put into the incinerator at one time is compared with the amount subsequently recovered in the residue and during the cleanout of the incinerator. This is to assure that there are no unusual accumulations of fissile materials. Further, a complete material balance of the area in Building 771 that includes the incinerator is performed every six months. Plant procedures call for any unusual discrepancies in such periodic material balances to be reported to both Health Physics and Criticality Safety personnel.

In conclusion, allegations concerning the incinerator in Building 771 do not appear to have any bearing on criticality safety. The Team asked plant personnel to make radiation measurements of equipment associated with the Building 771 residue incinerator, including heat exchangers, caustic leach spray chamber, anion exchange unit, mist tanks, fume scrubbers and exhaust ducts. The results are described in detail in Section 3.2, below. No significant holdup of plutonium was found in the Building 771 incinerator or associated systems.

2.5 Lax Practices

Charges have been made publicly that there are lax operational practices at Rocky Flats Plant. For example, one former plant employee said (incorrectly) that there are no materials balances kept, and another former employee said that safety practices at the plant are sloppy. Also, local government officials, including Colorado Governor Romer, have expressed concern to DOE that any lax criticality safety practices at the plant might affect the safety of the large amounts of plutonium residue stored there.

The Team investigated allegations of two former Rocky Flats Plant employees who expressed concerns about lax practices that could affect criticality safety. First, the Team examined Mr. James Stone's allegations (see Section 2.6) that material balances were not kept for fissile materials. This is incorrect. Rocky Flats Plant, like other DOE facilities handling special nuclear materials, performs thorough, periodic material balances.

The other former plant employee, Mr. Ted McCrea, was a machinist who retired in June 1989. In a July 9, 1989 article, The Rocky Mountain News wrote that Mr. McCrea and other machinists were ordered to work on atomic bomb parts under conditions that they knew would cause a criticality infraction, a violation of the procedures which are in place to ensure that a criticality accident does not occur. The situation described to the News involved machining oil containing plutonium shavings which should not be allowed to accumulate in the machines to a depth exceeding two inches because of a concern for a criticality accident. The allegation is that one night in late June 1989 the pumps that drain the oil from the machines were broken and the oil was accumulating; the machinists complained, but they were told to run the machines anyway. Allegedly, the oil accumulated to "way over" two inches before the machinists shut off their machines and walked off the job.

The Team discussed the specifics of this allegation with four people at the plant on August 9, 1989. The Operations Manager for foundry, machining, and assembly said that this former employee had worked on Heald machines in Module C of Building 707. The Operations Manager offered to find foremen with knowledge of the alleged incident. Subsequently, two foremen were interviewed. They said that on the day in question in late June, there indeed was a problem with removal of oil from the Heald machines. It was not caused by a broken pump, as alleged by Mr. McCrea, but was caused by an administrative inventory that was ongoing at that time that precluded the use of the pump. They said that foremen knew of the potential accumulation of oil in excess of the two inch limit and had instructed the machinists in advance that when the limit was reached, the machines were to be shut down. Subsequently, the limit was reached, the machines were shut down, and the machinists spent the rest of their shift in a ready room. They said the machinists did not walk off the job.

These foremen went on to say that they had signed this particular former employee out when he voluntarily left the employment of Rockwell International in June 1989

and that he expressed no safety concerns to them at the time. However, they also said that *no managers at the plant had talked to them* to see if the allegations in the newspaper had merit. The response to the News article prepared by plant managers *did not address the substance* of the criticality allegation raised. This lack of inquisitiveness by Rocky Flats Plant managers regarding potential safety concerns is viewed by the Team as a significant failure of management. Failure to follow up on such an allegation of unsafe practices should never be tolerated in DOE facilities. **The Team recommends that Rocky Flats Plant managers undertake more aggressive and Inquisitive followup on allegations of safety problems than was exhibited in this case.**

To further explore the allegations of lax practices, a variety of operations at Rocky Flats Plant were reviewed by the Criticality Safety Assessment Team. The matters examined were fissile material handling practices, maintenance, training, previous DOE safety assessments, building status, criticality safety analyses, criticality safety procedural infractions, safety alarm systems, special nuclear materials accountability, ventilation systems, measurement and storage of fissile materials, work practices, and management and worker attitudes.

In evaluating these topics at the plant, it must be recognized that a very large number of physical manipulations are made by the workers in handling fissile materials since very little of the plant is automated. Also, much of the equipment and many of the buildings are old. In addition, Rocky Flats Plant is a nuclear weapons facility at which security and "need-to-know" requirements prevent even most "insiders" from having access to detailed information about all operations at the plant. The members of the Team, of course, were allowed access to everything which, in their view, could affect criticality safety.

Based on its studies and interviews of plant personnel and the broad backgrounds of the various members of the Team, a number of areas were identified where improvements can be made in the quality of operations at Rocky Flats Plant. Management at this and any nuclear plant must continually strive for the highest levels of operational excellence. For example, **the Team recommends that better communications throughout the entire Rocky Flats Plant organization be developed. Senior managers must tour the buildings more often to assure that the very demanding nuclear safety policies and practices associated with nuclear facilities are reflected in daily operations. Middle and lower managers must also be more proactive in identifying and implementing improved operational practices.**

Another area needing improvement is training. The Team recognizes the recent improvements in the Training Department at Rocky Flats Plant; however, there are some basic nuclear safety philosophies which need reinforcement. For example, the Team is concerned with the informality of some plant workers in referring to safety issues. The Team notes that workers sometimes refer to criticality safety procedural infractions as *criticalities* or *criticality infractions*. Other workers could easily misinterpret the nature of these infractions or even conclude that criticality accidents are a frequent occurrence at the plant. Lack of formality in dealing with safety matters has been a problem with other nuclear facilities. **The Team**

recommends better training in the need for and the exercise of procedural discipline and communication formality at Rocky Flats Plant.

The uniqueness of some of the practices utilized at Rocky Flats Plant with respect to the rest of the nuclear scientific and industrial community tends to keep the plant isolated and behind the state-of-the-art in safety technology in certain areas. There is a potential problem at Rocky Flats Plant when managers assume that safety practices developed or used at other DOE facilities or in commercial nuclear facilities do not apply to this plant. The Team considers that plant management has failed to keep up with new and evolving nuclear safety technologies. Two areas in which the Team recommends improvement are (1) nondestructive assay (NDA), which is *vital in locating and identifying fissile materials* that may be accumulating in hard-to-reach locations (see recommendations in Section 3.2), and (2) the systematic examination of operating experience to search for root causes of errors *so they can be corrected* and their recurrence can be prevented (see recommendations in Section 5.5).

In addition, when a policy of "production first" is emphasized, as has been done at Rocky Flats Plant as well as other DOE facilities, activities such as maintenance, training, and safety practices are sometimes compromised. Weaknesses in maintenance and training have implications for overall safety. The Team found that the current attitudes toward safety of most people contacted at the plant were professional and conscientious. **The Team concludes, however, that isolation from the rest of the nuclear scientific and industrial community has contributed to the deficient or outdated safety practices observed. The Team recommends that Rocky Flats Plant managers continue to work to develop better interfaces within this community of experts and to optimize practices and philosophies.**

The Team also searched for lax practices in various procedures, training documents, criticality safety limits, facility design, fissile material measurements, and accountability practices involving the large quantities of plutonium residue stored at the plant. Although this last area has received considerable management attention, an unsatisfactory number of deficiencies was found. These are described in Section 4. **Generally, the Team recommends that the criticality safety of the storage areas be reviewed and improved, that further consideration be given to the criticality potential that might be created by an earthquake at the plant, and that planning for long-term disposition of the residues at the plant include steps to upgrade the current level of protection against criticality accidents. More detailed recommendations regarding the storage areas are provided in Section 4**

2.6 Review of Allegations of Mr. James Stone

Mr. James S. Stone, a former employee of Rockwell International at Rocky Flats Plant met with the Team on August 7, 1989. Mr. Stone had accepted the Team's invitation to elaborate on his concerns about unsafe criticality practices at Rocky Flats Plant. Mr. Stone has concerns in a number of areas besides criticality safety,

but the meeting did not range too widely, and this summary is confined to his views on the issue of concern to the Team: criticality safety at the plant.

The main criticality safety points *that he raised* were as follows:

1. A criticality allegedly occurs all the time at Rocky Flats Plant.
2. Too much reliance is placed on workers to prevent criticality. Greater automation of the plant should be required.
3. Material balances should be used to isolate areas where SNM might be missing. A material balance should be performed for the Building 771 incinerator, the liners in the incinerator should be changed out because that had never been done, but no evidence of contamination downstream of the HEPA filters in Building 771 was presented.
4. A letter from Lawrence Livermore National Laboratory (LLNL) appears to recommend the use of electrostatic precipitators at the plant in the process exhaust lines upstream of the HEPA filters.
5. Photos and reports show an accumulation of beryllium dust in the exhaust ducts from beryllium machining operations in Building 444. If beryllium could accumulate to the level of resembling sand dunes in these lines, then fissile material could accumulate in other lines and other buildings at the plant.
6. There is evidence of contamination in the ducts of Building 881, but the levels do not indicate a criticality concern; these issues were raised with plant managers out of concern for employee health in Building 881; and because ducts are often inaccessible, they are ignored.
7. Attention should be paid to the controls placed on physical access to areas in the plant where radioactive waste and residue drums are stored; in the 700 and 900 areas, unlabeled drums have been observed, but they may have been empty, and unpatterned arrays of drums may indicate a lack of attention to criticality controls.
8. Cesium and strontium levels found at Hillside 881 should be studied; there may be radioactive materials buried in or under clay pits at Hillside 881, and at a location to the south and west of Building 771; high priority should not be given to investigating what is underground since the levels measured to date seem to be very low.

9. Over-pressurizations of modules J and K in Building 707 should be reviewed, but they might not have any connection to criticality safety.
10. No proof of any criticality events at the plant was provided, but his feeling was that there were all levels of criticality occurring quite often. In response to questions from the Team, Mr. Stone stated that:
 - a. a specific criticality incident was not identified or observed by him personally;
 - b. he could name no other people who had specifically identified a criticality incident; and
 - c. the presumptions he made regarding accidental criticalities were based on plant-wide scuttlebutt (rumors).

The Team evaluates these main points as follows:

1. The perception that accidental criticalities occur often at Rocky Flats Plant is erroneous. The Team examined records of the plant, including (a) criticality safety procedural infractions (Section 5.5), (b) worker radiation exposure records (see Appendix E), (c) plant renovation records (see Section 3.2.2 and Appendix F), (d) results of offsite environmental monitoring (see Section 2.2), and (e) results of nuclear material accountability programs (see Section 3.2.1). This evidence strongly supports a conclusion that a criticality accident has never occurred at the Rocky Flats Plant.
2. It is correct that high reliance is placed on workers to prevent a criticality accident. Training, procedures, and the "double contingency" principle are applied at Rocky Flats Plant to guard against human error. The Team found that the high reliance placed on workers justifies greater effort at Rocky Flats Plant in the areas of training (see recommendations in Section 5.3), infraction reporting and followup (see recommendations in Section 5.5), defense-in-depth strategies (see recommendations in Section 5.8), configuration control (see recommendations in Section 5.9), and staffing of Criticality Engineering (see recommendations in Section 5.2).
3. The recommendation that material balances be performed is valid. Such balances, however, have been used for many years at Rocky Flats Plant and at all other government facilities handling special nuclear material. Material balance methods and results are classified for obvious security reasons, so not everyone would be aware of them. The methods and results of

nuclear material accounting at Rocky Flats Plant were reviewed by the Team and found to be in accordance with DOE practice. Nevertheless, the Team found that there is not a good *overall program* of material accounting, nondestructive assay, and criticality safety at Rocky Flats Plant (see Section 3.2). With regard to the liners of the Building 771 incinerator, they are already periodically changed to guard against excessive plutonium buildup (see Section 2.4), so this point is not valid.

4. It is correct that LLNL has recommended the use of electrostatic precipitators at Rocky Flats Plant. The Team is also concerned that prefilter technology at the plant needs early study and improvement to better prevent the accumulation of significant amounts of plutonium in exhaust ducts (see the specific suggestions in Sections 3.1).
5. It is correct that there can be accumulation of plutonium in exhaust ducts. The Team found a significant amount of plutonium in at least one exhaust duct in Building 771 that required prompt attention by Rocky Flats Plant (see Section 3.2). New programs of duct surveillance and exhaust system design will be required to prevent the recurrence of this problem (see recommendations in Section 3.2).

It is technically incorrect to state that the plutonium accumulation in ducts in plutonium processing buildings is *similar* to beryllium accumulation in ducts in Building 444, even though the Team did find plutonium accumulation in ducting. The principal difference is that, in the plutonium processing areas, one objective of the exhaust system is to keep the hazardous materials within the glovebox and away from the workers. In the graphite and beryllium areas, the objective is just the opposite, namely, to pull the fines (small particles) from the work area as efficiently and reliably as possible in order to avoid housekeeping problems and occupational health hazards. That is, the transport of materials into the exhaust line is to be promoted in the beryllium and graphite areas and prevented in the plutonium processing areas. Therefore, the filtration aspects of the ventilation system designs are different, and the accumulation rate would be significantly slower in the case of plutonium. Nevertheless, the suggestion to look for such a problem should have received a more inquisitive and positive response from plant managers.

6. The evidence cited of contamination of ducts in Building 881 was of two kinds. First, a document with pages numbered 8266 and 8267, appears to raise a criticality concern with Room 227. Secondly, contamination measurements were routinely made by Rocky Flats Plant Health Physics as part of routine worker radiation protection. The Team agrees that the routine Health

Physics monitoring does show some residual contamination in exhaust ducting in Building 881, but *Health Physics records* reviewed by the Team do not indicate that the amounts of fissile material in that building are sufficient to cause a criticality safety concern.

During its investigation, however, the Team found *other evidence* pointing to the possibility of significant amounts of fissile material remaining in the old ductwork of Building 881. First, the Team asked Rocky Flats Plant managers to provide evidence that there is *not* a significant amount of fissile material in the ducts and was told there was no conclusive evidence. Second, the Team discovered that *records of renovations* to old ductwork and process lines in Building 881 reveal the presence of significant amounts of radioactive materials, including one instance where 288 grams of uranium-235 was found in an old laundry line. Third, quantities large enough to be of concern for criticality safety have been found in ducts in other buildings (see Section 3.2). Fourth, there is the specter of criticality safety concern raised by document 8266/8267. Fifth, a large quantity of particulate material was found in a catch-plenum renovation, although it contained only small amounts of fissile material.

Document 8266/8267 was provided to the Team by Mr. Stone and, also, independently by Mr. Tim Holeman of Governor Romer's office. This document consisted of a note attached to a 1987 work order for a renovation done in Building 881 at Rocky Flats Plant. The note read as follows: "Looks like room 227 is the only 1 (sic) that will contain levels that could cause criticality. I'll work on having samples taken." Page 8266 shows the work order with the note attached. Page 8267 shows the document without the note attached.

A Mr. Steve Sergeson was identified as the author of the note and was contacted by the Team. He said that his use of the words "cause criticality" in the note he wrote to himself were "overkill." He meant them to mean "cause criticality engineering concerns," as such concerns were reflected in other comments already written on the work order by a Criticality Engineer. Mr. Sergeson said he knew that there was no real potential for criticality in the renovation of Room 227, but he was being cautious to preserve a good working relationship that he had established with the Criticality Engineering Group. He said that he knew that neptunium and plutonium samples were being analyzed in Room 227 in very small (microgram) quantities. The concern that he had for criticality was a very conservative one, specifically, that plutonium wastes left over from the wet sample analysis procedure that is performed in Room 227 might accumulate in the pipe that carries liquid wastes from the room.

Mr. Sergeson said that such waste lines had been dealt with routinely in other modifications to Building 881, and the procedures for radiation surveys in advance of cutting out old lines and the attendant health physics procedures were well understood by him and others involved in the potential renovation of Room 227.

Mr. Sergeson has a Bachelor of Science in manufacturing engineering and cost management. He said that he relies completely on the Criticality Engineering group at Rocky Flats Plant to know what is and what is not a criticality problem, but he personally did not think there was much of a potential for a criticality accident in Room 227 either at the time he wrote the note or today.

On the basis of this interview, the Team concludes that Mr. Sergeson simply wrote a note to himself so that he would remember to consult with the Criticality Engineering group before proceeding with the renovation of Room 227. The comments of the Criticality Engineering group on the work order reflect the caution required by standard operating procedures at Rocky Flats Plant when dealing with fissile material. Because of the small amounts of fissile material that have been processed in Room 227, it is unlikely that there is a large quantity of material that has built up in the line.

Nevertheless, if the Criticality Engineering group was concerned with the movement of the fissile material in the waste line of Room 227 during a renovation, as it said in the work order, then it would be prudent to document and establish formal approvals regarding the intent of plant managers regarding this contaminated line. Furthermore, there are other reasons (such as the ongoing health hazard) for plant managers to be inquisitive about what might remain in the ducts and waste lines in this building, as described above.

Therefore, the Team recommends that the waste line in Room 227 and any other lines or ducts in Building 881 that are of potential concern to the Criticality Engineering group be surveyed to determine whether or not there is a significant buildup of fissile material anywhere in that building. Long-term plans and potential consequences should be documented and approved.

7. Concerns regarding access controls for residue storage areas are not supported by Team observations. The Team toured the residue storage areas in Buildings 776 and 371. There are tight access controls, and work in the storage areas requires the use

of administrative procedures, including a buddy system, and special training (see Section 4). Out of thousands of drums that were examined, the Team found *no unlabeled drums that were not empty*. Also, unpatterned arrays of residue and waste drums have no criticality safety concern because the criticality analyses are performed for close-packed, planar arrays. Any other pattern, even if not very orderly, is *more safe* than this.

8. Concerns regarding the measured levels of cesium and strontium at Hillside 881 are misplaced for reasons given in Section 2.2. Also, since no other more definitive or confirming evidence can be found of a criticality accident in the past and since contaminated areas will be cleaned up in priority order, the Team concludes that there is no reason to investigate any of the contaminated areas from a criticality safety point of view.
9. The Team looked and could find no linkage between ventilation system over-pressurizations of modules J and K in Building 707 and criticality safety.
10. The Team could find no evidence of any accidental criticality events at Rocky Flats Plant, although the Team did find people who talked *too informally* about "criticalities" and "criticality infractions" in referring to criticality safety procedural infractions. The Team asked the Training Department why this occurred, and was told the trainers did not know. Better assessment of training effectiveness (feedback), in addition to the periodic retraining requirements that are already in place, may improve this situation (see recommendations in Section 5.3).

2.7 Criticality Safety Procedural Infractions

A number of people have alleged that infractions of safety procedures at Rocky Flats Plant are an indication of possible criticality events. For example, in his meeting with the Team, Mr. James Stone referred to plant reports of 143 *criticality events* when, in fact, he was talking about infractions or violations of criticality safety procedures. These infractions are violations of safety limits which are in place to prevent a nuclear criticality accident, but an infraction does not mean that a criticality accident has occurred. It *does* indicate, however, that at least one of the formal barriers required by the "double-contingency" principle for criticality safety has been violated.

In a similar accusation, Mr. Ken Grice, a businessman from Westminster, Colorado, and Director of the Rocky Flats TAG Coalition, in an appearance before the DOE Advisory Committee on Nuclear Facility Safety (ACNFS) on March 1, 1989, said:

"... the potential for criticality is immense. Mr. Sanchini [Rockwell] was quoted last year in the local papers stating that there were over two and a half potential criticalities per month, and we have not seen a list of all those criticalities since 1977."

There was no response to this statement by the ACNFS, but Mr. Grice apparently equates a procedural infraction more with an actual criticality accident than with a violation of one of the two contingencies.

Sometimes the wording in news articles is accurate but still leaves the wrong impression. For example, the Rocky Mountain News of June 16, 1989, quotes its own story of November 1988 as saying that "an internal memo to Rocky Flats employees chastised workers for repeated safety violations, including an average of 2.5 nuclear criticality infractions per month. An infraction is a violation of a safety rule designed to prevent a nuclear criticality accident." The article appears to use this *inside* information to refute statements by plant managers that a criticality accident has never occurred at Rocky Flats Plant. Even if such inaccurate implications are not intended, some readers could conclude that actual criticality accidents are a frequent occurrence.

Similarly, a statement made in the "Critical Mass" TV program in June 1989 by Dave Minshall, one of the reporters, was that there were 143 instances in which the criticality alarms did not work at Rocky Flats Plant. It is difficult for the audience to determine if 143 criticality accidents occurred where the alarm system did not work or if simple alarm system testing of many detectors over many years resulted in this data (see Section 5.4).

In order to determine whether such public impressions were valid, the Criticality Safety Assessment Team reviewed descriptions of the circumstances surrounding each criticality safety procedural infraction that has occurred since 1962 (see additional details in Section 5.5). The Team was told that no records were kept of any such infractions that occurred prior to 1962.

Over 600 instances of criticality safety procedural infractions have been recorded since 1962. Prior to 1983, these infractions were described only in minutes of meetings held by the Nuclear Safety Committee. Starting in 1983, a more detailed system of addressing criticality safety procedural infractions was established. Under this new system, the complete circumstances surrounding each infraction are described, including such topics as operating conditions at the time of the infraction, immediate action taken, final evaluation, lessons learned, and corrective actions.

The initial objective of the Team's review of criticality safety procedural infraction reports was to determine whether there was evidence in these records of past accidental criticalities at the Rocky Flats Plant, which the media and public understood were occurring frequently. In its review, the Team found no evidence of the occurrence of a criticality accident. However, the Team observed many infractions of a recurring nature. Thus, a second objective of the review was

undertaken: to gain an understanding of the underlying reasons for these recurring infractions.

The Team reviewed the infractions to identify those that were the most serious. Generally, the eight most serious infractions involved loss of control of a significant amount of fissile material (several kilograms). The review also revealed the recurring nature of the root causes of these as well as the less significant infractions. Overall, there are six general types of infractions of criticality safety procedures, namely:

- Nuclear material mass limits exceeded
- Spacing requirements violated
- Drums improperly stacked
- Material transferred improperly
- Material storage requirements violated
- Incorrect containers used

The Team also undertook a formal root cause analysis of the 214 criticality safety procedural infractions that have occurred since 1983. This analysis resulted in certain conclusions and recommendations for improvement of criticality safety at Rocky Flats Plant. Areas where significant improvements could be made in order to reduce the number of recurring infractions involve worker and management attitudes (culture) and, in certain areas, the working environment (see recommendations in Section 5.5 and descriptions of infractions in Appendix G).

3. Fissile Materials In Exhaust Ventilation Systems

The Team reviewed the design details of the Rocky Flats Plant ventilation systems as well as the history of renovations to ventilation systems. A detailed discussion of these topics is provided in Appendix F. Readers who are not familiar with the ventilation systems at Rocky Flats Plant are encouraged to read Appendix F before continuing. This section of the report provides the Team's comprehensive review and examination of issues associated with ventilation systems. Included are (1) information regarding the use of glovebox prefilters and (2) the Team's ventilation system survey conducted by the Team. Detailed survey data are provided in Appendix D.

3.1 High Efficiency Particulate Air (HEPA) Filters

All HEPA filters used at Rocky Flats Plant are tested for efficiency (DOP tested) and certified under a quality assurance program in the plant's accredited HEPA Filter Testing Laboratory. The filter media is Nomex, which is resistant to acid fumes. There are specifications for the dimensions of the package holding the filter media and the flatness of its mating surface. Glovebox exhaust filters are called *prefilters* since they are located upstream of the ventilation system, at the connection of the ventilation system to the glovebox.

A "Plant Services Filter Maintenance Report" is prepared at Rocky Flats Plant each month. This report shows: stage, type of filter, glovebox unit, room, line, number of filters, inspection reason, date last inspected, normal inspection interval, new date, remarks, and next inspection date for glovebox prefilters and for filters located in the filter plena. These data permit the Filter Systems Group to perform its job of inspecting all filters on a routine basis. These data also allow the identification of gloveboxes which have a history of dusty, dirty, or high aerosol operations. Should glovebox exhaust filters become "loaded" at any time, they are required by procedure to be changed in a matter of hours. Not only are prefilters changed on an as-needed or predetermined schedule, but they are also changed at the inventory period as part of the nuclear materials accountability process. Prefilters are not DOP tested in place since admitting DOP into a glovebox would not only contaminate the material in process but would result in slick surfaces of objects inside gloveboxes. An elaborate device that would take up a large volume inside the glovebox would be needed for a DOP test. Volumetric measurements of the atmosphere passing through each filter are not made and remain an unsolved problem. Thus, there is no quantitative test or method to measure the performance of glovebox prefilters.

Changed prefilters are "bagged out" of gloveboxes. Building filters are also encased in bags upon removal. Bagged filters are examined by nondestructive assay using a Ludlum "gram-counter" to estimate their content of plutonium. Based on this measured value and nuclear criticality safety limits (up to 200 grams per 55-gallon drum), one or more filters are loaded into a 55-gallon drum or crate. These are ultimately counted by a more accurate gamma-scan technique or passive/active neutron interrogation. Prefilters containing greater than 100 grams of plutonium are physically tapped inside the glovebox, and the loose material

which falls into a shallow tray is processed as scrap. Building operators handle this debris. The measured drums are kept in inventory, but no record is kept of the final disposition of individual filters.

Occasionally the larger ducts in the building ventilation system are inspected and cleaned by scraping. The material is evaluated and collected in appropriate containers (1 or 4 liter) as specified by nuclear criticality safety engineers. No such operations are performed for the exhaust ductwork from gloveboxes.

Installation of prefilters on gloveboxes began in earnest after the 1969 fire. Before this there were unfiltered exhausts on gloveboxes. All new glovebox installations were required to have prefilters, and a retrofitting program was begun for old gloveboxes. By mid-1970, most gloveboxes had prefilters. In the 1981-1982 time frame, there was a major effort in Building 771 to modify prefilter housings to effect a better seal between the filter and exhaust duct opening. There had been a history of workers puncturing the filter media with a sharp tool (e.g., screwdriver) or slipping the filter aside to permit greater flow through the glovebox if the filter was plugged. A letter was written in 1983 reporting this situation to building managers, but at least one Rocky Flats Plant manager stated that it still happens. If a filter is found abused today, it is reported.

A bypass valve is installed on certain gloveboxes. This valve opens automatically if the pressure drop across the glovebox prefilter reaches a preset value. The bypass line does not have a filter, thus glovebox atmosphere is drawn directly into the ductwork. The bypass valves are not alarmed to indicate when they are open, and the gages which indicate pressure drop across the bypass valves are not always easy to see.

A bypass line is connected to the sand, slag, and crucible milling and grinding glovebox in line 43 of Building 771. This operation is especially dusty, and significant quantities of this dust can be drawn into the exhaust ductwork when the bypass valve is opened. The Team evaluation of this line using nondestructive assay instrumentation revealed that about 5 kilograms of plutonium had accumulated in this exhaust ventilation line. A physical inspection involving samples drawn from the line by the contractor confirmed the Team's evaluation.

In certain cases the glovebox prefilters are difficult to change, if they are positioned at the limit of the reach of a person using the gloves. Also, some of the fixtures that position these prefilters are not rigid enough to ensure that the filter is positioned properly.

Examples of the plutonium loadings on the first stage filters of the main building exhaust ventilation line that were changed during the past year are given in Table 3-1. The operations in the various plutonium handling buildings are identified. The plutonium values were obtained by plant personnel using segmented gamma scanning.

Also, members of the Rocky Flats Plant Filter Systems Group estimated for the Team the average plutonium content for glovebox prefilters changed during the

past year from various operations. The Team was concerned that it might be possible that not enough attention was being given to those particular prefilters where it would be expected that significant amounts of plutonium would collect. The estimates provided are shown in Table 3-2.

TABLE 3-1
Plutonium Loadings on Filters From Various Operations

<u>Building No.</u>	<u>Filter Service</u>	<u>No. Filter Banks Changed</u>	<u>Plutonium Grams Per Filter Bank</u>
707	Foundry	13	1
707	Fabrication	33	0
771	Chemical Operations	94	48
771	Incinerator	13	162
776	Size Reduction	29	3
776	Advanced Size Reduction	68	13

TABLE 3-2
Filter Systems Group Estimated Average
Plutonium Content per Prefilter of Glovebox Prefilters
From Various Operations

<u>Building No.</u>	<u>Filter Service</u>	<u>Estimated Average Plutonium Content per Prefilter, grams (Ludlum Gram Counter)</u>
707	Foundry	<10
771	Peroxide Precipitation	<10
771	Hydrofluorination	<25
771	Button Breakout	<10
771	SS&C Milling	<10

Since no record is kept of the disposition of the individual prefilters after they are removed from service, the Team was interested in verifying these estimates to the extent possible. Records in Nuclear Materials Accountability were examined and showed the measured plutonium content of the 55-gallon drums used for the disposal of prefilters. If five prefilters (the usual number) were contained in each drum, an average value of the plutonium content per prefilter can be determined. Data from the past year are given in Table 3-3.

TABLE 3-3
Plutonium Content of Drums of Changed Prefilters

<u>Building No.</u>	<u>Filter Service</u>	<u>No. of Drums</u>	<u>Plutonium Estimated No. of Prefilters</u>	<u>Plutonium, Grams per Drum (per prefilter)</u>
707	Fabrication	1	5	3 (<1)
707	Foundry	4	20	206 (10.3)
771	Chemical Ops.	8	40	66 (1.65)

Comparison of Table 3-3 with Table 3-1 and Table 3-2 shows that the Filter Systems Group can determine if operations are being conducted in a consistent manner; that is, these data indicate that plant workers would be able to detect whether unusual operations took place in a glovebox between exhaust filter changes.

Glovebox exhaust filters, for the most part, are doing their job by keeping the bulk of the plutonium in the gloveboxes. However, there are three problems: dusty operations, very wet operations, and filter bypass (by improper seating, filter punctures, or operation of the unfiltered bypass valve). The atmospheric change rate (thirty changes/hour) in gloveboxes is quite high compared to other plutonium processing facilities. The Team was told that this rate was necessary to "sweep out dust and remove heat and moisture," if present. With this flow rate, dust cannot readily settle out on the floor of the glovebox. The sweeping operation keeps the dust suspended for a time which permits more dust to impinge on the face of the prefilter and causes early filter plugging. If the filter seal is not true or if the bypass is open, more dust will enter the ductwork because of this high air flow rate.

Ductwork from gloveboxes with wet operations is in certain cases combined with exhaust ducts from dry and dusty operations. This is the case with Line 43 in Building 771. Dust from the sand, slag, and crucible grinding operation has apparently combined with moist acid fumes from an adjacent glovebox to cause a "slime" to form inside the exhaust duct. This slime or slurry contains about 5 kilograms of plutonium, as noted above.

Various systems have been evaluated by the operating contractor at Rocky Flats Plant to increase prefilter life. These systems include electrofiber installations over the prefilters. It was reported by Rocky Flats Plant personnel that such changes did not increase prefilter life and were abandoned.

Based on the current assessment, the Team suggests that Rocky Flats Plant undertake the following studies of glovebox filter systems:

- 1. Development of prefilter aligning devices to assure seal of the filters to the exhaust duct inlets.**

2. Optimization of flow rates of air and nitrogen through gloveboxes to reduce carrying velocity.
3. Redesign of equipment to reduce heat, dust, and moisture where they are problems in gloveboxes.
4. Redesign of exhaust ducts to permit easier replacement, interior viewing of contents, and/or nondestructive evaluation. The redesign should separate the ducts which serve wet and dry glovebox operations.
5. Evaluate the use of additional prefilters over the face of glovebox exhaust prefilters to enhance plutonium recovery and to extend the life of the exhaust prefilters.
6. Consider using filters to cover inlets to automatic bypass valves and installing an indicator warning device when these valves are opened.

3.2 Accumulation of Fissile Material in Exhaust Ventilation Systems

Uncontrolled and undetected accumulation of fissile material in ventilation ducts has the potential to lead to a criticality accident. Since the exhaust ducting in the immediate vicinity of gloveboxes and other process areas is generally of small diameter, they are usually perceived to be "intrinsically safe" from a critical geometry point of view. However, the potential for a criticality accident, should large accumulations occur, is not negligible. Accumulations of material in exhaust ducting are not always stable; and small diameter ducting feeds into large diameter ducting, which has a greater potential for a criticality accident. Also of concern is the potential for precipitous transport of such an accumulation, especially if it is wet or in slurry form, to some location having an intrinsically unsafe geometry.

The Team notes that an incident involving the accumulation of fissile material in a ventilation system occurred in 1984 at the Erwin Facility, operated by Nuclear Fuel Services, Inc., in Erwin, Tennessee and regulated by the U.S. Nuclear Regulatory Commission (NRC). In that case, uranium accumulated in the plant uranium scrap recovery system (Complex 200), in the ventilation system and associated venturi scrubber walls. The details are available in NRC Report No. 70-143/84-41.

3.2.1 Holdup Measurement Practices at Rocky Flats Plant

The Team asked Rocky Flats Plant managers what the policy and practice are for routine and non-routine plutonium assays or surveys of ductwork. Key points that came out of that inquiry were:

- There are no routine measurements made for the purposes of nuclear material safeguards.

- On an as-needed basis, surveys have been done, primarily for radiation protection purposes.
- The history of duct surveys is as follows: Gamma surveys were done on request through the 1960s up to the early 1970s when new instrumentation was developed to estimate gram quantities. Radiation Protection did surveys of ducts and pipes in Building 771 during the early 1970s only for radiation exposure purposes; this practice was discontinued after a few years. Subsequently surveys were conducted for nuclear material accountability purposes.

Nevertheless, from general briefings and in-depth interviews, the Team determined that routine, *quantitative* measurements of fissile material holdup in the exhaust ducting at the plant are not being performed.

As part of the Rocky Flats Plant ALARA (as low as reasonably achievable) policy on radiation exposures, a Health Physics monitoring program is in place. In this program, gamma and neutron dose surveys of general work areas are performed regularly. These surveys generally cover exhaust ducting as a part of monitoring process areas where high radiation exposures might occur. It apparently has been the policy of the managers responsible for criticality safety to rely on the Health Physics monitoring program to discover any significant holdup of fissile material in the exhaust ducting "long before it became a criticality safety issue." The Team rejects this policy of relying on the ALARA program and radiation dose measurements to provide "criticality safety" warnings. Two actual situations discovered at the plant by the Team indicate that such reliance is not adequate.

First, in the Building 776 process area there are overhead exhaust ducts containing a small accumulation of americium-241. Because of the very high specific activity of americium-241 and its accompanying 60 keV gamma radiation, the gamma dose rates from this ducting are quite high and have long since been measured and recognized by the health physics monitoring program as requiring action to reduce worker radiation exposure. In fact, this overhead ducting has been wrapped with lead sheeting to reduce the 60 keV gamma ray dose. Unfortunately, from a criticality safety viewpoint, the presence of americium-241 and the action taken to ameliorate it both tend to mask any gamma radiation that plutonium-239, if present, would produce. In essence, if any significant plutonium-239 were present along with the americium-241, it would not likely be identified with the gamma radiation measuring apparatus being used. In addition, since this ducting is considered "Am-241 contaminated," no one at the plant has inquired as to whether plutonium might also be present.

A second example was found in the calcium fluoride process area in Building 771. Because plutonium fluoride (or related PuF compounds) are common in this region, high neutron dose measurements are usually interpreted as being produced by plutonium fluoride. Plutonium fluoride produces approximately 100 times the neutron dose rates per gram of plutonium than plutonium oxide or most of the other chemical forms of plutonium found at the plant. Thus, the neutron dose measurements in this area are unreliable for criticality safety assessment purposes.

Should significant plutonium oxide or other low neutron dose material be present, it would not be sensed above the neutrons emitted by plutonium fluoride and, thus, no concern would be raised for criticality safety.

The basic point that the Team is raising here is that the goals of an ALARA radiation dose monitoring program will not always support the goals of a criticality safety monitoring program. To properly evaluate criticality safety of fissile material in exhaust ducting or elsewhere in the various systems, one must have quantitative measurements.

3.2.2 Experience with Plutonium Holdup from Building Renovations

If plutonium had been accumulating in the exhaust ductwork over the 35 years of plant operations, then evidence of that accumulation should have shown up in the radiological assays that were part of the numerous building renovations over the years that involved ductwork changeout. The Team reviewed what records were available (see Appendix F). The records are inconclusive. Some of the records do not indicate that large amounts of plutonium (amounts, for example as large as those found in Line 43C, as described in Section 3.2.3.7.2) were found in the ductwork that had been removed. Other records showed that *significant* quantities of fissile material had accumulated in ductwork. The following records were examined by the Team:

- Building 776 ductwork associated with the 1969 fire
- Building 771 header replacement in line 24
- Building 771 duct replacement to FU-1
- Building 707 changeout of J Cell ducts
- Building 881 catch plenum replacement
- Building 771 duct replacement in glovebox exhaust ducting and FU-2 area in the late 1970s
- Building 881 laundry line removal

Records from these last two projects indicate that significant amounts of fissile material were found during renovations. This is not consistent with statements made by Rocky Flats Plant management to the Team early in the site visit that there is no evidence of plutonium in the exhaust duct system. Other Rocky Flats Plant personnel told the Team that a solid salt-like material was found during the removal of line 24 header in Building 771, but the material was not sampled or evaluated. In the mid-to-late 1970s, semi-annual plutonium surveys were made in Building 771 exhaust ductwork, including Zone FU-2 on the second floor. These surveys were done in preparation for cleanouts and duct replacements. One survey conducted in January of 1975 indicated that 17,605 grams of plutonium were present in 4,000 feet of duct. While this is a low quantity (4.4 grams per foot) on the average, it is interesting to note that some runs had greater than 100 grams per foot. The Team was unable to locate the records of any measurements made of the materials found in the ductwork when it was replaced. However, the Team was told that such records were kept during that period and that criticality engineers participated in the modifications.

3.2.3 Team Holdup Measurements

The Team determined that a major effort is required to be able to independently evaluate fissile material holdup in exhaust ducting at the plant with in situ measurements. The Team, after discussions with Rocky Flats Plant personnel from Operations Management, Criticality Safety, and Safeguards Measurements organizations, decided on an independently directed measurement effort using existing instrumentation and personnel from the Safeguards Measurements group at the plant. The measurements were taken by Safeguards Measurements group personnel with direct supervision and participation by Team personnel. All raw data were analyzed and interpreted by Team personnel. Copies of raw data and analysis results were made available to plant managers and are summarized in Appendix D. Considering the limited time available for these independent measurements by the Team, the ducting and associated equipment were carefully selected during tours of Buildings 771, 707, and 776. These buildings contain fissile material processing facilities (involving scrap, residue, and incinerator ash) and various associated chemical process activities. The Team selected areas for exhaust duct holdup measurements that it judged were most likely to experience accumulation of fissile material.

3.2.3.1 Description of Detection Equipment

The Team, after evaluation of the measurement conditions and radiation backgrounds in Buildings 771 and 776, determined that gamma ray spectral data would be required for reliable holdup measurements. Consultation with the Safeguards Measurements group revealed that two available instruments would be suitable for the purpose. One instrument was a collimated and shielded small sodium iodide detector (Jomar JHH.02, a production version of a background-updating, spectral-selective instrument developed originally in group N-2 at Los Alamos National Laboratory for use in special nuclear material searches). This instrument's small active volume and very small collimator opening (1/4"x 1/4") made it an ideal choice for "duct contact" measurements. In addition, this is a battery-powered (8-hour operating time between charges), hand-held unit. The entire instrument, including internal lead collimator and shield, weighs less than five pounds and is approximately 4"x4"x10" in size. It has a convenient LCD type readout. Readings taken with this instrument in contact with the external ducting surface are proportional to the specific "areal" plutonium source term. That is, on contact this instrument senses plutonium in grams per square inch in the immediate vicinity of the point of contact. This type of measurement maximizes the signal-to-background ratio and serves to pinpoint the plutonium distribution geometrically along the ducting.

The second instrument selected was a battery-powered, high purity, high resolution HPGe unit, with a battery-powered 4096 channel pulse height analyzer. This unit currently provides the best available gamma spectral resolution and, in addition, all measured spectra can be recorded on magnetic tape. The Team decided measurements with this instrument would be performed in "stand-off" geometry (30" to 36" directly under the line of ducting to be measured) so that a larger section of

ducting would be sampled in each spectral measurement. The section measured at this standoff distance is estimated to be about four feet FWHM (Full Width at Half Maximum). Thus, these measurements, with proper calibration and analysis, yielded the overall plutonium distribution in the ducting in grams per four-foot length of ducting.

3.2.3.2 Plutonium Standards and Calibrations

The Team was provided the use of several plutonium mass standards used at the plant for calibration of drum and package assay systems. Seven standards were used by the Team for instrument calibration: 23, 75, 92, 150, 195, 362, and 501 grams. Both detectors were calibrated in the same geometry as was used for their respective duct measurements. The standards are packaged in "matrix-mixed" cylindrical containers five to seven inches in diameter, which are similar to the actual ducting geometry.

3.2.3.3 Areas and Ducting Measured

Since the small sodium iodide detector is very easy to use, the Team used it for the general survey measurements in buildings 771, 707 and 776. In Building 771, ventilation ducting for gloveboxes, several process system structures, and the immediate output ducting associated with the residue incinerator were measured. For the incinerator system, the survey included heat exchangers, caustic leach spray chamber, anion exchange unit, mist tanks, and fume scrubbers. In addition, several overhead ducts in the vicinity of the incinerator were spot surveyed. Additional spot surveys in Building 771 led to a more detailed measurement campaign along a 40-foot length of overhead duct labeled 43C. This duct services several gloveboxes, including those associated with residue grinding operations. Finally, other areas in Building 771 were also spot surveyed--including glovebox 107 exhaust (fluoride line), glovebox 16 exhaust (calciner), and other "feed-in, feed-out" exhaust lines.

The same type of "areal source" spot survey measurements were performed in separate surveys in Buildings 707 and 776. In 707, measurements were made on exhaust piping and related structures associated with glovebox J-60 and near column 4J (Module B). In Building 776, the same type of measurements (exhaust ducts and related flanges, etc.) were performed for glovebox 206-501 and 046. This area was selected by the Team due to the presence of americium-241 and the associated piping that is wrapped in 1/8-inch lead sheet for radiation protection purposes.

In a third survey by the Team, the portable HPGe measurements were conducted. Due to the time required to obtain an optimum and uncontestable set of data, these measurements were restricted to line 43C in Building 771. This line was selected since the previously completed NaI areal source measurements indicated the probability of a sizeable amount of holdup.

3.2.3.4 Assumptions in Data Analysis

Most of the Team's holdup measurements were of the areal-source type. Since no direct transmission measurements were made, the unknown character of the actual internal holdup deposit had to be modeled to convert areal source data to a total fissile mass per unit length of ducting. It should also be appreciated that most of the Team measurements were of the "spot check" type and were not carried out in a systematic fashion along the length of a particular duct. To determine actual systematic holdup along the length of a ducting system requires a more detailed survey. Only for an approximately 40-foot length of line 43C in Building 771 did the Team perform measurements in that required level of detail. The other "spot check" measurements serve to indicate typical holdup levels that can help to guide later, more detailed measurements.

The model selected by the Team for data analysis assumes the measured areal source to extend over approximately 50% of the ducting surface, with average ducting attenuation effects assumed to be approximately equal to average calibration source attenuation effects. With these assumptions, an average calibration factor of about 1.0 count per second for each gram of fissile material in a foot-long section of ducting (6 to 8 inch diameter) is obtained. The uncertainty in the overall final results is expected to be about $\pm 50\%$, considering the several possible sources of error.

3.2.3.5 Results in Building 707

A systematic set of measurements was carried out along the glovebox J-60 exhaust piping (6-inch diameter). Twenty-one spot check measurements were made (results of individual measurements are given in Appendix D). Using the indicated plutonium standards calibrations and holdup model assumptions, the average for these twenty-one measurements of the glovebox J-60 exhaust ducting was 75 grams of plutonium per foot of ducting. The maximum reading was 220 grams per foot, and the minimum was seven grams per foot.

The exhaust ducting associated with column 4J in module B was also surveyed; eight measurements were made. The average for these measurements was 29 grams of plutonium per foot of ducting, with a maximum of 97 and a minimum of 0.

3.2.3.6 Results in Building 776. Lead Covered Pipes

See Appendix D for diagram and individual measurement results. In Building 776, the Team observed a considerable amount of ducting that had been wrapped with 1/8-inch thick lead sheets to reduce the personnel exposure levels produced by the 60 kev gamma rays from americium-241. One-eighth inch of lead reduces the 60 kev line intensity by about a factor of 100,000. However, the plutonium-239 lines at 376 and 414 kev are reduced only by a factor of about 2. The JHH.02 instrument was programmed to subtract the response from higher energy americium-241 gamma lines in the 414 kev plutonium-239 region of interest. The Team did not have the means to check the accuracy of this internal spectral correction factor.

Since considerable americium-241 is present in this ducting, it is assumed that the correction is proper. Additional uncertainty results from this condition. The Team applied a factor of two correction to the observed net count rates to properly account for transmission of the plutonium-239 gamma rays. Thus, for the lead wrapped ducting measurements, an appropriate calibration factor was 0.5 cps per gram of plutonium in each foot of ducting.

For the exhaust ducting associated with glovebox 206-501, a total of seven measurements were made. The average was 32 grams of plutonium per foot of ducting, with a maximum of 142 and a minimum of 4.

For the exhaust ducting associated with glovebox 046, the average observed for nine measurements was 66 grams of plutonium per foot, with a maximum of 146 and a minimum of 14. The average of six measurements on the inert return line B was 16 grams of plutonium per foot, with a maximum of 62 and a minimum of 2.

3.2.3.7 Results in Building 771

3.2.3.7.1 Room 149 Readings (Incinerator Area)

The results were as follows:

1. Heat Exchanger 2 and associated ducting: 21 grams of plutonium per foot, 35 maximum, 11 minimum.
2. Outlet of caustic leach spray chamber: 4 grams of plutonium per foot, 6 maximum, 2 minimum.
3. Exhaust ducting from anion exchange: 5 grams of plutonium per foot--6 maximum, 0 minimum.
4. FU2, Zone 2B and ball mill vicinity: 13 grams of plutonium per foot, 35 maximum, 2 minimum.
5. Glovebox 107 exhaust line (fluoride line): 53 grams of plutonium per foot, 120 maximum, 33 minimum.
6. Glovebox 16 exhaust line (calciner): 70 grams of plutonium per foot, 114 maximum, 31 minimum.

3.2.3.7.2 Exhaust Line 43C

An approximately 40-foot section of exhaust line 43C, which services several gloveboxes in room 149 of Building 771, including those related to crushing and grinding of sand and slag residues, was found to have an especially large holdup of plutonium. As a consequence, this line was selected for a detailed study. The ducting was marked in one-foot increments, with the first 45 degree "Y" joint designated as the reference point (0 foot). Downstream points along the ducting were designated as in the north or "N" direction. Points upstream of this point were

designated "S." The piping from 6S to 18N is 6-inch OD, and from 18N to about 35N (last accessible point) the pipe is 8-inch OD. The calculated average loading over the entire 40-foot section was 110 grams of plutonium per foot with a maximum of 246 (16N) and a minimum of 0 (6S). The indicated *total holdup* from the sodium iodide based areal measurements over the entire 40-foot length was 4.4 kg of plutonium.

It was not clear how accurate the NaI areal source measurements were. The Team decided that the modeling needed to obtain a total grams per foot value, as well as possible spectral problems that are known to plague low resolution NaI measurements, required an independent check. This check measurement was done by using the portable HPGe detector. The high resolution of this detector allows unambiguous quantification of the 376 and 414 kev plutonium-239 gamma line intensities. In addition, the check measurements were performed in an integrating geometry--about 36 inches below the ducting, looking directly up at the ducting. In this geometry the HPGe senses the entire source contained in the 4-foot length of ducting centered immediately above it. These measurements do not depend on the details of the distribution of material holdup in the pipe; only the average gamma transmission factor is required. Again, the Team assumed that the average transmission factor of the material held up in the ducting and the calibration sources were approximately equal.

Seven segments of line 43C were measured in this fashion, with 5 duplicate measurements at each location using the HPGe detector. In the coordinate system described above, these segments ranged between 0N and 20N. The average holdup observed over this 20-foot length was 170 grams of plutonium per foot, or about 3.4 kilograms total. The Team estimates by using the average measured HPGe-to-NaI response ratio over the 20-foot section, assuming that the same ratio applies over the remainder of the 40-foot line, that the total holdup for the entire 40-foot length would be 5.5 kilograms of plutonium.

After the Team's measurements were completed, Rocky Flats personnel drilled a small hole in line 43C, near the 20N location, to obtain a sample of the material for analysis. A laboratory analysis of this material indicated a plutonium-239 content of 0.09 grams per gram of total residue. The material density was measured to be 1.64 grams per cubic centimeter. A boroscopic view of the holdup in this vicinity indicated that the ducting contained a considerable amount of moist residue, filling perhaps as much as 25-30% of the total pipe volume. A second hole was drilled upstream of this point (approximately at the 14N location), and the holdup was again sampled and analyzed. At this point, the plutonium-239 content was 0.03 grams per gram of total residue and the density was 1.64 grams per cubic centimeter. The boroscope view indicated a considerably smaller volume of residue than for the 20N area. No quantitative estimate was offered. The Team has calculated approximate plutonium-239 concentrations from these data and found them to agree very well with both the HPGe and NaI "non-destructive" measurements.

3.2.3.8 Analysis of Measurements

The Team's measurements found considerable fissile material holdup in the glovebox exhaust ducting in several locations in Buildings 771, 707, and 776. Measurable amounts were found in virtually all areas. Exhaust line 43C in room 149 of Building 771 was measured in detail over a 40-foot length. The average holdup over this length was found to be in excess of 100 grams of plutonium per foot of ducting. The plant personnel confirmed the conclusions relative to line 43C by entering the line and obtaining a direct sample. The samples also confirmed the calibration and gamma ray transmission model used by the Team. Thus, the values reported above appear to be accurate within the stated $\pm 50\%$. Considering the physical state and total amount of plutonium in line 43C, it must be considered to have serious potential for causing a criticality accident under certain conditions.

The Team evaluated the criticality safety hazard of the material found in line 43C. An 8-inch pipe *could* be critical if filled with a plutonium slurry or solution greater than 40 grams per liter if the pipe was closely surrounded (reflected) by water or people. If reflected only partially (one side), it would take plutonium densities in excess of 90 grams per liter to cause a criticality. With no reflection, the pipe would require greater than 200 grams per liter for a criticality. The two samples taken from pipe 43C had 50 and 150 grams per liter of plutonium. The maximum concentration in the pipe is unknown but is likely to exceed 150 grams per liter. Since duct slurries could also be expected to be unstable in location, it is credible that these materials could move and fill some larger section of the pipe. Since there were no controls to limit personnel access to these ducts, full or partial reflection could occur. Without the additional reflection, the total amount of plutonium found in line 43C would not cause a criticality accident in an 8-inch pipe; yet the risk is significant without access controls on the affected pipe. Specifically, the Team calculated that an 8-inch schedule 40 pipe filled with 100 grams per liter of plutonium and a total of 5 kg of plutonium (five weight percent plutonium-240) has a k_{eff} of 1.002 ± 0.003 if fully water reflected. Thus, a criticality accident could occur in line 43C under some circumstances. Some of the other amounts of holdup observed by the Team, while presently posing lessor hazards, are also potentially serious. Also, there are other lines with potential for holdup that were not assayed by the Team. The areas measured in the vicinity of glovebox J-60 in Building 707 (average of 75 grams per foot), in particular, could pose a criticality safety hazard similar to that found for line 43C in Building 771.

The Team recommends that Rocky Flats Plant management initiate a systematic duct holdup measurement program in the near future. The Safeguards Measurements group has the proper expertise to perform and analyze such NDA measurements. This should not be viewed by management as a "single-shot" event. To assure continued criticality safety, periodic and systematic quantitative duct holdup measurements must be continued in conjunction with normal operations. This effort should be properly staffed and funded to assure long term excellence. Appropriate *remedial actions* should also be taken in a systematic and timely fashion.

4. Criticality Aspects of SNM Waste and Residue in Containers

4.1 Introduction and Background

Tons of plutonium are stored at the Rocky Flats Plant as "residue." According to DOE, residue from the plant's plutonium processing operations has sufficient plutonium content and is in suitable form to make it worth recovering and recycling for continued use in nuclear weapons production. Thus, *residue* is distinguished from *waste* by its salvage potential: residue is above *economic discard limits* (EDL) set by DOE. There are two separate categories of residue:

Category-1 residues contain plutonium which is recoverable using *current* technology; and

Category-2 residues contain currently unrecoverable plutonium, but for which a potential exists for *future recovery* as more efficient recovery processes are developed.

It is not clear in which category any given drum of residue at Rocky Flats Plant falls, but the principal impact on safety considerations is that Category-1 residues *could* be processed in the immediate future and therefore eliminated from storage, whereas Category-2 residues apparently *will continue to be stored* at the Rocky Flats Plant for an indefinite period. The Category-2 residues probably constitute a greater criticality risk factor since there are apparently no definite plans in place for eliminating them through processing, and yet they are considered to be too valuable to dispose of as waste.

The residues are stored in 55-gallon drums, and each drum has a plutonium content limit that depends on the residue's form. The basic limits are:

- 1,000 grams for solid dry residue
- 500 grams for solid wet residue
- 200 grams for liquid residue

There are also a number of older drums, left over from years when the limits were significantly higher, that contain more than 1,000 grams of plutonium. There is a "temporary" limit of 3,000 grams plutonium for these older residue drums.

In addition to the residue class of plutonium storage, substantial quantities of plutonium are stored at Rocky Flats Plant as waste (see Appendix H for a list of the various types of waste) awaiting shipment to offsite *high-level waste* repositories. In order for transuranic (TRU) waste drums to meet transportation requirements for offsite shipment, they must each contain less than 200 grams of plutonium.

Transuranic waste is currently defined within the DOE defense community as "Wastes containing long-lived alpha-particle-emitting isotopes in amounts or chemical/physical forms that preclude economic recovery." By definition, these wastes are those containing more than 100 nCi of long-lived alpha emitters per gram of waste matrix. Concentrations less than 100 nCi per gram of these alpha

wastes are defined as low-level waste (LLW) for purposes of storage or disposal. The strict upper limit for criticality safety on the fissile content of any 208 liter (55-gallon) size TRU waste drum is 200 grams. The Rocky Flats Plant and other DOE sites adhere strictly to this limit. The plant has to certify the contents of each TRU waste drum when shipped off site. This process is subject to frequent outside auditing (at least once per year) by the Waste Acceptance Criteria Compliance Committee of the Waste Isolation Pilot Plant (WIPP).

Although criticality is theoretically possible with plutonium in 200 gram-limit drums, the conditions required for this to occur are so difficult to achieve that the probability of such an occurrence is extremely small. This, of course, is not necessarily true for *residue* storage where up to 15 times the TRU waste limit (3000 grams) can be stored in each drum.

Mixed in with the storage of TRU waste and plutonium residues is the storage of plutonium metal in 10-gallon drums. The material limit on each of these drums is 5,000 grams of plutonium. Each of these smaller drums typically contains one can of material with about 3,000 grams of plutonium.

In addition to rooms specifically designed for residue storage, there are a number of temporary storage areas made necessary due to the large inventory of residues and TRU waste. For example, residue drums are stored under old glovebox processing lines in Building 776 which are no longer in use. As far as the Team could tell, there are no drums stored outside of buildings.

Criticality accidents are a concern in the storing and moving of plutonium residue drums. To provide some perspective on what it would take to have a critical array of drums, Rocky Flats personnel have calculated that a 15-drum by 15-drum planar array stacked two high in which each drum contains about 500 grams of plutonium (mixed with polyethylene) has "unacceptable criticality potential." That is, such an arrangement could have a " k_{eff} " (see Appendix N) between 0.94 and 1.00. These values are for slightly less than critical and for criticality, respectively. For this particular analysis, several drums were conservatively assumed to be double batched, i.e. assumed to contain 1,000 grams of plutonium.

In order to make a determination of the potential at Rocky Flats Plant for a criticality accident involving residue drums, the Team toured the drum storage areas; interviewed plant staff members from Operations, Criticality Engineering, and Safety Analysis; reviewed safety and criticality evaluations; and supervised the assay of randomly selected residue drums. The procedures and results of these efforts are described below.

4.2 Safety Analysis of Residue Storage

The safety evaluation of residue storage can be divided into two parts: (1) the evaluation of configuration subcriticality, configuration criticality, and procedural criticality limits and (2) the analysis of the probability and consequences of criticality accidents. Not only is this a convenient division, this division of safety concerns has been adopted at Rocky Flats Plant by assigning criticality evaluations

to the Criticality Engineering group and accident safety analysis to the Safety Analysis group. This segregation of responsibilities has its own safety implications, as discussed later, in Subsection 4.4.

4.2.1 Evaluation of Criticality Limits

The determination of criticality limits for a drum storage area with a desired or pre-specified arrangement of drums requires: (1) calculations of k_{eff} of the given array of drums and variations on that array using the KENO computer code (Appendix K) and (2) a comparison of a conservative array with predetermined limits that allow for a safety margin. The margin limits are $k_{eff} = 0.90$ for normal operations and $k_{eff} = 0.94$ for some accident situations.

The team reviewed the documents supporting the criticality limits for drum storage in room 3606 of Building 371. The principal document reviewed was the criticality evaluation for storage of 10-gallon drums in room 3606. There was also a document evaluating criticality for storage of 55-gallon drums, however it was not reviewed. There was no document evaluating the *mixed storage* of 10-gallon and 55-gallon drums. Since room 3606 is used for mixed storage, this is an omission in the criticality documentation.

The room is 49'4" long, 40-foot wide and 20-foot high. Three sets of shelves (racks) run along the walls, allowing four levels of storage including the floor. In the middle of the room, two sets of shelves are positioned back-to-back, allowing for three levels of storage. For 10-gallon drum storage, this arrangement permits storage of 1,344 drums (7 x 3 array in each section; 64 sections).

KENO simulations were made by Criticality Engineering with all shelf sections back-to-back, four high, and with each shelf loaded with 21 units of fissile material equivalent to the spacing of the 10-gallon drums. The fissile units used in these calculations were assumed to range from five kilogram plutonium metal spheres (equivalent plutonium density = 19.4 grams per cubic centimeter) to five kilogram plutonium oxide spheres (plutonium density = 2.1 grams per cubic centimeter). For this range of fissile units, various arrays were run on the computer: bare and reflected, semi-infinite (length and width), and infinite. In addition, runs were made with varying amounts of water in spaces between the drums to simulate, for example, discharge of water from sprinkler systems. For all cases except the x,y,z infinite array, which was included for "academic interest," the k_{eff} was less than 0.90.

For the case of "all 10-gallon drums," the Team found the calculations to be appropriate and the documentation to be clear and concise. The only information that appeared to be missing was a description of how the 4-level z-axis was modeled in the KENO calculation.

Normal criticality evaluations at the Rocky Flats Plant do not take the drum array model up to critical (that is, up to $k_{eff} = 1.00$) by either adding more plutonium to the drums, increasing the array, or otherwise increasing the level of k_{eff} . Thus, while the safety margin measured in terms of k_{eff} may be sufficient, the criticality engineer

doing the analysis generally does not know how much more moderator, reflector, or fissile material it would take to go critical.

It is, of course, important to verify that the KENO code accurately calculates the k-effective for the drum array model. The matter of experimental verification of the KENO code is discussed in Appendix K. Rocky Flats Plant has its own criticality laboratory and has conducted many experiments both in the lab and "in situ" to verify its computer analysis capability. The Team notes that KENO is a difficult code to use properly, especially when calculating large, low density plutonium arrays.

There are supposed to be documented evaluations of criticality conditions to support the criticality limits posted for each residue drum storage area. These evaluations are kept in "data books" in Building 886 where Criticality Engineering has its offices. The Team found at least one instance (basement storage area in Building 776) where this data book system failed to produce the documentation of the associated criticality analysis.

It is not normal practice at Rocky Flats Plant to perform criticality evaluations for the full range of accident situations that might arise. Other than evaluating the criticality implications of "multiple batching," distance violations, and of adding water to simulate the room sprinkler system turning on, it is policy at Rocky Flats Plant not to consider accidents in compiling the criticality limits. The principal evaluations performed focus primarily on the effects of making procedural errors.

4.2.2 Analysis of the Risk of Accidents

The documentation containing the analysis of accidents involving criticality can be located in the SARs (Safety Analysis Reports) for the various buildings that have plutonium. An assessment of SARs at Rocky Flats Plant can be found in Appendix C of this report. The discussion here is limited to accident analysis as related to criticality safety of residue drum storage.

There are virtually no analyses of the potential for criticality accidents involving drum storage in the SARs, themselves. In fact, there is very little analysis of the potential for criticality accidents in general. This is because the probability of criticality events occurring is considered to be very small, as are their consequences when compared to the consequences resulting from accidents involving the actual release of plutonium into the environment (e.g., fires or aircraft crash). The criticality accidents that are addressed in the SARs are those resulting from collapsed gloveboxes caused by an earthquake (page 8-38 of the Building 776/777 SAR), from collapsed tanks or piping containing plutonium caused by an earthquake (page 8-44 of the Building 771 SAR), and from an unidentified criticality event caused by an earthquake (page 8-39 of the Building 707 SAR).

The Safety Analysis staff at the plant has performed several additional accident analyses considering residue and TRU waste drums (hydrogen generation in drums containing plutonium, drum movement in and out of the basement of Building 776, and effects of external events on drum storage), but no analyses, to

the Team's knowledge, have been done by this group on the subject of the potential for drum criticality.

The reasons given by the Safety Analysis staff for not doing specific analyses of drum criticality accidents were that the consequences to the public from a criticality event are small (especially when compared to other consequences that could accompany other accidents) and that the probability of criticality accident events involving drums was very small since the buildings, rooms, shelving, etc. were designed to accommodate seismic events. Building 371 has a seismic design basis of 0.14g horizontal ground acceleration at bedrock. This means that the building could resist an earthquake centered at Denver's airport of severity 6 on the Richter scale. The other buildings of interest to the Team (771, 776, 777, and 707) have seismic capabilities less than this since their original design did not include earthquakes. Even assuming all of these buildings would not have structural damage during an earthquake, however, it is still necessary to ensure additional resistance to movement of fissile materials in order to preclude a criticality accident.

4.2.3 Residue Storage Criticality Safety

In Section 5, the Team evaluates the overall criticality program, policies, and practices. Included here are several additional Team observations directly related to criticality safety practices involving drum storage.

Criticality safety is supposed to be assured by a combination of administrative and physical controls and by safety margins included in the criticality limits. The Team inspections of drum storage addressed procedures, actual practice, the physical arrangement of storage areas, and the posted limits. The Team was told by the Manager of Criticality Engineering that the controls to avoid inadvertent criticality are basically administrative. For example, one limit is *no stacking of drums*. This stacking prohibition is implemented by:

1. workers who are trained to know and follow the rules;
2. managers who supervise the workers (part of a manager's performance evaluation is a consideration of his concern for criticality safety matters);
3. random audits by criticality engineers of worker compliance with rules; and
4. monthly audits by the Nuclear Criticality Safety Committee.

The Manager of Criticality Engineering noted that he had rejected a request to stack 500-gram drums even two drums high in Building 371.

In addition to general tours of buildings that contained storage drums, the Team specifically inspected the drum storage areas in Buildings 371 and 776. Several problems were found in the basement of Building 776:

1. Being a basement area, the room is susceptible to flooding.
2. The room has a history of leaks with clear evidence of water stains and mineral deposits. The roof had been leaking but has been fixed.
3. The basement and the rooms above the basement have sprinkler-system fire protection.
4. The basement sump pump did not appear to be operating very well when checked by a Team member. Subsequent check by plant personnel showed that the sump pump was not operational.
5. The posted criticality limit for the basement was 3,000 grams per drum. The criticality limit filed in the Building 776 locked file cabinet for the basement (which is suppose to be identical to the posted limit) was only 1,000 grams per drum. The basement contains a number of drums with more than 1,000 grams of plutonium, but none was greater than 1,200 grams.
6. No criticality analysis was found for the potential flooding of the basement; however, there is a memo that mentions that a flooding analysis was performed in 1974.
7. There is no radiation monitor in the basement. The selective alpha air monitor (SAAM) had been disconnected because maintenance was difficult. White coveralls, full face masks, and lead aprons are required for people entering the basement.

These problems were taken into account in developing the issues raised in Section 4.4.

4.3 Measurement of Plutonium Content of Drums

Each drum is labelled with information about its contents, including the amount of plutonium. It is, of course, very important that information on the amounts of fissile material in each drum be accurate.

Rocky Flats Plant has a large number of NDA systems in routine operational service. The primary system used to quantify plutonium residues in drums is the segmented gamma scanner (SGS). Plutonium residues are actually placed in smaller cans of about one gallon or less and are then measured before going into the 55-gallon drums. The SGS utilizes a high resolution, high purity germanium (HPGe) detector with a well-collimated scanning geometry. It measures the plutonium-239 gamma lines at 375 and 414 kev. Matrix attenuation corrections are measured by placing a transmission source on the opposite side of the can. The entire technique is automated, well documented and well established through about 15 years of routine use at DOE facilities and elsewhere. The plant uses commercial versions of these instruments operated by trained staff. Operators are trained to adhere to ASTM calibration standards and procedures. Considering the

small package sizes and generally uniform matrix conditions in a particular small can, the accuracy of these measurements is estimated to be in the 3-5% range. The primary SNM inventory records at Rocky Flats Plant are recorded for each small can placed into a 208-liter drum storage vessel.

Rocky Flats Plant has also used calorimetric techniques to quantify residues. This NDA method is based on measuring the alpha particle heat generated from a package. This technique is used most frequently to quantify "product" materials. If the plutonium isotopes and alpha emitting impurities (primarily americium-241) are well known, this technique has an accuracy of a few tenths of a percent. It is difficult to use and is generally restricted to NDA intercomparison studies in which the accuracy of a more convenient NDA technique (such as a segmented gamma scanner) is being established.

The plant also utilizes low resolution passive gamma ray counters and passive and active neutron counters. These are, however, seldom if ever used for residue cans. Their function is primarily to quantify the plutonium content of TRU wastes.

The official SNM inventory records for the stored residues at Rocky Flats Plant are predominantly based on small package assay values measured by a segmented gamma scanner. The Team studied these records and observed that, although the external storage container for these residues is a 208-liter drum, the inventory records subdivide each drum into the small inner cans. The actual inventory items are the small can assays, with each can being recorded by its own identification number and assay value. The only exceptions to this practice are a few older records which are in the process of being added to the archive record. That is, the individual small can records exist for these older drums but have not as yet been completely computerized. For those drums, the sum of the small can assays is in the computerized records at present but will apparently be updated to small can records eventually.

Since some of the older residues date back at least 10 years, the accuracy of the corresponding SNM inventory values is a potential concern. The Team learned that plant managers share this concern, and they plan to institute a reassay program for these older residues. This reassay program will include a systematic intercomparison of current waste and residue package assays performed with three of the plant's NDA measurement systems: (a) low resolution passive gamma ray counter (non-transmission corrected unit); (b) the segmented gamma scanner; and (c) the passive-active neutron system.

The Team discussed the merit of having direct "reassay" records available during its onsite visit and determined this was highly desirable. The Team was able, with the cooperation of the plant's Safeguards Measurements group, to obtain a reassay of a randomly selected sample of residue drums. Since it was not feasible (considering the scope of the Team's study and the time available) to open these drums and extract the individual small cans for reassay, the Team decided to use neutron measurements. This was done with an available passive-active neutron drum counter, which could be used to obtain totally independent total assay values

for a drum without breaking its security seal. Details of these measurements are presented in Appendix D.

Thirteen residue drums were selected from the official SNM inventory records. Since no generation dates are carried directly on the computerized records, the specific generation dates for these residues were not available to the Team. Presumably, the random selection process used by the Team resulted in a selection from some extended time period. In any case, drums were selected that covered a large fissile inventory range -- six grams to 1211 grams -- so as to test the accuracy over as wide a range as possible. These drums also contained residues of six separate matrix types. Only residues of one matrix type are placed in a given drum. The passive neutron measurements for a drum, done under the conditions the Team specified, are not as accurate as the sum of the individual small can measurements done originally by segmented gamma scan. Also, the Team did not attempt to apply corrections to the neutron measurements other than standard background and calibration factors, since the calculational effort required was judged to be beyond the scope of the study. The net effect of these corrections, had they been made, would most likely be to lower the average neutron assay values, with sizeable corrections anticipated for the drums having high neutron sources.

For the 13 measurements, the average ratio of "raw" neutron assay-to-inventory-value is 1.19 ± 0.27 . Thus, within the measurement errors, the Team confirmed the inventory values. This conclusion, within the stated error bounds, is also independent of fissile mass loading and matrix type.

The team reviewed measurements made in Idaho of TRU waste drums shipped from Rocky Flats Plant over many years. Over 250,000 drums have been handled at Idaho that have been shipped from Rocky Flats Plant since 1953. At least 15,000 intercomparison measurements have been made to date. These measurements, within error limits, consistently verified the amounts recorded at Rocky Flats Plant on the drum labels.^{1,2,3}

4.4 Issues Regarding Residue Drum Storage

Many of the Team's criticality safety concerns related to residue drum storage at the Rocky Flats Plant are primarily concerned with the *assurance* of safety through proper analysis, assessment, and documentation. The plant staff should better *demonstrate* assurances of criticality safety in a manner more consistent, for example, with the objectives of the "double contingency" principle (see Section 5.4). **The Team recommends that Rocky Flats Plant, through its**

¹ "Doe Assay Methods Used for Certification of Contact-Handled Transuranic (CH-TRU) Waste," Oak Ridge National Laboratory, ORNL-6485, 1989.

² "The Los Alamos Second-Generation System for Passive and Active Neutron Assays of Drum-Size Containers," Los Alamos National Laboratory, LA-10774-MS, 1986.

³ Private communication, "Results of INEL/SWEPP and RFP Drum Assay Intercomparisons Using a 10,000-Drum Data Base," Dr. J. R. Smith, EG&G Idaho, 1988.

Criticality Engineering group, implement a program to verify the validity of all posted criticality limits for drums. This should include, as a minimum, conservative and well-documented k_{eff} calculations that consider the presence of water, plastics, and other possible reactivity contributors, as appropriate. The posted limits should be checked against limits recorded in the controlled documents. This will considerably improve the assurance of drum criticality safety.

The situation in the basement of Building 776 described above is a case in point. Many residue drums containing plutonium in excess of 1,000 grams are stored there, yet the criticality-limit record book for Building 776 shows that a limit of 1,000 grams applies. This is in contrast to the limit posted at the door to the basement which indicates that 3,000 grams per drum are allowed. The basement is susceptible to flooding, has a sprinkler fire suppression system, and has a record of water leaks, yet the sump pump is not operational, there is no indicator outside the room of water in the sump, and there is no documentation of analysis of the criticality implications of flooding the basement. If some of the older drums were to leak (and there are many older drums), there is no early warning system since the SAAM (selective alpha alarm monitor) has been disconnected. **The Team recommends that a criticality safety review of the basement of Building 776 be conducted. As a minimum, the reactivity effects of flooding should be verified, the sump pump should be repaired, a sump level alarm should be installed, an alpha radiation monitor should be installed, and older drums that have more than 1,000 grams of plutonium should be repackaged; or such drums should be removed from this location.**

While this example points out both safety and safety assurance issues, many of the issues could be resolved if what is claimed about safety can be demonstrated. An additional example is the absence of a criticality analysis to support the mixed use of both 55-gallon drum and 10-gallon drum storage in room 3606 in Building 371. Fortunately, the analysis supporting storage of 10-gallon drums only indicates that criticality is not a problem for mixed use. Thus, there is *probably* no safety problem, but the level of safety assurance and documentation is inadequate.

One area that the Team first thought might be an issue -- assuring the accuracy of the individual residue drum plutonium inventory -- turned out not to be a problem. Independent measurements, monitored by the Team, verified the plutonium content posted on the labels of a sample of residue drums selected by the Team. The Team concludes that for plutonium storage in residue drums, the plant can demonstrate that the inventory records for special nuclear materials in drums are accurate. That is, one may with confidence use inventory values to analyze the level of criticality safety. Additionally, the plant is in the process of improving access to these records by computerizing all small can assay values. The residue reassay program that is planned will also provide additional information on inventory reliability.

At Rocky Flats Plant, however, there is virtually no systematic, mechanistic examination of residue drum criticality accident possibilities for initiators that have a

low probability of occurrence. The Criticality Engineering staff does not perform these types of analyses and, while the Safety Analysis staff accounts for criticality accidents in a very broad sense, there is no detailed assessment of specific accident sequences for credible situations in the plant. For example, would the drums in room 3606 go critical if a seismic event caused them to tumble off the four-level high racks? Would there be a subsequent possibility of recriticality or autocatalytic effects? Would the criticality event act as an energy source for releasing significantly more plutonium to the environment than would have otherwise been released? What protective features are in place to minimize consequences if an unanalyzed sequence develops? **The Team recommends that drum criticality events be more fully incorporated into safety analyses. These analyses can be put into a systematic risk analysis context through the probabilistic risk assessments (PRAs) and hazards assessments that are being performed at many DOE facilities. Included in these assessments should be a consideration of risk to plant workers and consideration of whether a criticality event can act as an initiator for increased release of plutonium. External initiating events should be evaluated in a comprehensive manner.**

The dependency on administrative controls is another issue. While the Team witnessed a high respect for the posted criticality limits by workers, and the discipline and professionalism appeared high, the nearly complete reliance on administrative controls is troublesome. For example, a 10-gallon drum is easy to lift and carry over other drums, thereby violating the criticality limit.

Since most (if not all) the residue drums will apparently continue to be stored at Rocky Flats Plant, it would appear that maintenance of drum integrity is a major criticality safety concern. The criticality safety calculations presented to the Team assume intact drums, and potential flooding is treated only as an external reflective effect. If the drums are breached by corrosion (which can also occur from the inside out), the safety concerns are magnified. A positive factor for safety is the fact that all residues within the drums are contained within one or more smaller sealed cans. That is, if the drum rusts through, the residues may still be contained within the smaller cans. Still, basement storage at the plant -- with the demonstrated chronic water leakage problem -- appears to be a poor practice for the long term.

Many residue drums contain quantities of plutonium in the 900 to 1,000-gram range. The SGS can counter has an individual assay accuracy of about 5%. If the practice required by the NRC for commercial TRU wastes (actual content 2 sigma below the limit value) were applied to the residue drums at Rocky Flats Plant, many residue drums would not qualify. **Rocky Flats Plant should review the policy of filling drums with amounts of plutonium measured to be more than 900 grams. With a limit of 1,000 grams, the possible 10% (2x5%) uncertainty in the measurements makes this policy inconsistent with NRC waste shipment policies and generally accepted practices in the industry. The actual uncertainty should be determined and applied to the approved loading limits for the drums.**

5. Assessment of Criticality Program

A major objective in the operation of a nuclear fuel cycle facility, such as the Rocky Flats Plant, is the avoidance of a criticality accident. This accident, if it occurred, could be in storage facilities or process systems that were probably designed without adequate means for gaining control or removing heat and would have insufficient shielding to protect workers from exposure to the resulting direct, lethal radiation. The Rocky Flats Plant management system that addresses this risk is the Criticality Safety Program. This program involves the prevention or termination of criticality accidents, mitigation of consequences, and protection against injury.

5.1 Criticality Safety Organization

The Team reviewed the Rocky Flats Plant criticality safety organization to identify areas where general improvements are needed. The organization and assignment of responsibilities should meet the minimum requirements of the compliance standard ANSI-ANS 8.1-Reaffirmed 1988, "American National Standard for Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors." These requirements can be summarized as:

1. safety responsibility and priorities established by management;
2. process analysis that includes the effects of credible abnormal conditions;
3. written procedures for pertinent operations;
4. controlled movement of fissionable materials, including labeling and posting of limits;
5. prompt reporting, investigation, and correction of process deviations that affect safety;
6. frequent independent operational reviews;
7. emergency procedures in place to mitigate the consequences if a criticality accident should occur; and
8. plant-wide training and circumspect follow-up on that training.

The criticality safety management system at Rocky Flats Plant appears to meet most of the minimum requirements of ANSI-ANS 8.1, but the Team suggests that areas 1, 2, 4, and 6 be strengthened. Also, certain aspects of area 8 on training (see Section 5.3, below) should be reviewed to ensure an understanding of criticality safety by all plant workers.

The Team has concerns about requirement 1 in the ANSI standard in terms of follow-up and credibility. A good management system should have a clear policy

that safety has a priority comparable to that of production goals of the facility. The policy should result in rewarding managers who have good safety performance and penalizing those who sacrifice safety to other goals. A good nuclear safety management system should measure implementation of the safety policy and assess performance against a high standard. This self assessment should necessarily result in corrective actions that are appropriate and prompt.

Such a program of critical self-assessment and appropriate response should be significantly more effective in developing a good safety program than responding reactively to outside reviewers. It should be a plant objective to achieve this mode of operation. Rocky Flats Plant management assured the Team this is its intent. However, the Team found indications that not all middle managers had achieved safety awareness, especially in the maintenance area. The Team's perception is that the new safety policy is in place, but some remnants of previous attitudes and procedures remain. For example, the Team found one high level maintenance procedure that unduly emphasized production over safety. When this was pointed out, the procedure was immediately changed. Maintenance managers also pointed out that seldom do building managers request priority efforts on safety related repairs, but that they often seek high priorities for their production line repairs, even at the expense of overall plant maintenance planning efficiency. Thus, the Team concludes that what has been written in policy has not necessarily been achieved in practice. **The Team recommends that Rocky Flats Plant and DOE management continue to support and emphasize the highest priority for safety and also reduce the emphasis on production goals and schedules relative to safety goals.**

The organization and responsibilities of the Criticality Safety Program are well defined and documented in the Health, Safety and Environment Manual, HSE 17.01 through 17.04. The role of the criticality engineers is documented in "Procedures for Criticality Engineers" (March 1989) and in the Health, Safety and Environment Quality Program Plan, Section 3 (November 1988).

5.2 Staffing of Criticality Engineering

The Criticality Engineering group at Rocky Flats Plant is the key professional organization in developing Nuclear Materials Safety Limits, training personnel in criticality safety, auditing criticality safety and investigating procedural infractions. Problems at Rocky Flats Plant in staffing Criticality Engineering have been of concern since 1987, according to records of Technical Safety Appraisals performed by DOE. The Team reviewed these problems independently and determined that little progress has been made. The Team's assessment of these ongoing staffing problems and recommendations for correction are provided below.

Plant workers are required to have a security clearance, which often takes many months to obtain unless a very high priority requirement is identified. The Criticality Engineering group currently consists of five cleared and four uncleared criticality engineers reporting to the Manager of Criticality Engineering who in turn reports to the Manager of the Nuclear and Industrial Safety Department. Including the

Manager of Criticality Engineering, only two people are currently *certified* in the Rocky Flats Plant program as Criticality Engineers.

The cleared staff includes professional backgrounds in radiochemistry, chemical engineering, facilities engineering, nuclear engineering, and health physics. Table 5-1 shows the staff profile.

The three most recent of the cleared engineers average less than one year experience. The other two have five and six years experience, and the major work load appears to be on these two most experienced engineers.

The experienced engineers tend to work long hours with high stress and no overtime pay. The cleared staff were asked by the Team about special concerns in criticality safety. A consistent concern of most was *staffing* in Criticality Engineering. There has been a high turnover rate in the group, and by the time individuals become familiar with the production processes in their assigned areas, they tend to leave and accept better jobs elsewhere in the plant.

The four uncleared engineers have less than a year in the job and no experience in the plant. The uncleared staff members all have an educational background in nuclear engineering, and two have core physics experience.

For all of the new criticality engineers, the effort to learn about the intended or design operations of the various processes necessarily takes precedence over inquiring about potential abnormal operations or unexpected locations for accumulations of fissile material.

Those engineers with the most experience and qualifications are under considerable additional pressure because they bear more of the workload; therefore, upset (abnormal) condition analysis is easily lost in the press of simply supporting normal operations. Several engineers believe, however, that some process upsets of concern to criticality engineers would be discovered by the Tank Surveillance Group. This latter group periodically surveys all Rocky Flats Plant tanks for possible plutonium accumulations using sampling and nondestructive analysis techniques. The prevailing optimism about abnormal conditions being discovered even in tanks, without rigorous and comprehensive analysis, seems unwarranted. In view of the Team's discovery of kilogram quantities of plutonium in ventilation ducting outside of the material control system and unsuspected by the plant management, many more types of equipment should be surveyed routinely.

The Team recommends that the problems of security clearances and high turnover in the Criticality Engineering and Critical Mass Laboratory groups (see Section 5.8 of this report) be solved, in part, with increased priorities in these areas. While new people are being recruited and trained, some experienced criticality safety people in other Rocky Flats Plant divisions should be transferred back to Criticality Engineering temporarily to help, or assistance should be sought from other laboratories or contractors. The current staffing

TABLE 5-1 - Criticality Engineering Department Personnel

NAME	JOB TITLE	EDUCATION	CRITICALITY ENGINEERING	EXPERIENCE ROCKY FLATS	OTHER EXPERIENCE
J L Byrd	Criticality Safety Engineer	B S Nuclear Engineering	11 months	11 months	None
D P Heinrichs	Senior Principal Criticality Safety Engineer	B S Nuclear Engineering M S Nuclear Engineering	9 months	9 months	MSU Systems Inc Yankee Atomic Electric Co CEA/CEN de Cadarache KMS-Fusion Inc 6 75 years
B I Krogtuss	Advanced Criticality Safety Engineer	B S Chemistry	6 months	9 months	USGS Isotope Lab Accu-Lab Research Co 3 years
D L Mayfield	Senior Principal Criticality Safety Engineer	B S Radiological Protection Engineering M S Nuclear Engineering	6 years/5 months	6 years/5 months	Texas A&M University Staff Health Physics 2 years Camp Dresser & McKee Radiological Engineer 1 5 years
D N Poland	Advanced Criticality Safety Engineer	B S Nuclear Engineering M S Nuclear Engineering	10 months	10 months	General Electric Corp Nuclear Engineer 1 75 years
J M Radigan	Principal Criticality Safety Engineer	B S Mechanical Engineering	1 year/1 month	4 5 years	Royal Insurance Engineering Representative 5 years/5 months
V L Risner	Criticality Engineering Manager	B S Nuclear Engineering	7 years/1 month	7 years, 1 month	United Nuclear Corp Fuel Element Engineer 3 years
P J Sentieri	Advanced Criticality Safety Engineer	B S Nuclear Engineering M S Nuclear Engineering	3 months	3 months	None
C E Stuart	Criticality Safety Engineer	B S Nuclear Engineering	10 months	10 months	None
J M Walton	Senior Criticality Safety Engineer	B S Chemical Engineering	4 years/11 months	4 years/11 months	None

level is not sufficient to accomplish its normal work and also respond to the recommendations of this assessment.

5.3 Assessment of Criticality Safety Training

Training is rightfully the backbone of the criticality safety program. The detailed certification process for criticality engineers is comprehensive and well conceived. **The Team recommends that Rocky Flats Plant strive to assure that at least 75% of the criticality staff is certified.** The current 11% is too low. Solving the turnover problem should address this issue.

Training is also provided to all the plant employees with unescorted access to fissile material areas. A three to four-hour course is given with the aid of a "criticality simulator." This training was audited by a Team member and is described in detail below.

Material is presented first by slides, which are accompanied by a synchronized, recorded audio commentary. This presentation is followed by a second set of slides covering much the same material which was presented in the first set, but this time a live commentary is provided by the administrator. At intervals, there is a break during which the course administrator asks for and responds to questions. After these two segments, the simulator is used to illustrate how criticality accidents may occur and to indicate how very small physical changes (in a system near criticality conditions) can produce a transition from an innocuous system to a criticality accident. The development and innovative use of the simulator is an excellent effort and the Team commends it.

The material covered includes a brief introduction to neutron interactions with nuclei, a description and illustration of a chain reaction, and an illustration of how one may introduce physical changes in a system which take it to critical or to supercritical conditions. Considerable emphasis is given to this latter topic with illustrations related to situations encountered in the plant environment. Relationships between the criticality limits set by Criticality Engineering and avoidance of criticality are discussed.

Throughout the presentation, it is emphasized that if an operation is proposed or undertaken which does not appear to be covered by a Criticality Engineering Review, this should be reported immediately to a supervisor or to a Criticality Engineer. If a criticality limit is inadvertently exceeded during the course of an operation, it should stop immediately, a report should be made to a Criticality Engineer, and nothing further should be done until written instructions are provided by a Criticality Engineer.

Criticality alarms are discussed as part of this training. Emphasis is placed on immediate evacuation using the shortest route to a designated assembly area. Illustrations are given of proper and improper routes and of differences in radiation dose to the worker than can result. It is made clear that re-entry into an evacuated building is not to occur until it is authorized by one's supervisor.

The simulator is operated by the instructor to produce a striking demonstration of some of the principles covered. This is followed by another opportunity for questions. At the end, an examination is given. Answers require multiple choice or true false decisions. Exams are graded immediately, and any incorrect answers are discussed with the trainee. Passing grade is 80%.

This formal course is complemented by on-the-job training, a one-on-one exercise involving a supervisor and a trainee. A checklist of activities, required to be submitted to Criticality Engineering at the time of the class, contains an extensive list of equipment and activities with which the trainee must become familiar. The on-the-job training is clearly an important part of the training process.

The course material and the level of coverage are considered by the Team to be appropriate. Observation of trainees in the class indicated attentiveness. Questions were asked and there was some discussion. Informal conversation, however, indicated that some supervisors take the on-the-job training less seriously than one might wish. **The Team suggests that more attention to the on-the-job training phase of the operator training program be considered.**

In summary, the training program for employees with access to fissile materials seems appropriate, and the method of presentation appears to be adequate. The examination covered important concepts, and the immediate feedback is effective. Because of the importance of training in making human error less likely in the various processes, this program is of paramount importance and should have continuing attention. **Efforts should be made to ensure that supervisors are aware of the importance of the on-the-job training and the need for their contributions to this training. There does not, at present, appear to be any formal evaluation of the course by trainees. It is important to those responsible for the course to have trainee feedback on the quality of course content after they have been on the job for a few months.** This would also allow the plant an opportunity to identify and retrain workers who may have been confused by specific occurrences in the plant.

In terms of some of the more subtle aspects of nuclear facility training, however, the Team notes some lack of appreciation by plant managers for the need to emphasize to all of the workers at the plant that nuclear safety requirements are part of the job and not merely unnecessary regulatory interference that slows things down. Also, the Team detected indications that "formality training" is not adequate since slang terminology is reportedly used by some operators in referring to criticality safety procedural infractions as "criticalities." **Thus, the Training Department should supplement the technical training with more emphasis on discipline of operations and communications and provide better perspective in some areas related to nuclear safety requirements and procedures.**

5.4 Risk Analysis and Risk Management Philosophy

The Manager of Safety Analysis and a member of his staff described the risk analysis program at Rocky Flats Plant with emphasis on that part of the analysis used to estimate the risk and the consequence of a criticality accident. The Department of Energy made a commitment to the Governor of Colorado in 1979 to perform a long-range study of the risks of operation at the Rocky Flats Plant and of the costs and risks of operation at an *alternate* site. Most of the formal safety analysis that forms the basis for building Safety Analysis Reports (SARs) and the formal risk analyses of the plant began as a result of that commitment.

As part of these studies, various *design basis events* have been defined for the plant, including the occurrence of seismic events and high winds. A *maximum credible accident* has also been defined for purposes of emergency planning, and for use in an environmental impact statement. The event chosen was the crash of a 747 aircraft into any one of the buildings at the Rocky Flats Plant. It is assumed that a maximum release of 100 grams of plutonium results.

A Safety Analysis Report has been written for each building which has been identified by a screening analysis formulated by the Safety Analysis staff. The safety analyses use a combination of mechanistic and probabilistic approaches to provide both qualitative and quantitative estimates of risk to the public and to workers in the plant. The methods used are similar to those developed by the U.S. nuclear industry in conjunction with the U.S. Nuclear Regulatory Commission and others for safety analyses of nuclear power plants.

In the risk analyses, consideration is given to the calculation of risks attributable to criticality accidents. If one compares the predictions of the analyses with the behavior observed during previous criticality accidents at other facilities, the results appear plausible. The risks calculated by Rocky Flats Plant for members of the public and for workers are so low as to be negligible in comparison to other risks to which members of the public are normally exposed.

It is impossible to confirm the validity of all of the various risk calculations without a more detailed review than was feasible for this study. However, there are features of the analyses performed to date that appear anomalous to the Team. For example, following what was described as DOE guidance, risk contributing sequences with probabilities greater than 1×10^{-6} per year were normally analyzed in detail. However, for sequences initiated by natural phenomena, the treatment did not consider an initiating event with a probability less than that of the event identified as a design basis event. For the seismic design basis event identified, a contractor estimated a probability of about 1×10^{-3} per year, and Lawrence Livermore National Laboratory estimated a probability of about 2×10^{-4} per year. It would appear that an approach consistent with the 1×10^{-6} guidelines would have considered seismic events of lower probability, and thus of larger magnitude, than the design basis event.

In the calculation of the risk of a criticality accident, plant engineers estimated the probability of such an accident to be about 3×10^{-4} per year. This included both

solution and metal criticality events. However, information available from the Department of Energy indicates that in processing plants operated by the DOE and its predecessors, there had been, as of 1980, about one criticality accident every 80 plant-years in chemical processing alone. It also appears to be unjustified that, with data on the size of criticality accidents available, a log normal distribution of sizes was assumed by plant engineers to calculate a standard deviation.

Further, in the course of calculating the risk of criticality accidents, there has not been a systematic, detailed study of the specific operations performed at the Rocky Flats Plant, nor an estimate of the associated probability of human error. Such a study might well produce results different from those resulting from generic data for human error that were used. The data presented in Section 5.5, below, should aid in such analyses. Of even more importance to safe operation at the plant is the fact that a detailed study of the plant-specific operations might identify possibilities for human error that have not yet been observed. This could be a rich source of new safety information. **In light of the amount of manual manipulation that characterizes many of the Rocky Flats Plant operations, and the reliance on human performance as an accident preventive, the Team suggests that a more systematic investigation of the likelihood of human error be undertaken. The framework for the investigation already exists. What is needed is a more detailed study of those processes in which the possibility of a criticality accident exists.**

Since a considerable investment of resources is represented by the Safety Analysis Reports and the risk analyses that have been performed, the Team tried to determine whether these had had any influence on Criticality Safety analyses and practices at Rocky Flats Plant. Other organizations have found cooperative effort, involving both operational staff and analysts, an effective way of discovering and correcting previously unidentified vulnerabilities. The Team found no evidence of such cooperation at the plant. Responsible managers appear to be skeptical of probabilistic analysis and its predictions. There does not appear to be a recognition of the fact that the detailed systematic analysis of systems and operations can provide quantitative estimates of risk and, of equal importance, can frequently identify steps in the processes which can be modified to decrease risk. **The Team suggests that additional interaction between those groups responsible for day-to-day operations and the Safety Analysis group is necessary in order to obtain maximum benefits from these analyses.**

One example where such an interaction might be useful is in an evaluation of the reliability of the criticality alarm system. Although this is an important mitigative system in case of a criticality accident, there are no quantitative reliability goals for the system. This may be due to the fact that the group responsible for its operation considers its reliability to be 100%. This conclusion was reportedly reached as a result of the observation that at least two detectors would have to fail simultaneously to disable the system, and that two simultaneous failures have never been observed. However, data from tests of individual detector performance indicate that over the first six months of 1989, 15 failed detectors were identified in a population of 903.

Assuming that these were random failures, and that testing is performed monthly, the expected unavailability of an individual detector is 1.38×10^{-3} per demand. If it is assumed that detector failures are independent, one calculates for simultaneous unavailability of two detectors (which can produce unavailability of the system) 1.9×10^{-6} per demand. However, current probabilistic risk assessment practice would give considerable weight to common mode failure (since the detectors are identical in design), and would predict an unavailability significantly larger than this. It should be noted that this calculation also does not take into account the unavailability of the public address system.

5.5 Infraction Reporting and Followup

The core of the Rocky Flats Plant self-assessment and off-normal analysis programs is the criticality safety procedural infraction reporting system. The Criticality Safety Assessment Team reviewed descriptions of the circumstances surrounding each criticality safety procedural infraction that has occurred at the plant since 1962. The Team was told that no records were kept of any such infractions that occurred prior to 1962.

Over 600 instances of criticality safety procedural infractions have been recorded since 1962. Prior to 1983, these infractions were only described in minutes of meetings held by the Nuclear Safety Committee. Starting in 1983, a formal system of addressing criticality safety procedural infractions was also established. Under this new system, the circumstances surrounding each infraction are described in detail, including such topics as operating conditions at the time of the infraction, immediate action taken, final evaluation, lessons learned, and corrective actions.

The original objective of the Team's review of criticality safety procedural infractions was to determine whether there was evidence of past criticality accidents at the Rocky Flats Plant. In its review of these records, the Team found no evidence of the occurrence of a criticality accident. However, the Team observed many infractions of a recurring nature. Thus, a second objective of the review was initiated to gain an understanding of the underlying reasons for these recurring infractions.

5.5.1 Nature of the Infractions

In its review, the Team found several instances of serious criticality safety procedural infractions. Eight of these instances are listed in Table 5-2. Generally, these serious infractions involved loss of control of a significant amount of fissile material.

In the first infraction listed in Table 5-2, 14 kilograms of sludge consisting of about 80 percent uranium-235 were found when a press which had a cracked plate was being decontaminated.

In the second incident, fluorides containing about 32 kilograms of plutonium were allowed to accumulate because of poor visibility through a viewing window in a glovebox.

The third and fourth instances in Table 5-2 both involve a large amount of sludge that was allowed to accumulate in tanks. In one case the primary cause of the buildup was a failure to filter the solution transferred to the tank. A contributing cause was that the tank calibration reports were not fully understood by the operators.

TABLE 5-2
Instances of Serious Criticality Safety Procedural Infractions

1. Hydraulic press accumulation of 14 kg sludge, ~ 80% uranium-235 (1968)
2. Hydrofluorinator box accumulation, ~ 32 kg plutonium (1971)
3. Sludge accumulation in tank, 5 kg plutonium (1972)
4. Sludge accumulation in tank, more than 15 kg plutonium (1974)
5. Freeze-up of plutonium casting metal during loss of electric power event, 9 kg plutonium (1968)
6. Improper loading of can bird cage, ~ 10 kg plutonium (1981)
7. Overload of dissolver pot, almost twice gram limit of plutonium (1968)
8. No material balance maintained on glovebox, ~ 12 kg plutonium loading (8 kg limit) and failure to distribute in batches. (1985)

Item five of Table 5-2 involved the freeze-up (solidification from the molten state) of plutonium metal in a trough following a loss of power. Because of fear that a crucible would be damaged if the metal were allowed to solidify in the crucible, action was initiated to pour the metal from the crucible, through the trough to a safe container. However, nine kilograms of plutonium metal froze in the trough because of solidification in the drain lines leading from the trough.

The sixth item in Table 5-2 concerned an intentional loading of five cans containing a total of 10 kilograms of plutonium into a "bird cage," a transportation cart limited to only two cans. In this instance, the worker was rushing to complete his work so he could go to the credit union.

The seventh item in Table 5-2 deals with an instance in which almost twice the weight of plutonium as permitted by the Nuclear Material Safety Limit was loaded into a dissolver pot.

In the eighth significant incident, about 12 kilograms of plutonium were allowed to accumulate in a box with an 8-kilogram limit. In addition, the batch requirement was also violated. No material balance sheet was in use at the time of this infraction.

The list of serious infractions cited above is not meant to be all inclusive. These examples were selected through the combined judgment of the Team members most knowledgeable of criticality safety procedural infractions. Almost as significant as these serious infractions is the recurring nature and quantity of the less serious infractions. On the average, about 25 infractions have occurred *each* year since 1962. The majority of these infractions may be grouped in one of six categories listed in Table 5-3. The initial review conducted at the plant revealed the recurring nature of these infractions. Consequently, the Team undertook the task of analyzing the root causes of these recurring infractions as part of its criticality safety assessment.

TABLE 5-3
Types of Less Serious Criticality
Safety Procedural Infractions

- Nuclear material mass limits exceeded
- Spacing requirements violated
- Drums improperly stacked
- Material transferred improperly
- Material storage requirements violated
- Incorrect containers used

5.5.2 Root Cause Analysis

Although the entire history of criticality safety infractions at the plant was reviewed, a root cause analysis was done only for those infractions that occurred during the period beginning at the start of calendar year 1983 to present. This shorter period was chosen because the description of the earlier infractions (1962 through 1982) generally did not contain sufficient information upon which to base such an analysis. The methodology used for this root cause analysis was developed from techniques being used for licensed nuclear power plants and previously applied by SCIENTECH to the DOE Savannah River Plant production reactors.

Root cause is defined as "the *most basic* reason(s) for an effect which, if corrected, will prevent recurrence." The following three criteria were considered by the Team in determining root causes:

1. A solution to the root cause that *prevents recurrence* must be identified.
2. The solution to the root cause must be within management's control.
3. The solution must allow management to meet its other objectives.

The infractions were classified into four categories based on their root causes. The four categories are management, equipment, procedures, and personnel. More specific subcategories are also assigned to each. Table 5-4 provides details of the subcategories. Appendix G lists all the infractions individually with their root causes.

The term "management" refers to those individuals responsible and accountable to *direct* an organization's operations and functions. "Personnel" are those individuals, *other than managers*, responsible to *execute* assigned operational duties and functions. The list of subcategories is generic and can be used in root cause investigations for most facilities.

The criticality safety procedural infractions at Rocky Flats Plant were evaluated by the Team as written; no attempt was made to verify the information presented in the reports. Further, the findings were evaluated as of the date the reports were published and did not take into consideration any subsequent corrective action by DOE or the contractor.

Experience suggests that problems are often not attributable to a single root cause; rather, problems result from a combination of several causes, some more important than others. Rather than attempting to ascribe a finding to a single cause, where multiple categories and subcategories are identifiable, a primary root cause is identified, followed by any secondary root causes. See Table 5-5 and Appendix G.

Table 5-5 summarizes the root causes of criticality safety procedural infractions. It should be noted that not all the general subcategories listed in Table 5-4 are applicable to a specific criticality safety procedural infraction. The principal root cause category at Rocky Flats Plant is *personnel*. Personnel were the primary root cause for 141 of the infractions, with 106 of these due to personnel complacency and 25 due to procedural complacency.

The management category was responsible in 57 of the root cause cases. Of these, 27 were *management not perceptive* and 21 were *management complacency*. When combined with the Personnel category, it is clear that the human element is the primary day-to-day element of criticality risk at the Rocky Flats Plant.

In contrast, there were only 10 cases where procedures were responsible for criticality infractions. Inadequate procedures were the primary root cause in 9 cases and were the secondary root cause in 14 more. This category also involves a human element.

TABLE 5-4
Risk Analysis: Root Cause Categories

MANAGEMENT

M1 Not Perceptive	Failure to think-out, plan, or implement a course of action to avoid potential problems or findings.
M2 Noncompliance	Not operating within codes, standards, regulations, policy, Orders, procedures, etc.
M3 Complacency	Inappropriate attitude, inadequate capabilities, inadequate qualifications, inapplicable organizational structure, etc.
M4 Risk Analysis LTA*	No threat or risk identification, risk analysis incomplete or incorrect, etc.
M5 Resource Provision LTA	Inadequate dollars, personnel, training, tools, etc.
M6 Communications LTA	Inability to listen, written and/or oral ambiguities or breakdowns, or complete failure to communicate.
M7 Lack of Understanding	Failure to appreciate the complexities and nuances for effective management and oversight necessary to achieve nuclear safety requirements.

EQUIPMENT

E1 Design LTA	Inappropriate design of equipment or material to accomplish intended task.
E2 Application LTA	Equipment applied to inappropriate task or improperly used.
E3 Maintenance LTA	Improper maintenance, or none at all.
E4 Manufacture LTA	Manufacturer's or Constructor's error.
E5 Identification	Improper or no identification or labelling of pipes, cables, and equipment.

PROCEDURES

Pr1 Not Implemented	Procedures are written, but not being used.
Pr2 Nonexistent	DOE Orders exist, but implementing procedures do not.
Pr3 Inadequate	Procedures are outdated, incomplete, unavailable, etc.
Pr4 Incorrect	Procedures are misinterpretation of DOE Orders, Codes, Standards, or regulations; provide erroneous information; etc.

PERSONNEL

P1 Complacency	Lack of attention to task, etc.
P2 Procedural Complacency	Not following approved procedures.
P3 Training LTA	Training given but not retained by individual.
P4 Capabilities	Qualifications and/or capabilities not adequate.
P5 Communications LTA	Inability to listen, written and/or oral ambiguities or breakdowns, or complete failure to communicate.

*LTA = Less Than Acceptable

TABLE 5-5
Root Causes of Criticality Safety Procedural Infractions

<u>Root Cause Category</u>	<u>Primary</u>	<u>Secondary</u>
<u>PERSONNEL</u>		
P1 Complacency	106	9
P2 Procedural Complacency	25	8
P3 Training LTA	6	7
P4 Capabilities	0	2
P5 Communications LTA	4	6
<u>MANAGEMENT</u>		
M1 Not Perceptive	27	10
M2 Noncompliance	3	1
M3 Complacency	21	12
M5 Resource Provision LTA	1	2
M6 Communications LTA	0	1
M7 Lack of Understanding	5	1
<u>PROCEDURES</u>		
Pr1 Not Implemented	0	1
Pr2 Nonexistent	1	0
Pr3 Inadequate	9	14
Pr4 Incorrect	0	0
<u>EQUIPMENT</u>		
E1 Design LTA	0	4
E2 Application LTA	0	1
E3 Maintenance LTA	0	5
E5 Identification	1	0
No Root Cause Assigned	5	
TOTALS	214	84

Incredibly, the equipment category was the primary root cause in only one case, and was a secondary root cause in only 10 more. Equipment root causes are clearly more significant as secondary contributors to criticality infractions than primary causes, but their relative contribution to criticality safety risk is negligible at Rocky Flats Plant.

5.5.3 Analysis of Criticality Safety Procedural Infractions

From its evaluation of the root causes of the 214 infractions that have occurred since 1983, the Team reached certain conclusions and developed recommendations which should be considered in developing a program to improve criticality safety at the plant. In developing these conclusions and recommendations, the Team identified two principal aspects of the daily risk contributions from people--namely, *cultural weaknesses* as evidenced by poor attitudes and practices of both workers and management, and *work-place environmental situations* which may have set the operators up to make mistakes. Both of these fundamental (common mode) causes occur at Rocky Flats Plant. The recommendations which follow are meant to address the people problems and the environmental problems.

At Rocky Flats Plant, there appears to be an attitude of acceptance of recurring infractions of criticality safety procedures without requiring action to solve the underlying causes of the problems. Many of the infractions are due to worker and management complacency. The same types of mistakes appear to be made over and over again, due in large measure to inattention to basic work principles. In most instances where operator inattention is evident from the records, *strong action was not taken* to reprimand the persons responsible for the infraction. Thus, it appears that a culture has developed where mistakes are condoned. This is in marked contrast to the practice in the commercial nuclear power industry where strong measures are taken in cases *where violations are caused by sloppy work habits and operator inattention*. In the commercial nuclear power area, recurring problems are not accepted, and strong measures are taken to determine the root causes of recurring infractions. The Team recognizes that a fine line must be drawn between actions that encourage cover-up of infractions because of fear of reprisal against an individual who makes an honest mistake and inaction that allows the recurrence of similar errors. Based on the infraction reports, it appears that many of the infractions at the plant are not caused by one-time, unavoidable mistakes. This is not acceptable for criticality safety at Rocky Flats Plant since high reliance is placed on human performance. **The Team recommends that management reconsider its policies on disciplinary action for recurrent human error involving operator or supervisor inattention. The Team suggests that DOE convey to the Rocky Flats Plant contractor the need to reduce human error.**

As for the second principal cause of recurring mistakes, many appear to result from confusion over which nuclear materials safety limits apply. There are a number of different limits for weight, number, volumetric requirements, and spacing for seemingly similar tasks. In some cases, adjacent gloveboxes that contain the same material may have different limits since different operations may be assigned to and conducted in each glovebox. Where feasible, the similarities should be identified and the limits should be simplified by use of mutually acceptable limits.

The Team recommends that a comprehensive review of criticality limits be made on a plant-wide basis with a view toward human factors (e. g., consolidation and simplification) so that the number of future

mistakes attributable to different limits for each task can be reduced. Other potential advantages of consolidation and simplification of limits and procedures are:

1. the transfer of workers among tasks is facilitated (training may be more efficient because the same procedures and limits would apply to several work stations), and
2. a reduced number of limits to remember will result in a reduced number of infractions. The likelihood of forgetting special limits may also be reduced.

Another related type of infraction is being caused by the use of *incorrectly sized containers*. A significant number of infractions occur simply because container sizes exceed a limit (e.g., a 4-liter bottle was used when only 2-liter bottle was allowed; or a box was used having a 4-inch depth when only 2-inch depth was allowed). Each work station appears to have a multiplicity of container sizes, greatly increasing the possibility that the wrong size will be used. **The Team recommends that a comprehensive review be undertaken to validate the size of containers that are needed for each work station and limit the different sizes with a view toward simplicity and safety. Sizes that are not actually needed should be removed.** This approach has been used successfully at Los Alamos National Laboratory.

Some of these container problems may be caused by *productivity pressures* which also may lead to rushing the job. Permitting multiple limits and the use of a number of various size containers at Rocky Flats Plant leads to confusion, and imposing concurrent productivity concerns significantly increases the associated probability of human error. The Team concludes that such combinations of requirements lead to a degradation of safety that is not acceptable.

Another cause of a number of the criticality safety procedural infractions was the work-place environment. For instance, better lighting and more frequent replacement of clouded viewing glasses might have prevented a number of infractions where an item or material already in a box had not been seen. **The Team recommends that the design of the facilities and their maintenance practices, such as criteria and responsibility to initiate replacement of glovebox windows, should receive a human factors review. The Team suggests that a professional lighting engineer be employed to provide continuous, proactive efforts to ensure proper lighting levels in all work areas, especially in gloveboxes.**

5.6 Criticality Calculations and Analysis

The calculations performed by criticality engineers are done by use of well established and accepted computer codes. A few spot checks by the Team showed proper code usage. The need to validate the calculations is well understood by personnel at Rocky Flats Plant, and such validations are accomplished in the Critical Mass Laboratory. The Team noted an *over reliance*

on computer calculations, however. Handbook data and simple calculational methods should be used to supplement the computer analysis methods as a *check for reasonableness*. While it is clear that computer codes are more able to deal with complex calculations, the results are often dependent on a range of assumptions or dependent on accurate data entry. Thus, such results should be verified to be reasonable. Also, the Team notes that the rationale behind the assumptions for calculational models is rarely well documented at Rocky Flats Plant. The Team suggests that corrective actions be taken in these areas.

The basis for a good criticality safety control system is a comprehensive understanding of what can go wrong. The plant should:

1. provide a rigorous and documented analysis to determine off-normal events (including process upsets) which could cause a criticality accident, and assign responsibility for maintaining this analysis current;
2. develop formal criteria or standards for barriers used to prevent criticality accidents;
3. develop double contingency, independent barriers to all credible criticality accidents;
4. formalize the barriers (administrative and physical) for each scenario as Operational Safety Requirements and obtain DOE approval for each; and
5. formalize the system that assures Operational Safety Requirements are implemented and meet criteria.

The criticality safety analysis at Rocky Flats Plant is overly dependent on historic review of operations and should involve methods which are used elsewhere in the nuclear industry to assess risk and guide changes. The development of scenarios for which controls are required currently appears to be an informal process with varying thoroughness. The documentation of the assumptions of the criticality safety evaluations are in personal notebooks. The validity of the assumptions is not generally reviewed by process experts. It is not clear that all credible scenarios have been documented and reviewed. The use of the techniques discussed in the Risk Assessment Guide would significantly enhance the criticality safety program. These methods are used to assess other risks at Rocky Flats Plant.

The safety analyses should be more comprehensive and formal, including documentation and review. The important assumptions made in safety analyses should be clear, documented and periodically verified. Safety analyses should be kept current. When physical changes in equipment or facilities would increase safety, a criterion

for backfit should be available, and appropriate backfits should be funded.

5.7 Criticality Experiments

One of the major strengths of the criticality safety program at Rocky Flats Plant is the Critical Mass Laboratory. The facility develops data to validate criticality safety calculations and safety margins. It provides a much improved understanding of the realities of safety margins, critical masses and sensitivity to controlled parameters. The data developed from the 1700 critical mass experiments in the laboratory are a local and national resource.

The critical experiments program at Rocky Flats Plant has been inactive the past year awaiting an upgraded ventilation system. In the past, Rocky Flats Plant experiments have involved the use of high-enriched uranium metal, plutonium metal, low enriched uranium oxide, and uranyl nitrate solution. **The Rocky Flats Plant does not have the capability for plutonium solution handling or experiments, even though more risk is associated with solutions than solids in Building 771.¹** Also, no other U.S. critical mass laboratory can handle plutonium solutions since the shutdown of the Plutonium Critical Mass Laboratory at Hanford. Therefore, the Team suggests Rocky Flats Plant review its capabilities for conducting criticality experiments with plutonium solutions and consider developing such a capability if it is determined to be appropriate.

5.8 Defense in Depth

In developing a safety philosophy for nuclear facilities in the United States, the industry has established the principle of *defense in depth*. This principle requires that several different and, so far as is feasible, independent features for prevention or mitigation of a serious accident be interposed between expected normal operation and a serious accident. In the nuclear power field, the approach can be described as having three levels of intervention:

1. High quality in the areas of design, construction, and operation result from the use of a specially developed set of standards and specifications for the plant equipment and from a well-organized training program for operational personnel.
2. It is, however, assumed that mistakes may occur in any of these areas. Such potential mistakes as errors in design and construction, equipment failures, and various human errors are assumed to occur. Safety systems are designed with enough backup features to make it highly unlikely that the consequences of these types of incidents are unacceptable.

¹ "Building 771 Final Safety Analysis Report," June 1987 (Section 8.1.4).

3. Finally, it is assumed that some low probability events may occur in spite of the above precautions. Features are added to the plant to mitigate the consequences of these events.

When one looks for defense in depth against nuclear criticality accidents, Rocky Flats Plant appears to apply the levels of protection described above. Corresponding to level 1, the plutonium processing operations are designed to prevent criticality. In level 2, it is assumed that mistakes may occur, and a set of equipment failures and some human errors are postulated and analyzed. If necessary, a plutonium processing operation can be modified to make the consequences of these events acceptable. Finally, one might characterize the criticality alarm system at Rocky Flats Plant, the building evacuation procedures, and offsite emergency response as corresponding to level 3 of defense in depth.

In the Team's examination of defense in depth as practiced by the criticality safety organization of the plant, the Team talked with several people including the Manager of Nuclear and Industrial Safety and the Manager of Criticality Engineering. Protection against nuclear criticality accidents is specifically required in a double contingency principle in the Department of Energy Order, DOE 5480.5. Specifically, this Order requires that:

"Process designs shall incorporate sufficient safety factors so that at least two unlikely, independent, and concurrent changes in process conditions must occur before an accidental nuclear criticality is possible."

According to the Manager of Nuclear and Industrial Safety, this Order guides all analyses of operations involving the handling of fissile material made by Criticality Engineering. He also takes note of the "at least" phrase in the Order. Criticality Engineering tries to ensure that operations are protected from criticality accidents by *more* than the two changes which must occur in order to make an accident possible. "Changes" are not defined in the DOE Order. A change is interpreted by Criticality Engineering as a departure from specified procedures or a failure or malfunction of equipment.

Additional conservatism is introduced both in the analyses made by Criticality Engineering and by additional requirements that may be set by other groups such as Health Physics and Industrial Safety. For example, Rocky Flats Plant's Criticality Safety Guide for the Design of Plutonium Processing Equipment specifies that "Sufficient conservatism shall be applied in the analytical approach that, given the occurrence of two independent concurrent faults, a criticality accident is still unlikely."

When asked how analyses are conducted, the Manager of Nuclear and Industrial Safety responded, "We take a process design and 'what if' it to death." The initial analysis assigned to a Criticality Engineer is subject to several levels of review and, depending on the complexity of the process or of the issues raised during the review, may involve ultimate review by the Manager of Nuclear and Industrial Safety.

The Criticality Safety Guide referred to above provides guidance on features and characteristics of equipment design to be considered during analyses. It is clear from an examination of the guidance that considerable experience and a detailed knowledge of the plant is required in the use of this guidance to achieve the high level of safety being sought. Thus, well trained and knowledgeable Criticality Engineers are an essential component in safety assurance.

Much of the processing of fissile material at Rocky Flats Plant involves manual handling, transport, and manipulation of fissile material. Thus, accounting for and guarding against human error is as important to safety as is proper equipment design and equipment reliability. However, the likelihood and consequences of human error are, at the same time, the least predictable. According to the Manager of Nuclear and Industrial Safety, effort is made to diminish the probability of human error by design of the processes and systems. For example, some fissile material storage containers are welded in place to ensure proper location and spacing, and a fissile material holder on a transport cart is permanently attached to the middle of the cart to preserve appropriate spacing. Beyond that, the analyst assumes that a limited number of human errors occur, analyzes their consequences, and sets limits on the basis of the predicted consequences. The importance of controlling human errors at Rocky Flats Plant is discussed in more detail in Section 5.5.3.

However, the type of written guidance provided in the Procedures for Criticality Engineers for the consideration of equipment and system design has not been developed for human error analysis. Guidance in the choice of errors to be considered comes almost entirely from previous experience, although there are no systematic analyses of operating experience as reflected, e.g., in criticality procedural infractions. It appears that there is an assumption made that if errors, failure modes, or process upsets have not been observed by now, they are sufficiently unlikely that they can be ignored. Thus, there are limits to how far the "what if" questions have been carried at Rocky Flats Plant, as ultimately there must be at any hazardous facility. It is clearly a matter of experience and judgment as to when this limit is reached. The Team concludes in Section 5.5.3 that the limit has not been reached at Rocky Flats Plant.

Rocky Flats Plant management places major emphasis on the training of operating personnel to make human error contributions improbable. New employees are required to take a formal course of three to four hours duration in criticality safety. A refresher session is now scheduled six months after hiring of new employees. Because a 1984 analysis of criticality infractions gave some indication that the previous retraining cycle of every two years is not often enough, the interval between required training sessions for all employees should be reviewed. The Criticality Safety Assessment Team has also determined that not enough formal feedback has been obtained on the effectiveness of this training, so it is not known if workers are receiving unambiguous instruction in this highly complex area of safety. The Team suggests that training be revised to obtain continuing feedback on criticality safety training effectiveness to help avoid personnel error.

Over the past several years, quantitative risk analyses have been developed for Rocky Flats Plant. A criticality accident and its consequences are among the events that have been considered. **It appears that quantitative risk analysis could provide an appropriate framework for a more systematic consideration of human error. The Team suggests that this level of human error analysis be undertaken.**

Although the responsible plant managers claim that criticality safety analyses are guided by a double contingency principle and are believed to include a consideration of off-normal equipment function and process behavior, the Team concludes from conversations and interviews that the double contingency principle is not generally applied in an appropriate fashion. Also, there is inadequate consideration given to off-normal behavior of operating personnel and equipment.

Admittedly, the definition of double contingency as given in the DOE Order is ambiguous. An example of where the Team believes the double contingency principle is improperly applied at Rocky Flats Plant is line 13 in Building 771. A nuclear criticality safety limit of 150 grams of plutonium per liter has been established for the tanks in this line. The first contingency is the proper sampling of the solution in the glovebox process equipment before transfer to the tanks. The second contingency was described to the Team to be the *conservatism* of the 150 grams of plutonium per liter limit itself. Obtaining a sample is a satisfactory first contingency. If the results of the sample are satisfactory and no errors were made by the chemist, the first contingency has been met. If the results of the sample were satisfactory, *but* the chemist made a mistake or the chemical reagents were defective in obtaining these results, then the first contingency has failed and reliance is placed on the second contingency for the required safety. If the sample has failed however, the actual concentration of the fissile material is not known, so the second contingency proposed (conservatism in the limit) in this case cannot be applied and will provide no *assurance* of safety. The philosophy of considering the conservatism of the safety limit as a contingency to meet the double contingency principle simply does not meet the spirit of that principle.

If, however, an *independent* second sample were taken by a second chemist, and the second chemist used a different method of analysis (or simply an independent set of reagents), *then* it could be argued that a second contingency has been applied. *Even in this case*, one might argue that some non-independent part of the process of sampling compromised the double contingency principle. This is because the objective is to "eliminate the possibility of any unsafe accumulation of fissile material which might produce a nuclear excursion..."² In the nuclear industry, possibilities are said to be acceptable, since they seldom can be entirely *eliminated*, if their chance of occurrence is less than one in ten thousand to one in a hundred thousand years. The Team believes that the combination of two contingencies, therefore, should be reliable enough to provide a probability of failure of less than one in ten thousand per year. Obviously, one contingency plus conservative analysis will not usually meet such a standard.

² "Nuclear Criticality Safety Policy," Policies, Rockwell International, RFPM MHS 3-001, dated November 11, 1988.

Thus, the Team is concerned that the application of the double contingency principle to protect against a criticality accident at the Rocky Flats Plant is not well understood and is not properly implemented for all situations involving a potential accident. If a double contingency principle is to be followed, then DOE should ensure that the guidance for the principle is more definitive.

The Team recommends that quantitative goals for criticality accident risks be established by DOE and that contractors for facilities such as Rocky Flats Plant be required demonstrate through criticality safety analyses that the goals are met in their operations. The Team recommends that, as a minimum, criticality analysts should ensure that at least two independent errors in process design (hardware failure), operation (human error), or in some aspect of total system performance must occur in order that a criticality accident be possible. The Team believes that this should be done uniformly throughout plant areas where fissile materials are handled.

The Team is concerned, also, about what is considered to be an off-normal occurrence at Rocky Flats Plant such that an analysis would be performed. The answers provided in response to a question as to how off-normal behavior is addressed included the assumption that only events or occurrences of the type *that have been observed previously* need be considered. This, coupled with the fact that the Criticality Engineering staff members are so severely overloaded that they can no longer afford the time to ask the needed additional "what-if" questions, leads the Team to conclude that the criticality safety analysis process at Rocky Flats Plant is inadequate in its approach to off-normal events.

Thus, the Team concludes that DOE's guidance in this complex area could be improved. DOE Order 5480.5 entitled "Safety of Nuclear Facilities" contains (in the version dated September 23, 1986) two sections that address Criticality Safety. One is labelled Nuclear Criticality Safety Elements, the other, Nuclear Criticality Safety Control Parameters. These two sections contain a mixture of general guidance and specific instructions. However, the general guidance needs elaboration in order to be applied, and the specific instructions do not provide adequate details to ensure proper application.

For example, the general guidance includes the double contingency principle; however, a *contingency* (said to be unlikely) is not well defined, nor is *unlikely* further described. The specific guidance, apparently in an effort to make it generally applicable, is equally ambiguous. As a result, a considerable amount of interpretation is needed if one is to formulate a program applicable to a specific operation. At Rocky Flats Plant, as discussed above, the interpretation is to "eliminate the possibility," a goal which the Team considers to be commendable yet unrealistic.

The Team recommends that a better set of general guides be developed by the DOE, and that each applicable DOE facility, including Rocky Flats Plant, be required to formulate specific operational strategies and rules based on these general guides. It

should be required that, before application, these rules be reviewed by a knowledgeable group, including representatives from outside the facility. The detail in the rules should be at a level similar to that found in the Technical Specifications of nuclear power plants in the United States. The rules should be revised as experience in operations accumulates.

5.9 Configuration Control

A prerequisite to a sound criticality safety program and a controlled operation is a detailed knowledge of the configuration of the equipment used to store, handle or process fissile material. A comprehensive safety evaluation clearly requires this information. A safeguard against uncontrolled operation is the operator's knowledge of the equipment. This knowledge affects procedures, training and practices. A normal keystone in this knowledge structure is up-to-date drawings and other documentation of system design and operation. Safety review and approval of changes are significantly improved in effectiveness if the current status of a plant is known through up-to-date design basis documentation.

At Rocky Flats Plant, structures, underground utilities, and electrical systems have up-to-date drawings. Production equipment and HVAC systems do not. This increases the burden of the criticality safety analyst and could well require periodic dismantling of production equipment for Criticality Engineering review to avoid surprises.

Normally, awareness of the design basis of the various systems at the plant would be needed in order to perform an appropriate inspection of the entire plant, even with regard to a limited concept as criticality safety. Several helpful definitions regarding design basis and configuration management are provided in Appendix H.

The age and evolving nature of the Rocky Flats Plant make the design basis and the associated configuration control documentation inadequate for many of the process systems at the plant. Fortunately, the absence of detailed system design basis documentation at the plant was not a significant obstacle to the Criticality Safety Assessment Team. It is far easier to note that something is missing than to evaluate it if it happens to exist. The absence of design basis requirements, nevertheless, may impact the ability of plant managers to understand and control the more subtle design features of the systems at Rocky Flats Plant and, consequently, safety related problems may be more likely to occur.

The Team recommends that Rocky Flats Plant management (1) undertake the development of complete design basis documentation for those safety related areas where it does not exist and (2) establish the configuration control program necessary to maintain this information over the rest of the life of the plant.

6. Recommendations and Suggestions

This section is a summary of the recommendations and suggestions which are included in other sections of this report, where they are highlighted by **bold lettering**. They are provided here for convenience, but the actual discussion of the source of each recommendation is located in the section indicated.

6.1 Regarding Lax Safety Practices (Section 2.5)

The Team recommends that better *communications* throughout the entire Rocky Flats Plant organization be developed. Senior managers must tour the facilities more often to assure that the very demanding nuclear safety policies and practices associated with nuclear facilities are reflected in daily operations. Middle and lower managers must also be more proactive in implementing improved operational practices.

The Team recommends *better training* in the need for and the exercise of procedural discipline and communication formality at Rocky Flats Plant.

The Team concludes that *isolation* from the rest of the nuclear scientific and industrial community has contributed to the deficient or outdated safety practices observed. The Team recommends that Rocky Flats Plant managers continue to work to develop better interfaces within this community of experts and to optimize practices and philosophies.

The Team recommends that plant managers undertake *more aggressive and inquisitive follow up* on allegations of safety problems, including allegations voiced external to the plant.

Generally, the Team recommends that the criticality safety of the *storage areas* be reviewed and improved, that further consideration be given to the criticality potential that might be created by an *earthquake* at the plant, and that planning for *long-term disposition* of the residues at the plant include steps to upgrade the current level of protection against criticality accidents.

6.2 Regarding Accumulation of Fissile Material in Ventilation Ducts (Section 2.6)

The Team suggests that the waste line in room 227 of Building 881, and any other locations that are of potential concern to the Criticality Engineering group, be surveyed using nondestructive assay techniques to determine whether or not there is a significant buildup of fissile material anywhere in that building. Long-term plans and potential consequences should be documented and approved.

6.3 Regarding Fissile Materials in Exhaust Ventilation Systems (Section 3)

The Team suggests that Rocky Flats Plant undertake the following studies of glovebox filter systems:

- a. Development of prefilter aligning devices to assure seal of the filters to the exhaust duct inlets.
- b. Optimization of flow rates of air and nitrogen through gloveboxes to reduce carrying velocity.
- c. Redesign of equipment to reduce heat, dust, and moisture where they are problems in gloveboxes.
- d. Redesign exhaust ducts to permit easier replacement, interior viewing of contents and/or nondestructive evaluation. The redesign should separate the ducts which serve wet and dry glovebox operations.
- e. Evaluate the use of additional prefilters over the face of glovebox exhaust prefilters to enhance plutonium recovery and to extend the life of the exhaust prefilters.
- f. Consider using filters to cover inlets to automatic bypass valves and installing an indicator warning device when these valves are opened.

The Team recommends (Section 3.2.) that Rocky Flats Plant management initiate a systematic duct holdup measurement program in the near future. The Safeguards Measurements group has the proper expertise to perform and analyze such NDA measurements. This should not be viewed by management as a "single-shot" event. To assure continued criticality safety, periodic and systematic quantitative duct holdup measurements must be continued in conjunction with normal operations. This effort should be properly staffed and funded to assure long term excellence. Appropriate *remedial actions* should also be taken in a systematic and timely fashion for those ducts in which significant quantities of fissile material are found.

6.4 Regarding Criticality Aspects of SNM Waste and Residue in Containers (Section 4)

The Team recommends that Rocky Flats Plant, through its Criticality Engineering group, implement a program to verify the validity of all posted criticality limits for drums (Section 4.1). This should include, as a minimum, appropriately conservative and well-documented k_{eff} calculations that consider the presence of water, plastics, and other possible reactivity contributors. The posted limits should be checked against limits recorded in the controlled documents. This will considerably improve the assurance of drum safety.

The Team recommends that a criticality safety review of the basement of Building 776 be conducted. As a minimum, the reactivity effects of flooding should be evaluated, the sump pump should be repaired, a sump level alarm should be installed, alpha radiation monitors should be installed, and older drums which contain more than 1,000 grams of plutonium should be repackaged; or such drums should be removed from this location and stored more safely elsewhere.

The Team recommends that drum criticality events be incorporated into safety analyses. These analyses can be put into a risk context through the probabilistic risk assessments (PRAs) and hazards assessments that are being performed at many DOE facilities. Included in these assessments should be a consideration of risk to plant workers and consideration of whether a criticality event can act as an initiator for increased release of plutonium. External initiating events, such as earthquakes, should be evaluated in a comprehensive manner.

Temporary storage areas and temporary storage drums (containing greater than 1,000 grams of plutonium) should be just that--temporary. The Team recommends that the Department of Energy place final disposition high on its priority list, especially for drums with more than 1,000 grams of plutonium, and that residue drums be removed from basement storage.

The Team recommends that Rocky Flats Plant review its policy of filling drums with amounts of plutonium without considering the uncertainties in the measurements. For example, with a limit of 1,000 grams, the possible 10% (2 x 5%) uncertainty in the measurements makes this policy inconsistent with NRC waste shipment policies for the regulated nuclear industry and with generally accepted practices in the industry. The actual uncertainty should be determined and applied to the approved loading limits for the drums.

6.5 Regarding the Criticality Program

Criticality Safety Organization (Section 5.1): The criticality safety management system at Rocky Flats Plant appears to meet most of the minimum requirements of the applicable national standard ANSI-ANS 8.1, but the Team suggests that areas 1, 2, 4, and 6 listed in Section 5.1 be strengthened. Also, certain aspects of area 8 on training (see Section 5.3) should be reviewed to ensure an understanding of criticality safety by all plant workers. The Team recommends that Rocky Flats Plant and DOE management continue to support and emphasize the highest priority for safety and, correspondingly, reduce the emphasis on production goals and schedules.

Staffing of Criticality Engineering (Section 5.2): The Team recommends that the problems of security clearances and high turnover in the Criticality Engineering and Critical Mass Laboratory groups (see Section 5.8 of this report) be solved, in part, through increased priorities in these areas. While new people are being recruited and trained, some experienced criticality safety people in other Rocky Flats Plant divisions should be transferred back to Criticality Engineering temporarily to help, or assistance should be sought from other laboratories or contractors. The current staffing level is not sufficient to accomplish its normal work and also respond to the recommendations of this assessment.

Criticality Safety Training (Section 5.3): The Team recommends that Rocky Flats Plant strive to assure that at least 75% of the criticality staff is certified as soon as possible. The Team also suggests that more attention to the on-the-job training phase of the operator training program be considered. Efforts should be made to

ensure that supervisors are aware of the importance of the on-the-job training and the need for their contributions to this training. There does not, at present, appear to be any formal evaluation of the course by trainees. It is important to those responsible for the course to have trainee feedback on the quality of course content after they have been on the job for a few months. The Training Department should also supplement the technical training with more emphasis on discipline of operations and communications and provide better perspective in some areas related to nuclear safety requirements and procedures.

Risk Analysis and Risk Management Philosophy (Section 5.4): In light of the amount of manual manipulation that characterizes many of the Rocky Flats operations, and the reliance on human performance as an accident preventive, the Team recommends that a more systematic investigation of the likelihood of human error be undertaken. The framework for the investigation already exists. What is needed is a more detailed study of those processes in which the possibility of a criticality accident exists. The Team suggests that additional interaction between those groups responsible for day-to-day operations and the Safety Analysis group is necessary in order to obtain maximum benefits from these analyses.

Criticality Safety Procedural Infractions (Sections 2.7 and 5.5.3): Areas where significant improvements could be made in order to reduce the number of recurring infractions involve worker and management attitudes (culture) and, in certain areas, the working environment. Thus, the Team recommends that management reconsider its policies on disciplinary action for *recurrent* human error involving operator or supervisor inattention, and that a comprehensive review of criticality safety limits be made on a plant-wide basis with a view toward human factors (e. g., consolidation and simplification) so that the number of future mistakes attributable to different limits for each task can be reduced. The Team suggests that DOE convey to the Rocky Flats Plant contractor the need to reduce human error. The Team recommends that a comprehensive review be undertaken to validate the size of containers that are needed for each work station and limit the different sizes with a view toward simplicity and safety. Sizes that are not actually needed should be removed. The Team recommends that the design of the facilities and their maintenance practices, such as criteria and responsibility to initiate replacement of glovebox windows, should receive a human factors review. The Team suggests that a professional lighting engineer be employed to provide continuous, forward looking efforts to ensure proper lighting levels in all work areas, especially in gloveboxes.

Criticality Calculations and Analysis (Section 5.6): The Team suggests that corrective actions be taken in the area of criticality safety analysis. Handbook data and simple calculational methods should be used to supplement the computer analysis methods as a *check for reasonableness*. While it is clear that computer codes are more able to deal with complex calculations, the results are often dependent on a range of assumptions or are dependent on accurate data entry. Thus, such results should be verified to be reasonable. Also, the Team notes that the rationale behind the assumptions for calculational models are rarely well documented at Rocky Flats. The safety analyses should be more comprehensive and formal, including documentation and review. The important assumptions

made in safety analyses should be clear, documented and periodically verified. Safety analyses should be kept current. When physical changes in equipment or facilities would increase safety, a criterion for backfit should be available, and appropriate backfits should be funded.

The basis for a good criticality safety control system is a comprehensive understanding of what can go wrong. The plant should:

1. provide a rigorous and documented analysis to determine off-normal events (including process upsets) which could cause a criticality accident, and assign responsibility for maintaining this analysis current;
2. develop formal criteria or standards for barriers used to prevent criticality accidents;
3. develop double contingency, independent barriers to all credible criticality accidents;
4. formalize the barriers (administrative and physical) for each scenario as Operational Safety Requirements and obtain DOE approval for each; and
5. formalize the system that assures Operational Safety Requirements are implemented and meet criteria.

Criticality Experiments (Section 5.7): The Criticality Measurements Laboratory at Rocky Flats Plant does not have the capability for plutonium solution handling or experiments even though more risk is associated with solutions than solids in Building 771¹. Also, no other U.S. critical mass laboratory can handle plutonium solutions since the shutdown of the Plutonium Critical Mass Laboratory at Hanford. Therefore, the Team suggests Rocky Flats Plant review its capabilities for conducting criticality experiments with plutonium solutions and consider developing such a capability if it is determined to be appropriate.

Defense in Depth (Section 5.8): The Team suggests that training be revised to obtain continuing feedback on criticality safety training effectiveness to help avoid personnel error. It appears that quantitative risk analysis could provide an appropriate framework for a more systematic consideration of human error. The Team suggests that this level of human error analysis be undertaken. The Team recommends that quantitative goals for criticality accident risks be established by DOE and that contractors for facilities such as Rocky Flats Plant be required to demonstrate through criticality safety analyses that the goals are met in their operations. The Team recommends that, as a minimum, criticality analysts should ensure that at least two independent errors in process design or operation or in some aspect of total system performance must occur in order that a criticality accident be possible. The Team recommends that this be done uniformly throughout the plant areas where fissile materials are handled.

¹ "Building 771 Final Safety Analysis Report," June 1987 (Section 8.1.4).

The Team recommends that a better set of general guides be developed by the DOE, and that each applicable DOE facility, including Rocky Flats Plant, be required to formulate specific operational strategies and rules based on these general guides. It should be required that, before application, these rules be reviewed by a knowledgeable group, including representatives from outside the facility. The detail in the rules should be at a level similar to that found in the Technical Specifications of nuclear power plants in the United States. The rules should be revised as experience in operations accumulates.

Configuration Control (Section 5.9): The Team recommends that Rocky Flats Plant management (1) undertake the development of complete design basis documentation for those safety related areas where it does not exist and (2) establish the configuration control program necessary to maintain this information over the rest of the life of the plant.

6.6 Regarding the Use of the KENO Computer Code (Appendix K)

The Team suggests that the Department of Energy provide resources (money, equipment, etc.) to enable the Critical Mass Laboratory to design and carry out subcritical experiments that could be used to validate the KENO code under circumstances relevant to Rocky Flats Plant needs. The Team also suggests that up-to-date sets of cross sections, which reflect the current state-of-art, be made available for use with KENO at Rocky Flats Plant.

APPENDIX A
CHARTER FOR CRITICALITY SAFETY ASSESSMENT TEAM
INVESTIGATING PLUTONIUM ACCUMULATION AND THE
ASSOCIATED POTENTIAL FOR INADVERTENT CRITICALITY
AT ROCKY FLATS PLANT
JUNE - SEPTEMBER 1989

MISSION

As agreed by the Department of Energy (DOE) and the Governor of Colorado, an independent team of experts shall assess safety issues related to the potential for inadvertent criticality of any plutonium accumulation in ventilation systems and plutonium residues that are stored in containers at the Rocky Flats Plant. The Team shall be dedicated to questions relating to public health and safety; i.e., the mission of the assessment includes the protection of people from the consequences of an inadvertent criticality at RFP and does not include consideration of the need for the materials that are produced at the plant.

The Team's effort shall include a review and independent verification of methods used to (a) measure the quantity and location of plutonium in ventilation duct work and in storage containers, and (b) control materials and residues within RFP to avoid conditions that could lead to inadvertent criticality.

In particular, the Criticality Safety Assessment Team shall assess the potential for inadvertent criticality arising from:

1. possible accumulations of plutonium in various exhaust ventilation systems that support the process systems used at the Rocky Flats Plant (RFP);
2. possible accumulations of plutonium in the exhaust system of the incinerator located in building 771; and
3. the geometric configuration of containers of residues, which include special nuclear material (SNM), stored at the facility.

The scope of the Criticality Safety Assessment Team's evaluation shall include the following:

1. review of measures used to prevent inadvertent criticality, especially in ventilation ducts, including ducts associated with the incineration process for concentrating residues, to determine if there is an adequate implementation of the defense in depth policy for criticality safety. The measures to be addressed include design, verification of analytical methods, quality assurance, surveillance, procedures, and training;

2. review of operating experience for lessons learned and corrective actions implemented, including
 - a. records of criticality measurements,
 - b. records of criticality infractions,
 - c. results of off-site environmental monitoring,
 - d. records of plant personnel exposure to neutrons, and
 - e. results of nuclear material accountability programs;
3. verification of estimates made by the operating contractor of plate-out of plutonium in the filters, pipes, valves, and components of the ventilation systems. This verification will include review of operating procedures, training programs, maintenance methods, plant operating logs, and radiation measurements. Consideration will be given to the need for independent measurements;
4. a criticality safety evaluation of the storage array of plutonium ash containers reported to contain 100 grams or more of SNM, and a smaller number of other containers containing SNM. This evaluation will specifically consider the potential for critical arrays and will evaluate the adequacy of the criticality safety measures that are provided.

TEAM COMPOSITION

Team Leader	Roger Mattson
Deputy Team Leader	Larry Ybarrondo
Team Coordinator	Charles Jones
Senior Safety Experts	William Kerr
	Harry Lawroski
	J. Ernest Wilkins
Colorado Health Physics Expert	Thomas Borak
Criticality Expert	Robert Wilson
NDA Measurement Expert	John Caldwell
Plutonium Technology Expert	William Maraman
Safety Analysis Expert	James Meyer

TEAM QUALIFICATIONS

Thomas B. Borak is a PhD physicist with over 25 years experience, primarily in the fields of radiation protection and dosimetry, medical physics, and measurement techniques. For the past 10 years, Dr. Borak has been a professor for the Department of Radiology and Radiation Biology at Colorado State University. His previous experience includes work at Argonne National Laboratory as a physicist

for the Division of Biological and Medical Research and the Division of Environmental Impact Studies. Dr. Borak served as a Visiting Scientist at the Health Physics Division, CERN, Geneva Switzerland and was a physicist at the National Accelerator Laboratory, Batavia, Illinois. He is certified by the American Academy of Health Physicists and is a member of the American Physical Society and Health Physics Society.

John T. Caldwell is a PhD physicist with 30 years of experience, primarily in the field of nuclear measurements, including 18 years at Los Alamos National Laboratory, and 8 years at Lawrence Livermore National Laboratory. He is an independent consultant in transuranic assay and monitoring instrumentation and has performed plutonium waste holdup measurements at the Nuclear Fuel Services Erwin facility and evaluated plutonium holdup at the Plutonium Finishing Plant at Hanford. Dr. Caldwell is an expert in gamma ray and neutron physics and associated detection hardware. His patents in the radioactive waste assay field have been recognized by the Industrial Research and Development Council and Los Alamos National Laboratory. He is a member of the American Physical Society.

Charles R. Jones is a mechanical engineer with 23 years of experience, including a 20 year career in nuclear technology with the United States Navy. In the Navy he served as a senior nuclear engineer on several nuclear powered vessels, qualified as Chief Engineer on the U.S. Nimitz CVN68, and participated in team inspections of nuclear plants for the Pacific Fleet. He served as an engineering trouble shooter for technical problems with ship machinery. From 1981 to 1986 he worked in the Navy advanced weapons program on nuclear safety, security, and control matters. Since his retirement from the Navy in 1986, he has assisted in safety system inspections and system operational reliability studies for various nuclear power plants. He is a member of the American Nuclear Society and an employee of SCIENTECH, Inc.

William Kerr is a PhD electrical engineer with 47 years of experience. He has been a professor at the University of Michigan since 1953, where he served as Chairman of Nuclear Engineering for 13 years and director of Michigan Memorial-Phoenix Project from 1961 to the present time. He has been a member of the Advisory Committee on Reactor Safeguards (ACRS) of the Nuclear Regulatory Commission since 1972, having served three years as ACRS Chairman, most recently in 1987 and 1988. Dr. Kerr has consulted with Atomic Power Development Associates, Oak Ridge National Laboratory, and the Department of State and was a member of the Michigan Governor's Task Force on Nuclear Waste Disposal. He has received the Compton Award of the American Nuclear Society, Outstanding Educator in America Award, and the NRC's Meritorious Service Award.

Harry Lawroski is a PhD chemical engineer with 38 years experience in energy producing industries. At the Idaho National Engineering Laboratory he served five years as Superintendent of Operations of the plutonium fueled EBR II reactor, five years as Manager of Design and Construction of Zero Power Plutonium Reactor, and three years as Assistant General Manager of the chemical processing plant.

His career also includes twelve years consulting for nuclear and fossil energy producers, five years of safety research in nuclear reactor fuels and eight years of research and development in petroleum refining and petrochemicals. He has consulted with the Electric Power Research Institute, the President's Commission on Three Mile Island, and Governor Deukmejian of California concerning the Diablo Canyon nuclear power plant. Dr. Lawroski was President of the American Nuclear Society in 1981 and is a Fellow of the American Nuclear Society and American Institute of Chemical Engineers.

William J. Maraman is a chemical and mechanical engineer with 45 years of experience, including 37 years at Los Alamos National Laboratory where he worked in chemical and metallurgical processes connected with plutonium and other materials. He was project manager for construction of the Los Alamos TA-55 Facility for processing and research on plutonium. Since his retirement from Los Alamos in 1983, he has served as an independent, expert consultant in plutonium chemistry and metallurgy.

Roger J. Mattson is a PhD mechanical engineer with 25 years of experience. He worked in nuclear facility design for three years at Sandia Laboratory, served the Atomic Energy Commission and the Nuclear Regulatory Commission in the regulation of nuclear facility safety for 17 years, managed radiation surveillance and emergency preparedness at the Environmental Protection Agency, assisted in the U. S. response to accidents at Three Mile Island and Chernobyl, and assisted the International Atomic Energy Agency with siting standards and safety principles. For seven years at NRC, Dr. Mattson directed the technical review of applications for construction permits and operating licenses for nuclear power plants. He received Meritorious and Distinguished Service Awards of NRC. Since 1987 he has been Vice President of SCIENTECH, Inc. where he manages a Washington D.C. office and consults on nuclear safety, waste management, and environmental protection.

James F. Meyer is a PhD nuclear engineer with 25 years in nuclear safety work, including 14 years with the Nuclear Regulatory Commission (NRC) where he was responsible for accident analysis for a number of reactor facilities and served as a technical assistant to one of the Commissioners. He worked at Argonne National Laboratory on plutonium fueled critical assemblies and reactors for five years before joining the NRC. Dr. Meyer is an employee of SCIENTECH, Inc. where he assists government clients in a variety of probabilistic risk assessments of severe nuclear accidents and other safety studies. He is a member of the American Nuclear Society.

J. Ernest Wilkins, Jr. is a PhD mathematician and mechanical engineer with 47 years of experience, including seven years as Deputy General Manager of EG&G, Idaho for Science and Engineering, two years with Argonne National Laboratory as a Fellow and Visiting Scientist, 10 years with General Atomic Company in theoretical physics and computational research, a total of 10 years with Tuskegee Institute, University of Chicago and Howard University, the last of which he served as Distinguished Professor of Mathematical Physics. He is a member of the National Academy of Engineering, a Fellow of the American Association for the

Advancement of Science and the American Nuclear Society (which he served as President in 1975), and he is a member of a number of other professional societies. He has served as an advisor to the State of New York, Atomic Energy Commission, National Research Council, and National Science Foundation. He has been a member of the Assembly of Engineering of the National Research Council and Chairman of the Army Science Board.

Robert E. Wilson is a PhD nuclear engineer with 23 years of experience in nuclear criticality safety, including the last 16 years with Westinghouse. He served from 1975 to 1987 as manager of criticality safety for Westinghouse Idaho Nuclear Company at the Idaho Chemical Processing Plant. He has taught criticality safety at the Universities of Idaho and New Mexico, and his thesis provided a new criticality measurement system. He has a number of technical publications in the field of criticality safety. Dr. Wilson is a member of the American Nuclear Society and has served in various capacities in the Nuclear Criticality Safety Division of ANS.

Lawrence J. Ybarrondo is a PhD mechanical engineer with 29 years of experience who worked in nuclear facility design, construction, analysis, testing, and operations at the Idaho National Engineering Laboratory, rising to the position of Associate General Manager of EG&G, Idaho in charge of operations of four nuclear reactor facilities. He has served on the Board of Directors of the American Nuclear Society and its executive committee on nuclear reactor safety, and he assisted the U.S. government in responding to the accidents at Three Mile Island and Chernobyl. He is President of SCIENTECH, Inc. and manages its Idaho Falls office from which he serves clients in the areas of nuclear safety, system reliability, and management of technology.

PLAN OF ACTION AND SCHEDULE

- Phase I Initial site visit by SCIENTECH (2 days duration). Visit by Team Leader, Deputy Team Leader, and senior staff of SCIENTECH to refine the definition of the Team's mission, walk down some of the systems and areas in question, and meet key technical and management personnel of DOE and its contractor at Rocky Flats Plant and a representative of the Office of the Governor of Colorado.
- Phase II Planning Phase (3 weeks duration). Team selected and the Team charter, plan of action, schedule and protocols for the assessment developed. Special Q clearances arranged for those not already having them. Team Members supplied with background reading material for orientation to Rocky Flats Plant.
- Phase III Site orientation visit for Team Members (1 week duration). Visit to provide the Team with information and data to accomplish its independent assessment. At the start of the visit, a meeting will be held to define Team assignments, to define the mission and scope of the assessment, and to disseminate additional written material

gathered during Phase 1. During the site orientation visit, the Team Members will agree on Team assignments, meet technical counterparts from DOE and Rockwell, review documents, conduct initial interviews, and walk down systems and areas important to criticality safety.

Phase IV Finalize plan of action for the Team (1 week duration). During this phase, a detailed agenda will be developed by each Team Member and integrated into an overall assessment plan. An outline of the report will be prepared to serve as a guide to Team Members during the on-site appraisal.

Phase V Conduct on site appraisal (2 weeks duration). Team Members will conduct the appraisal and develop a draft report for their individual areas of responsibility. Team Members will confirm factual matters in their areas of review through discussions with their assigned counterparts from the plant. Through Team meetings, the observations and judgments of the Team Members will be integrated into a preliminary set of findings and conclusions. An exit meeting of about one days duration will be held with the contractor and DOE site personnel to assure that the matters of fact reported in the Team's draft report are correct.

Phase VI Develop Final Report (5 weeks duration). Draft report sections from the individual Team Members will be developed into a final draft report. The report will contain a description of the matters reviewed, the findings reached, and conclusions regarding the adequacy of criticality safety in those plutonium operations at Rocky Flats Plant addressed by the Team. This final draft report will be coordinated by the Team Leader and submitted to the Team Members for comment before being submitted to the Deputy Assistant Secretary for Environment, Safety and Quality Assurance of the Department of Energy.

REPORTING

The Criticality Safety Assessment Team will report to DOE's Deputy Assistant Secretary for Environment, Safety, and Quality Assurance.

The Team's on-site appraisal operations will be monitored by William Kinney, a headquarters DOE employee who reports to the Deputy Assistant Secretary. Mr. Kinney will also assist the Team with logistical and administrative matters pertaining to the assessment.

Biweekly progress reports will be telecopied by the Team Leader to the offices of the Deputy Assistant Secretary and the Governor of Colorado before close of business on Friday afternoons beginning July 14 and continuing through the end of the project.

Any significant safety concerns with current operations that are found in the process of performing the safety assessment will be reported promptly by the Team Leader to the senior on-site DOE manager and by telephone to the Deputy Assistant Secretary; documentation of any such concerns will be provided by the Team Leader on the following day to both DOE and the Governor.

A final report will be issued by the Criticality Safety Assessment Team to DOE no later than September 29, 1989.

APPENDIX B

TEAM BIOGRAPHIES AND ASSESSMENT RESPONSIBILITIES

This appendix provides a summary of the background of each of the team members and also indicates the particular areas in which the individual team members took the lead in the assessment of criticality safety at the Rocky Flats Plant.

The Team was selected based on high levels of experience in the nuclear industry and significant expertise in a technical area required by the team. The Team was not only interested in discovering specific plant strengths and weaknesses, but also in determining the relative standing of safety performance at Rocky Flats Plant compared with other nuclear facilities in the United States.

THOMAS B. BORAK

Colorado Health Physics Expert

Association: Professor, Department of Radiology and Radiation
Biology, Colorado State University

Experience: Over 25 years

- Physicist, Division of Biological and Medical Research,
Argonne National Laboratory
- Physicist, Division of Environmental Impact Studies,
Argonne National Laboratory
- Visiting Scientist, Health Physics Division, CERN, Geneva,
Switzerland
- Physicist, National Accelerator Laboratory, Batavia, Illinois
- Certified: American Academy of Health Physics

Education: Ph.D., Physics, St. Johns University, Collegeville

CSAT Team Responsibilities:

- Representative of the State of Colorado, nominated by the
Governor
- Reviewed all data related to environmental concerns and
accidental criticality
- Assessed cesium and strontium issues raised by workers
and the public
- Reviewed radiation exposure data to determine causes of
highest exposures

JOHN T. CALDWELL

Expert on Non-Destructive Assay (NDA) Measurements

Association: Consultant, Pajarito Scientific Corporation, Los Alamos, New Mexico

Experience: 30 Years

- Photonuclear Physics, Gamma Ray and Neutron Detection Instrumentation, Lawrence Livermore National Laboratory
- Project Leader Transuranic Waste Assay, Nuclear Weapons Accident Residue Assay, Strategic Defense Initiative Instrumentation, Los Alamos National Laboratory
- Pu Waste Holdup Measurements, Nuclear Fuel Services, Erwin Facility
- Pu Holdup Evaluation, Plutonium Finishing Plant, Hanford

Education: Ph.D., Physics, University of California

CSAT Team Responsibilities:

- Provided expertise on NDA measurements
- Supervised monitoring of ventilation ducts for accumulation of fissile materials
- Investigated health physics measurements of radiation levels and relation to control of fissile materials
- Assessed criticality potentials involved with storage of fissile waste and residue
- Evaluated accuracy of quantities of fissile materials stored in drums

CHARLES R. JONES

Team Coordinator and Nuclear Systems Expert

Association: SCIENTECH, Inc.

Experience: 23 Years

- Nuclear Reactor Plant and Nuclear Weapon Safety Technology, United States Navy
- Safety System Inspections and System Operational Reliability, Various Commercial and Navy Nuclear Power Plants

Education: M.S., Mechanical Engineering, Massachusetts Institute of Technology (MIT)
Ocean Engineer, MIT
Navy Nuclear Propulsion Chief Engineer

CSAT Team Responsibilities:

- Coordinated Team activities and questions raised between members and DOE/Rockwell coordinators
- Reviewed relation of plant programs for maintenance, training, and operating procedures to assurances of criticality safety
- Inspected basement drum storage and flooding hazards
- Assisted in oversight of NDA measurements
- Conducted computer searches in Rocky Flats Plant Library for documents related to criticality safety

WILLIAM KERR

Senior Safety Expert

Association: Professor, University of Michigan

Experience: 47 Years

- Chairman, Nuclear Engineering, University of Michigan
- Director, Michigan Memorial-Phoenix Project, University of Michigan
- Director, Office of Energy Research, University of Michigan
- Member and former Chairman of Advisory Committee on Reactor Safeguards (ACRS) of the Nuclear Regulatory Commission
- Member, Governor's Task Force on Nuclear Waste Disposal, State of Michigan

Education: Ph.D., Electrical Engineering, University of Michigan

CSAT Team Responsibilities:

- Reviewed the design and sensitivity of the Criticality Alarm System
- Reviewed implementation of defense-in-depth principles at the plant
- Reviewed adequacy of DOE orders on criticality safety
- Evaluated what has been done to estimate criticality risk at Rocky Flats Plant, including Safety Analysis Reports
- Audited engineering changes for past 5 years to confirm that criticality analyses were performed

HARRY LAWROSKI

Senior Safety Expert

Association: Consultant

Experience: 38 Years

- Superintendent of Operations, Plutonium and Uranium Fueled EBR-II Reactor, Idaho National Engineering Laboratory
- Manager of Design and Construction, Zero Power Plutonium Reactor, Idaho National Engineering Laboratory
- Assistant General Manager, Chemical Processing Plant, Idaho National Engineering Laboratory
- Consultant: nuclear and fossil energy producers; safety research in nuclear reactor fuels; research and development in petroleum refining and petrochemicals; Electric Power Research Institute; President's Commission on Three Mile Island; fourteen nuclear utilities

Education: Ph.D., Chemical Engineering, Pennsylvania State University

CSAT Team Responsibilities

- Investigated propagation of error in material balances, including residue
- Interviewed union, health physics, and management personnel
- Evaluated a Criticality Safety Committee meeting
- Reviewed Rockwell criticality analysis of Building 771 incinerator
- Reviewed Rockwell senior management involvement with criticality safety
- Evaluated the role of Quality Engineering and Control (QA) in criticality safety

WILLIAM J. MARAMAN

Plutonium Technology

Association: Consultant

Experience: 45 Years

- Chemical and Metallurgical Processes, Los Alamos National Laboratory
- Construction Project Manager of Los Alamos TA-55 Facility for processing and research on plutonium.

Education: M.S., Mechanical Engineer (Nuclear Option),
University of New Mexico

B.S., Chemical Engineering
University of Texas, Austin

CSAT Team Responsibilities:

- Evaluated ventilation systems in various plant buildings
- Researched material balance losses to detect potential for holdup in ventilation systems
- Reviewed records on fissile materials found in process system filters
- Reviewed data on plutonium residue drum inventory
- Reviewed lessons learned from 1969 fire as related to criticality safety

ROGER J. MATTSON

Team Leader and Senior Safety Expert

Association: Vice President, SCIENTECH, Inc., Rockville, Maryland

Experience: 25 Years

- Nuclear Facility Design, Sandia Laboratory
- Nuclear Safety Regulation, Atomic Energy Commission and Nuclear Regulatory Commission
- Radiation Surveillance and Emergency Preparedness, Environmental Protection Agency
- U.S. Response to accidents at Three Mile Island and Chernobyl
- Safety Principles, International Atomic Energy Agency
- Safety reviews of Hanford and Savannah River

Education: Ph.D., Mechanical Engineering, University of Michigan

CSAT Team Responsibilities:

- Directed Team activities
- Addressed media accounts of criticality safety allegations
- Reviewed employee concerns for criticality safety raised to plant management in the past
- Conducted inspections of Buildings 881 and 444 for the Team and investigated related issues

JAMES F. MEYER

Safety Analysis Expert

Association: SCIENTECH, Inc., Rockville, Maryland

Experience: 25 Years

- Accident Analysis, Nuclear Regulatory Commission
- Plutonium fueled reactors, Argonne National Laboratory: supervision and experimentation
- Probabilistic Risk Assessment

Education: Ph.D., Nuclear Engineering, Pennsylvania State University

CSAT Team Responsibilities:

- Reviewed history of ventilation system renovations
- Evaluated program for safety analysis and criticality safety of stored plutonium residue
- Investigated tiered storage of 55-gallon and 10-gallon residue drums
- Inspected residue storage in Buildings 371 and 776 for criticality issues

J. ERNEST WILKINS, JR.

Senior Safety Expert

Association: Consultant

Experience: 47 Years

- Deputy General Manager for Science and Engineering of EG&G, Idaho
- Visiting Scientist, Argonne National Laboratory
- Theoretical physics and computational research, General Atomic Company
- Professor at Tuskegee Institute and Howard University
- Advisor, State of New York, Atomic Energy Commission, National Research Council, National Science Foundation, U.S. Army

Education: Ph.D., Mathematics, University of Chicago
M.M.E., Mechanical Engineering, New York University

CSAT Team Responsibilities:

- Searched for material balance problems related to criticality safety of ventilation systems
- Reviewed records for indication of criticality safety concerns
- Evaluated the use of the KENO code in criticality calculations at Rocky Flats Plant
- Reviewed 1957 fire for possible criticality safety issues
- Reviewed DOE Albuquerque Field Office audits of Rocky Flats Plant criticality safety

ROBERT E. WILSON

Criticality Safety Expert

Association: Westinghouse

Experience: 23 Years

- **Manager, Criticality Safety, Westinghouse Idaho Nuclear Company, Idaho Chemical Processing Plant**
- **Member, Plant Safety Review Committees--Radiation and Safety Committee, Chair Fissile Material Handling Committee**
- **Professor, Criticality Safety, University of Idaho; faculty, Criticality Safety, University of New Mexico**

Education: Ph.D., Nuclear Engineering, University of Washington

CSAT Team Responsibilities:

- **Defined quantities of fissile material that are of a criticality concern under normal and abnormal plant conditions**
- **Evaluated philosophy of process line operation to assure compliance with criticality safety limits**
- **Evaluated practice of controlling operations using parameters that have no specified safety limits**
- **Addressed control of process system configuration affecting criticality safety limits**
- **Investigated the criticality evaluation process, including plutonium in solutions**
- **Interviewed certified Criticality Engineers to learn about any concerns for criticality safety**
- **Considered the potential for nonplanar arrays of components which might fall from conveyers**
- **Inspected Building 886 critical mass laboratory**

LAWRENCE J. YBARRONDO

Deputy Team Leader and Senior Safety Expert

Association: President, SCIENTECH, Inc.

Experience: 29 Years

- Managed nuclear facility design, construction, analysis, testing, and operations for four reactors, Idaho National Engineering Laboratory
- Associate General Manager for Nuclear Technology, EG&G, Idaho
- Assisted United States Government in responding to accidents at Three Mile Island and Chernobyl

Education: Ph.D., Mechanical Engineering, Georgia Institute of Technology

CSAT Team Responsibilities:

- Assistance to the Team Leader
- Quality assurance review of Team assignments and reports

APPENDIX C
SUMMARY OF PLANT BUILDINGS

List of buildings toured by the Team:

371	PLUTONIUM RECOVERY FACILITY
444	BERYLLIUM AND LOW ENRICHED URANIUM MANUFACTURING, FOUNDRY AND ASSEMBLY FACILITY
707	PLUTONIUM MANUFACTURING AND ASSEMBLY FACILITY
771	PLUTONIUM RECOVERY FACILITY
776/777	PLUTONIUM MANUFACTURING, PROCESSING, AND ASSEMBLY FACILITY
881	FORMERLY URANIUM AND PLUTONIUM OPERATIONS

BUILDING 371 - PLUTONIUM RECOVERY FACILITY

Purpose: **ORIGINALLY:** To recover plutonium from all (usually solid) residues generated by plutonium-related fabrication, assembly, and research activities; to convert the recovered plutonium into high-purity metal buttons; and to recover associated americium and convert it to americium dioxide.

CURRENTLY: Used for plutonium residue drum storage and material packaging

PLANNED: To replace Buildings 771 and 776 component retirement processing.

Size: **AREA:** 342,000 sq. ft.
STAFFING: 150 workers; 5-day, 2-shift operation

Built: 1976 - 1981 (Built with inoperable process systems).

Safety Analysis Report:

The SAR section on criticality (6.3.1) has not been reviewed since it is dated July 1981 and does not reflect the current use of the building.

BUILDING 444 - BERYLLIUM AND LOW ENRICHED URANIUM MANUFACTURING, FOUNDRY, AND ASSEMBLY FACILITY

Purpose: Beryllium and uranium component assembly; assembly/disassembly areas for non-fissile parts; machining of depleted uranium and beryllium; component coating facility; support for Buildings 707 and 460; and support for tooling, tool grinding, and carbon molds.

Size: AREA: greater than 200,000 sq. ft.
STAFFING: 325; 5-day, 2-shift operation

Built: 1953

New exhaust systems for the work surfaces have been installed in the beryllium processing area within the past five years to improve worker protection.

Safety Analysis Report:

The SAR for Building 444 was not reviewed since there is no criticality safety problem in that building

BUILDING 707 - PLUTONIUM MANUFACTURING AND ASSEMBLY FACILITY

Purpose: This building is primarily used for plutonium fabrication and component assembly into nuclear weapon components. It also has special facilities for plutonium storage. Major operations include metallurgy, fabrication, assembly, inspection, and non-destructive testing.

The radioactive metals that are handled in this building are mostly solids rather than liquids.

Size: AREA: 200,000 sq. ft.
STAFFING: 350 workers; 5-day, 3-shift operation

Built: 1970

Safety Analysis Report:

See the Building 776/777 SAR criticality safety section discussion presented below in this appendix.

BUILDING 771 - PLUTONIUM RECOVERY FACILITY

Purpose: The principal operation performed in Building 771 is the recovery of plutonium from scrap solids, solid residues, and various liquid process streams during plutonium-related fabrication, assembly, and research operations throughout the Rocky Flats Plant.

The basic operations conducted in the building are:

- chemical and physical processes for recovering and refining plutonium metal and americium oxide;
- plutonium chemistry research; and
- radiochemical analyses of samples for isotopic content, impurities, and trace elements.

Size: **AREA:** 151,000 sq. ft. (including expansions)
 STAFFING: 475 workers; 7-day, 3-shift operation

Built: 1952

Safety Analysis Report:

In this building, solution as well as metal criticality events are possible. The frequency of occurrence of a solution and metal criticality by the use of fault tree methodology is given as 2.0×10^{-4} per year and 3.0×10^{-5} per year, respectively. The SAR does not relate these frequencies to operational experience and appears to be inconsistent with experience (see the discussion for Buildings 776 and 777, below).

BUILDING 776/777 - PLUTONIUM MANUFACTURING AND ASSEMBLY FACILITY

Purpose: Fabrication and manufacturing processes in Buildings 776 and 777 support the weapons production processes in Building 707 on a regular and standby basis.

The three major functions for these buildings are:

- Solid waste processing,
- Retirement Pu recovery, and
- Weapons component manufacturing.

Examples of operations performed include: machining and fabricating plutonium metal parts; making special assemblies; disassembling site-return units; refining plutonium metal; conducting radiographic and other nondestructive tests; waste operations including size reduction and drum storage; and developing new techniques for manufacturing metal components

Size: **AREA:** 231,000 sq. ft.
 STAFFING: 250; 5-day, 2-shift operation

Built: 1957

Appearance: Water stains and mineral deposits on walls and floor in basement. The stains and deposits may be the result of groundwater seepage. The building has had previous problems with roof leaks and water collection in the basement drum storage area such that some drums were rusting and had to be cleaned.

Safety Analysis Report:

The risk from criticality events is reported in Section 8.1.4 of the Final Safety Analysis Report (June 1987) for Buildings 776 and 777. This section states that a solution criticality is not credible due to the low solution concentration in the Buildings and because there are few locations in the Buildings that handle or store fissile solutions. The information provided in the SAR is insufficient to verify that the risk from solution criticality is negligible.

According to Section 8.1.4, a metal criticality event is credible due to the quantities and frequency of use of plutonium metal and the large number of human interactions in the handling and storage of plutonium metal in the Buildings.

The annual frequency (risk) of a metal criticality is estimated in the SAR as 3.0×10^{-4} . The SAR also states that the "number of fissions for this criticality is obtained from the average size of past criticalities." This implies that criticality events have occurred. If one would assume that only one such event occurred and the operating history spans 100 years, a frequency of 1.0×10^{-2} per year would be indicated. The Team has determined by its own analysis that an average of one criticality event per 80 plant years have occurred in DOE processing facilities other than Rocky Flats Plant as of 1980. This frequency appears to be inconsistent with the calculated frequency in the SAR; however, the SAR discussion does not relate the calculated numbers to the experience record.

The SAR provides the frequencies for groups of initiating events (fires, explosions, spills, criticality, etc.) but does not provide any information on the causes for individual initiating events (e.g., spacing violations or mass limitations exceeded) within a group. However, to judge or accept the risk results, knowledge of the contributors (and how they were derived and treated) is essential.

A particular concern is the treatment of human errors. Although the involvement of humans in the process is mentioned, the treatment of human errors in the risk analysis is not addressed. The SAR does not include sufficient detail. At least basic assumptions and data, as well as the process, used to derive the results need to be documented. The example calculation in Appendix C of the SAR is insufficient.

BUILDING 881 - FORMERLY URANIUM AND PLUTONIUM OPERATIONS

Purpose: This building is currently used as an analytical and environmental laboratory (non-plutonium materials) and computer center. It provides maintenance and R & D support (robotics, testing of plutonium process line developments). Included in this building are a small machine shop and an information systems management center. Building 881 was previously used to process U-235 components and to process plutonium to a limited degree, which has led to concerns for fissile materials that might have accumulated in old ductwork.

Size: AREA: 245,000 sq. ft.

STAFFING: 350; 5-day, 3-shift operation

Built: 1953

The Main Plenum System in Building 881 was replaced from 1985 to 1987.

The Laboratory was renovated during 1988 and 1989.

APPENDIX D

MEASUREMENT DATA

As discussed in the main body of the report, the Team conducted actual measurements of ventilation ducting (see Section 3.2.3) and storage drums (see Section 4.3). The actual data which were collected are provided in this appendix.

The Team directed plant personnel to conduct nondestructive assay (NDA) measurements at locations and for drums selected by the Team. The Team then supervised and monitored the actual calibration of the instruments and the collection of data. The data were then evaluated by the Team.

The portable instruments used for measurements detect gamma radiation by use of crystal sensors: the high purity germanium (HPGe) crystal and the sodium iodide (NaI) crystal.

Both instruments were calibrated over a range (75-506 grams) of plutonium residue standards in order to maximize the accuracy of the measurements. The NaI calibrations and measurements were done using direct contact with the calibration sources and the ducting. The HPGe measurements of the ventilation ducts and the associated calibration data were both taken at the same range. In measurements of line 43C in Building 771, the HPGe instrument was recalibrated in the middle of the data collection process. Five readings on this instrument were conducted at each location. Each HPGe reading (collection of gamma energy spectra) was for 100 seconds. Similarly, five NaI measurements were taken at each point, but only 10 seconds were needed for each measurement.

1. Residue Drums -- Measured in Passive-Active Neutron Counter

Drum ID No.	Content Code	Tag Value (grams of plutonium)	Measured Value (grams of plutonium)	Ratio of (Meas./Tag Value)
D575500107258	312	988	903±58	0.91±0.06
D420890258052	331	349	446±74	1.28±0.21
D149900104660	310	961	1238±174	1.29±0.18
D619190911673	336	130	145±51	1.12±0.39
D618500257461	331	182	209±36	1.14±0.20
D382500600709	336	25	26±21	1.04±0.84
D624350257994	331	427	482±65	1.13±0.15
D48381214729	300	42	27±3	0.64±0.07
D242720105653	420	872	1478±833	1.69±0.96
D171130104851	310	932	1460±396	1.57±0.42
D314390105721	420	789	1055±496	1.34±0.63
D143730107372	310	1211	1463±676	1.21±0.56
D411949206958	331	6	6.7±.6	1.12±0.10

2. HPGe Spectral Data

Description	Net cps for 376+414			Line 43C gram/feet **
	355 kev net cps	376+414 kev	Calib. (cps per gram)	
Background room 147	366.1	1.1		
75 gram standard @ 36"	363.5	9.1	0.121	
150 gram standard @ 36"	362.5	18.2	0.121	
195 gram standard @ 36"	359.9	21.1	0.108	
362 gram standard @ 36"	357.0	28.8	0.080	
501 gram standard @ 36"	359.2	45.2	0.090	
Line 43C background	372.0	11.4		
0N, 34" under line	357.4	60.4		151
2N, 34" under line	354.0	63.4		158
3N, 34" under line	351.4	68.2		170
12N, 30.5" under line	348.7	47.2		118
16N, 34.75" under line	337.1	77.1		193
18N, 34.75" under line	329.9	78.6		197
20N, 34.75" under line	325.1	82.9		207

* Live time correction using 355 kev, $1/r^2$ correction to 36"

** Uses calculated FWHM=4.0 feet, average calibration (376+414): 0.1 cps/gram

3. JHH.02 Nal Data. Line 43C. Building 771. Room 149

Measurement Location (Feet N or S)	Net cps	Grams of Plutonium (per foot of duct)
Room background	8.0	-
6S	0.3	4
3S	41.9	33
0 Foot reference	205.9	163
1N	99.4	79
2N	197.7	157
3N	199.8	159
4N	182.2	145
5N	166.0	132
6N	141.8	113
7N	12.3	89
8N	87.3	69
9N	62.2	49
10N	43.7	35
11N	34.8	28
12N	40.1	32
13N	26.5	21
14N	21.7	17
15N	92.9	74
16N	245.8	195
17N	189.1	150
18N	130.1	103
18.5N	118.5	125
19N	154.1	163
20N	197.0	208
21N	178.0	188
22N	156.8	166
23N	120.3	127
24N	104.6	111
25N	120.3	127
26N	105.7	112
27N	106.4	113
28N	100.9	107
29N	104.1	110
30N	91.1	96

4. JHH.02 NaI Data. Standards Calibrations

Description	Net cps	Net cps/gram
92 grams Pu	65.2	0.709
195 grams Pu	142.4	0.730
362 grams Pu	184.0	0.508
506 grams Pu	292.7	0.578
4 standard average		0.631±0.106

NOTE: These are the Rocky Flats Plant "500" series of plutonium standards used to calibrate can and drum counters. They are 6" diameter and 12" high.

Calibration model: cylindrical ducting is "coated" with active source material on 50% of surface area. Calibration sources have active source material on 100% of all internal surface areas. Thus, the Team has a factor of 2 ratio between observed calibration cps/gram and model duct source. The "effective" model source is cps/gram=1.262. This is the calibration factor for 6" diameter ducting. For a different diameter duct, correct for the different surface area, i.e., 8" diameter duct, cps/gram=(1.262)(6/8)=0.95.

5. Additional JHH.02 NaI Data Taken in Building 771

Description	Net cps
<u>Room 149. Miscellaneous Measurements Near Residue Incinerator</u>	
Room background	3
Heat exchanger, position #1	17
Heat exchanger, position #2	12
Heat exchanger, position #3	11
Heat exchanger, position #4	28
Duct elbow, 4 feet downstream	35
Spray chamber, duct elbow	2
Exhaust header, 20 feet downstream	6
<u>Anion Exchange Exhaust Duct</u>	
Position #1	0
Position #2	6
Position #3	8
Position #4	4
<u>FU2 Zone 2B</u>	
At elbow of 6" line	6
At "X" marked on duct	35
1 foot downstream of "X" mark	22
Background 4 feet down from duct	3

1 feet upstream from "X" mark	20
At exit of line to room 148	3

Adjacent 6" Line--GB Vacuum Pumps

Background 4 feet from line	1
Anion exchange exhaust	3
Mist tank/fume scrub line	2

Fluoride (GB 107) Exhaust Ducts

Background	4
At first "Y"	52
At second "Y"	90
At bend ("CV" mark)	120
2 feet downstream	38
Just after "GB Vac" sign	35
8" line by weld mark	33
8" line at "GB VAC" sign	37
10" line 15 feet downstream from 8"	42
10" line at exit from room	34

Calciner (GB 16) Exhaust Ducts

Room background	7
6" line after 3 duct entry point	32
Downstream at "GB VAC" sign	73
Midpoint of last two measurements	108
At upward bend point	114
Just beyond up bend	62
Midway along upslope section	31

6. JHH.02 NaI DATA TAKEN IN BUILDING 707 (Refer to diagram for arrangement.)

Description	Net cps
-------------	---------

GB J-60. First Filter Exhaust Valve Line

Room background	7
Bottom, first elbow	40
Top, first elbow	140
4" downstream, net weld	137
Under plug	42
Weld downstream of plug	45
Bypass intersection	39

GB J-60. Second Filter Exhaust Valve Line

Room background	5
At flange	47
Weld downstream from flange	83
Intersection with second bypass line	58

First weld of vertical elbow	34
Top weld, wall side	7
Next weld	32
Flange at wall	22
Top of filter	200
Bottom of filter area	204
Above flange at weld	53

GB J-60 Third Filter Exhaust Valve Line

Top of filter	220
Bottom of flange	116
Top of weld elbow	30
Middle of pipe run along GB wall	15
Downstream weld, oblique elbow	14

Building 707, Module B, Column 4J

(No exhaust filters)	
Room background	18
Line 1 blue valve flange	6
Downstream flange	10
Elbow, downstream weld	5
Line 2 blue valve flange	19
Downstream flange	97
Main line weld at cross 1,2	24
Junction weld cross 1,2	73
Main line upturn elbow	0

DIAGRAM OF GB J-60 AREA

7. JHH.02 NaI Data Taken in Building 776. (Refer to diagram for locations.)

Description	Net cps
-------------	---------

GB 206-501 Area (Lead Covered Pipes)

Room background	2
Pipe bottom at 206-501 exhaust (1)	71
Top, blue valve flange (2)	13
Upstream weld, first bend section (3)	11
Downstream of vertical elbow (4)	6
Bend area (5)	5
Upstream connection to main line (6)	2
Downstream connection to main line (7)	3

GB 046 Area (Lead Covered Pipes)

Room background	4
Middle first horizontal run	31
Same line, at downstream bend/rise	11
Vacuum line, expansion fitting	7
Under first elbow	26
First horizontal elbow upstream	50
Downstream joint	53
Top of piping (no lead covering)	73
Middle of horizontal pipe	23
Vertical elbow, upstream	22

Inert Return Line B Area

Room background	1
Flange upstream of valve	1
Downstream of first vertical elbow	1
Middle of first horizontal line	31
2 feet back from vacuum line	2
First horizontal elbow	1
Upstream of second vertical elbow	10

DIAGRAM OF GB'S MEASURED IN BUILDING 776

APPENDIX E

WORKER RADIATION EXPOSURE RECORDS

An accidental criticality will generate high levels of neutron and gamma radiation. An event yielding 10^{17} fissions would produce a dose equivalent of about 500 rem at 3 meters. Most criticality accidents in the past have resulted in large exposures to individuals; in a few cases there have been worker fatalities.

Many of the processes at the Rocky Flats Plant are labor intensive and require the presence of operators and monitors. It is reasonable to conclude that if a criticality accident had occurred, people would have been in the vicinity. Since all workers carry personnel dosimeters, past records of radiation exposure might provide a clue regarding the possibility of a previous accident.

Personal radiation exposure records have been kept for all active and retired employees of the Rocky Flats Plant. In addition, several DOE laboratories have tabulated statistics with regard to annual exposures at the Rocky Flats Plant.

Since the plant started operations in 1953 there have been over 10,000 employees. A selection criterion was established by the Team for the purpose of investigating high annual exposures without having to review thousands of files unnecessarily. The following procedure was developed:

- a) from 1953 to 1967 any recorded annual exposure greater than 6 rem was selected for review; and
- b) from 1968 to the present any recorded annual exposure greater than 4 rem was selected for review.

Using this procedure, the Team identified 195 employees having high exposures from over 100,000 person years of exposure records.

Employee records were retrieved for these identified exposures and the files were reviewed by a Team member in the presence of a health physics employee of Rockwell International. The objective of the Team's review was to determine if the high exposure could be attributed to a single event rather than continuous exposure of the individual during routine operations.

The review was completed for 181 of the 195 high exposures. From this set of data, four events were unusual in the sense that the high exposure occurred during a single badge change period (two weeks to three months). Individuals associated with these events were interviewed along with other plant personnel who were familiar with the situation at the time of exposure. In all cases but one, the high exposures were attributed to special operations at the plant. The one exception involved an accident with a Cobalt-60 source. In no case was there any observation or indication that a criticality accident had occurred.

The 14 high exposures that were not reviewed occurred before 1958. The record keeping system at that time did not identify the names of individuals receiving more than 6 rem. The annual limit was based on 3 rem/quarter or 12 rem/year. The Team decided that it would be of marginal benefit to locate and search through the files of all individuals employed during that period, so the Team focused on the last 30 years of records.

APPENDIX F

VENTILATION SYSTEMS AND RENOVATION RECORDS

In this Appendix, information about the various ventilation systems is provided, followed by a discussion of what fissile materials were found during the renovations made to ventilation systems.

PLUTONIUM FACILITY VENTILATION

The Team was provided a detailed briefing on the various ventilation systems. The figures that are included at the end of this appendix were provided by Rocky Flats Plant.

There are two main functions for heating, ventilating, and air conditioning (HVAC) systems in plutonium handling facilities. The HVAC system should provide a safe, comfortable working environment for personnel and equipment; and it is an important factor in containment of plutonium particles. This containment function is accomplished by controlling the static differential pressure between the various areas within the building. Air should flow from areas of least potential for contamination into areas of greatest potential and then be exhausted through very efficient filters so that there is essentially no release to the environment.

As shown in Figure F-1, there are three containment zones through which the air flows. The primary containment is a glovebox or work chamber. The primary zone (Zone I) is maintained at a static pressure of -1.05 inches of water gauge (W.G.) referenced to the outside of the building. Work chambers are surrounded by rooms in which the operators work (Zone II) that are maintained at -0.30 inches W.G. The corridors giving access to the laboratory spaces and service spaces are Zone III and are maintained at -0.15 inches W.G. These steps down in pressure from the areas of least potential for contamination to areas of greatest contamination, when combined with the proper air flow volumes, serve to contain the plutonium and minimize the magnitude and spread of contamination through leaks. Excessive air flows will cause turbulence, which will increase the the potential for the spread of contamination. Inadequate air flows will not maintain the pressure differentials needed to contain contamination.

The proper conditions of flow and pressure are achieved through the use of two ventilation systems: building and glovebox. Figures F-2 through F-5 should be examined in conjunction with the discussion that follows.

Types of Building Ventilation

There are two types of ventilation systems for plutonium processing buildings: single pass and recirculation. Older buildings at the plant, such as Building 771, employ single pass ventilation, which was the state-of-the-art at the time of their construction. Recirculation systems were used in later designs, for example, in Building 707.

In either case, air from outside the building or from the second floor mechanical area is conditioned by preheating, filtering, precooling, dehumidifying, and reheating, as shown in Figures F-2, F-3, and F-4. For buildings, the air is supplied to Zones II and III. For example, air is drawn from Zone III into Zone II, and then Zone II is exhausted. The exhausted air passes through a heat absorption chamber and through two banks of high efficiency particulate air (HEPA) filters before being blown out of a stack. All banks of HEPA filters are tested in place with dioctylphthalate (DOP) to assure that they are efficient in removing particles from the air.

Recirculation of air is accomplished by routing air from the discharge of the second HEPA filter bank back through another bank of HEPA filters into the incoming air path for Zones II and III. The amount of recirculation depends on building needs and static pressure control.

Part of the conditioned air is supplied to the corridors (Zone III). This air leaks into rooms (Zone II) containing the gloveboxes. The bulk of the air stream is supplied directly into Zone II through a diffusion ceiling. Zone II air is exhausted through furnace-type filters on grilles into ducts. The grilles are located near the floor.

The heat absorption chambers located ahead of the HEPA exhaust filters in the buildings at Rocky Flats Plant were designed, tested, and installed after the 1969 fire. Incoming air to the heat absorption chamber impinges on a baffle plate, flows through a chamber into a metal screen (mist eliminator), and then flows into the first and second HEPA filter banks. The space before the screen is protected by an automatic sprinkler system which actuates automatically and triggers various alarms when the air reaches 190°F. A manually controlled sprinkler system covers the volume between this fire screen and the first bank of HEPA filters. (Water will damage HEPA filters and reduce their ability to filter.) These plena are provided with criticality drains which funnel water to special tanks designed to hold the fire-fighting water. The height and diameter of these drains are designed to accommodate a geometrically safe slab of water and plutonium without permitting a nuclear criticality accident.

The exhaust filters at Rocky Flats Plant are performing well. The total plutonium discharged from all sources at the plant in 1986 was estimated to be 21 micrograms; in 1987, the total discharge was estimated to be 22 micrograms.^{1,2}

Types of Glovebox Ventilation

There are three types of ventilation systems for gloveboxes used for plutonium processing. These are recirculating inert gas (nitrogen rich), single-pass dried air, and room air, as shown in Figures F-2 and F-3. All glovebox exhaust streams pass through four stages of HEPA filters (see Figure F-5) before finally being exhausted

¹ "Annual Environmental Monitoring Report, January-December 1986," Rocky Flats Plant report ENV-86.

² "Annual Environmental Monitoring Report, January-December 1987," Rocky Flats Plant report ENV-87.

to the outside atmosphere. Each stage of these filters receives a DOP efficiency test in place. These banks are protected from fire by the same type of heat absorption chamber that is used with the building filters.

Inert Gas Gloveboxes

Some of the gloveboxes in plutonium processing buildings at Rocky Flats Plant are supplied with nitrogen to reduce the potential for fire. The flow of the nitrogen-rich air mixture is from the gloveboxes (and certain vault rooms), through two stages of HEPA filters, through coolers and heaters to reduce moisture, and back into the gloveboxes. Fresh nitrogen is added to the supply side to maintain a proper oxygen level in the supply (less than 3.5%) and gloveboxes (less than 5%). A bleedoff of the exhaust to accommodate the fresh nitrogen input is passed through two more banks of HEPA filters before being exhausted to the atmosphere.

The nitrogen inlets into the gloveboxes are not filtered, but almost all of the exhaust outlets are filtered. These exhaust filters are standard 8-inch by 8-inch HEPA filters, which are rated at 35 cfm at Rocky Flats Plant. This flow rating is lower than the generally accepted 50 cfm per filter.

Single-Pass Dried Air Gloveboxes

Operations in certain gloveboxes are provided with a dried air atmosphere. In this system, the inlet air passes through a single HEPA filter bank, into a two-stage dehumidifier, through a bag-type filter, through reheat coils, into the supplied air ducts, and finally into the gloveboxes. The supplied air into the gloveboxes is not filtered at the glovebox inlet. The glovebox air is exhausted through a standard 8-inch by 8-inch HEPA filter into ductwork. The combined exhaust from several gloveboxes passes through a heat absorption chamber and four banks of HEPA filters before being exhausted to the atmosphere.

Room Air Gloveboxes

Operations which do not require nitrogen-rich or dried air atmosphere are supplied with room air. This air enters the gloveboxes through HEPA filters. The room air glovebox exhaust is handled in the same manner as the dried air glovebox exhaust.

VENTILATION SYSTEM RENOVATION RECORDS

Ductwork renovation records were reviewed to obtain insight into how much plutonium and other fissile materials currently reside in the ductwork ventilation systems.

The Team addressed the following questions in examining the Rocky Flats Plant renovation Records:

1. What is the history of past renovations? What procedures were used? What organization was in charge? Was Criticality Engineering included in the renovation approval process?
2. What is the present practice at Rocky Flats Plant? What are the present ductwork renovation plans?
3. In any of the renovations to date, have substantial amounts of plutonium or other fissile materials been found?

The Team requested renovation records for any ductwork that might have contained sizable amounts of fissile material. Specific records for the following renovations were reviewed:

- Cleanup of ductwork after the 1969 fire in Building 776
- Duct replacement to FU-1 in Building 771
- Header replacement in line 24 of Building 771
- Changeout of the J cell ducts in Building 707
- Plenum system replacement in Building 881 in 1985
- Renovation (phase III, 4/87) of Building 881

Unfortunately, the record keeping was not complete for some of the renovations reviewed. In addition, the type of records varied from one renovation to the next. Nevertheless, the following conclusions were drawn by the Team following the review:

- The focus of the measurements for plutonium made before, during, and after the modifications was primarily on radiation safety and worker exposure. Thus, quantitative measurements of plutonium content for criticality safety evaluations were not made consistently. Some quantitative data were found for work done in the late 1970s. General radiation readings recorded for the worker environment were satisfactory for radiation safety and can not be used to infer a criticality safety problem.
- In the cases where quantitative data were found, the amount of fissile material ranged from gram to kilogram quantities. This would be expected, depending on the length of time the ductwork was in service, the environment to which it was exposed (some processes are much more dusty than others), and whether there had been prefilters installed upstream of the ductwork.
- The management at Rocky Flats Plant was (and perhaps is) sufficiently compartmentalized that records of the fissile materials found during the

renovations were not adequate, were not assessed from a criticality accident perspective, seldom were passed on from one management generation to the next, and rarely crossed organizational lines. Thus, information was fragmented and not readily available for criticality safety evaluations.

- The lack of "as-built" drawings for use in planning and executing ductwork modifications is a significant disadvantage in the process and could become a criticality safety concern. Unknowns of this type, when dealing with fissile material processing lines, are problematic. The Team was told that no maintenance work orders (including routine duct replacement) are put on "as-built" drawings
- During some of the renovations, the ductwork was gamma scanned and surveyed for contamination, but the contents of the ducts were not analyzed. For example, in the line 24 header stripout (Building 771), scan records are available, but apparently the solid salt material found in the header was not sampled or identified.
- From the records reviewed, the most significant find of plutonium in ductwork was identified in the ducting cleanout and replacement records for Building 771. During the mid-to-late 1970s, routine surveys of the ductwork in Building 771 were performed. The records are clear that kilogram quantities of plutonium were detected, with some in concentrations greater than 100 grams per foot. Yet it appears that, when the actual renovations were accomplished, analyses of the contents of the ducts were either not done or not recorded. This information was not known to high-level Rocky Flats Plant management in August 1989, including engineering and operations managers.
- The HS&E organization, which includes Criticality Engineering, approves all ductwork modifications; however, the organization typically must approve 200 work orders per month. Thorough reviews of criticality issues must be very difficult to complete, considering the present Criticality Engineering staffing level and qualification as discussed in Section 5.2.

DIFFERENTIAL PRESSURE ZONES

Figure F-1

INERT GLOVEBOX SYSTEM

Figure F-2

DRY AIR GLOVEBOX SYSTEM

Figure F-3

ROOM VENTILATION SYSTEM

Figure F-4

*Different risers within the building provide redundant supply.

PLENUM FIRE PROTECTION

Figure F-5

APPENDIX G

CRITICALITY INFRACTIONS DATABASE

In this appendix, the descriptions and root causes of the criticality safety infractions which occurred from January 1983 through July 1989 are provided for information. This database was used to develop the analyses provided in Section 5.5 of the report.

Inclusion of such detailed information is considered necessary, both to better inform the public as to the exact nature of criticality safety procedure infractions and to substantiate the recommendations for improvement provided by the Criticality Safety Assessment Team.

The Team believes this listing shows that the reported "frequent criticalities" at the Rocky Flats Plant are actually only procedural violations. Nevertheless, the Team is concerned that many of these infractions reflect an attitude of complacency and, thus, could be avoided by improving worker and supervisor indoctrination on the need for significantly enhanced emphasis on safety at nuclear facilities. Sustaining an awareness of and the long-term respect for nuclear material safety limits in 100 percent of the work force is a very difficult task.

Criticality Safety Procedural Infraction Database

Infraction	83-01	Date	1/24/83	Location	Bldg 707
Description	A pendant broke off chainveyor; when it was replaced by Maintenance, the pendant spacing was reduced to 48 inches. A minimum of 54-inch spacing is required.				
Category	Spacing violation			RC Category	P1
Root Cause Description	The cause of this infraction was an error by Maintenance personnel in not maintaining the proper spacing as required in the Nuclear Material Safety Manual. Also, an error was made by the person filling out the work order in not stating the expectations of the Maintenance Department and for not following up by checking to see whether the work was done properly.				

Infraction	83-02	Date	2/1/83	Location	Bldg 771
Description	Maximum container size limit violated in glovebox 153D.				
Category	Volume violation			RC Category	M3/P1
Root Cause Description	A precipitator pot was needed in the glovebox. Its size exceeded the posted general NMSL. The operator violated the limit by allowing the pot in the box. The pot could have been allowed in the box had management used the alternative NMSL for the box.				

Infraction	83-03	Date	2/15/83	Location	Bldg 371
Description	Material inadvertently transferred from tank D152B through a leaky valve (D152B had not been sampled).				
Category	Unauthorized operation			RC Category	Pr3/E3
Root Cause Description	The existing procedures for circulation and transfer of waste failed to include verifications of valve positions for valves affecting the transfers. The valve position indicator panel and transfer valves need to be tested regularly and included in the preventive maintenance program.				

Infraction	83-04	Date	4/13/83	Location	Bldg 776
Description	Foreman authorized the stacking of drums before safety limits were issued.				
Category	Other (Stacking violation)			RC Category	M2/P1
Root Cause Description	Lack of attention to the procedure requirements by both supervision and operator.				

Infraction	83-05	Date	4/15/83	Location	Bldg 776
Description	Incorrect size of containers used during a valve cleanout.				
Category	Volume violation			RC Category	P5
Root Cause Description	Failure of workers to follow temporary NMSL was due to miscommunication.				

Criticality Safety Procedural Infraction Database

Infraction	83-06	Date	4/15/83	Location	Bldg. 371
Description	A plastic enclosure was constructed without criticality safety slits.				
Category	Volume violation			RC Category	P1
Root Cause Description	Operators did not give proper attention to conducting their work assignment.				

Infraction	83-07	Date	4/21/83	Location	Bldg 771, Room 114
Description	Mass limit exceeded in a dissolver on line 5.				
Category	Spacing violation			RC Category	P1
Root Cause Description	Lack of follow-through activities to verify that the task was effectively performed. This operation was being performed by two operators, one experienced and the other inexperienced. The experienced operator did not provide adequate supervision to the less experienced operator.				

Infraction	83-08	Date	4/22/83	Location	Bldg 707, Module K
Description	Weight limit exceeded on a scale.				
Category	Mass violation			RC Category	P1/M3
Root Cause Description	Personnel failed to pay attention to the NMSL when weighing material. A contributing factor was the different weight limits in K-45. Requests were made to make the weight limits uniform, but this request was still under evaluation. This delay is indicative of management complacency.				

Infraction	83-09	Date	4/23/83	Location	Bldg 371
Description	A criticality drain was plugged by an inexperienced operator.				
Category	Other (Criticality drain violation)			RC Category	M3/P4
Root Cause Description	Management failed to provide proper training.				

Infraction	83-10	Date	5/9/83	Location	Bldg 371
Description	Drums stacked in an unauthorized configuration.				
Category	Other (Stacking violation)			RC Category	P1
Root Cause Description	Personnel complacency caused the Material Safety Procedures to be ignored.				

Criticality Safety Procedural Infraction Database

Infraction	83-11	Date	7/1/83	Location	Bldg 371
Description	55-Gallon drums stacked in an unauthorized configuration.				
Category	Other (Stacking violation)			RC Category	P1/M5
Root Cause Description	Personnel complacency resulted in exceeding the NMSL. Inadequate training contributed to this infraction.				

Infraction	83-12	Date	7/8/83	Location	Bldg 771, room 149
Description	Mass limit exceeded in a glovebox on line 22.				
Category	Mass violation			RC Category	P1
Root Cause Description	Failure to inspect the glovebox before adding more material was the cause of this infraction. This showed a lack of attention to procedures.				

Infraction	83-13	Date	7/20/83	Location	Bldg 779, Room 137
Description	Number of containers in glovebox 106-1 exceeded limit.				
Category	Volume violation			RC Category	P2/M3
Root Cause Description	A procedure was routinely violated. This infraction was caused by procedural complacency. Management complacency is also evident by the length of time it took to discover this infraction.				

Infraction	83-14	Date	8/9/83	Location	Bldg 776, room134
Description	Depth limit exceeded in a jig bore box in glovebox 752.				
Category	Volume violation			RC Category	M1/E3
Root Cause Description	Failure to repair and maintain a previously damaged valve was the cause of this infraction since the fluid leaked through the valve causing the level to exceed the NMSL. Management did not make provision for the maintenance of this previously damaged valve.				

Infraction	83-15	Date	9/15/83	Location	Bldg 707, Module J
Description	Mass limit exceeded during a casting.				
Category	Mass violation			RC Category	P1/P5
Root Cause Description	The primary cause of this infraction was the day shift operator's failure to check before continuing someone else's work. He did not pay adequate attention. A contributing factor was the poor communication between shift workers.				

Criticality Safety Procedural Infraction Database

Infraction	83-16	Date	9/16/83	Location	Bldg 707, Module J
Description	Mass limit exceeded in glovebox J10.				
Category	Mass violation	RC Category			M3/M5
Root Cause Description	Management failed to provide proper supervision and training of new personnel.				

Infraction	83-17	Date	9/12/83	Location	Bldg 371, glovebox 36.
Description	Mass limit exceeded in the electrorefining area.				
Category	Mass violation	RC Category			P1
Root Cause Description	Operator failed to diligently comply with NMSL.				

Infraction	83-18	Date	9/29/83	Location	Bldg 707
Description	Spacing requirements not maintained between 4-liter waste bottles.				
Category	Spacing violation	RC Category			M1/P1
Root Cause Description	Management failed to provide adequate posting of temporary limit to avoid the infraction. Operators failed to pay adequate attention to safety limits. A contributing factor was the inadequate posting of temporary limits as a result of management's failure to thoroughly plan a course of action to avoid potential infractions.				

Infraction	83-19	Date	10/11/83	Location	Bldg 771, Room 169
Description	Bricks stacked on a transfer cart containing fissile material providing a thickness shield of 4 to 8 inches; the limit is 2-5/8 inches.				
Category	Unauthorized operation	RC Category			P1
Root Cause Description	Lack of regard for posted safety limits on the part of operators.				

Infraction	83-20	Date	10/14/83	Location	Bldg 771, Room 147
Description	Mass limit exceeded in a drum.				
Category	Mass violation	RC Category			P2
Root Cause Description	Operators failed to follow existing procedure.				

Criticality Safety Procedural Infraction Database

Infraction	83-21	Date	10/17/83	Location	Bldg 707, Module A
Description	Mass limit exceeded in a casting mold.				
Category	Mass violation	RC Category		P1/P5	
Root Cause Description	The operator failed to seek clarification of a note that confused him. The cause of this infraction was lack of attention to the task. A contributing factor was poor communication.				

Infraction	83-22	Date	10/26/83	Location	Bldg 707, Module C
Description	Number of containers in glovebox C110 exceeded limit.				
Category	Mass violation	RC Category		M1/M2	
Root Cause Description	Management failed to plan and provide the resources to do the job in a timely manner. The infraction report states that this situation is widespread in the foundry.				

Infraction	83-23	Date	12/1/83	Location	Bldg 771, room 114
Description	Mass limit exceeded in the fluorinator for lines 6 & 7.				
Category	Mass violation	RC Category		Pr3	
Root Cause Description	Based on the summary report of this infraction, the cause was an inadequate procedure.				

Infraction	83-24	Date	12/3/83	Location	Bldg 707, Module K
Description	Mass limit exceeded in glovebox K 45.				
Category	Mass violation	RC Category		M3	
Root Cause Description	Management failed to provide adequate maintenance and calibration schedules for instruments.				

Infraction	83-A	Date	7/23/83 -	Location	Bldg 771, Room 146A
Description	A plastic enclosure was constructed without criticality safety slits.				
Category	Volume violation	RC Category		M7/P3	
Root Cause Description	Management failed to understand the nuclear safety implications related to inadequate training and qualification of personnel performing plant maintenance activities.				

Criticality Safety Procedural Infraction Database

Infraction	84-01	Date	1/17/84	Location	Bldg 771, Room 114
Description	Number of filters in glovebox exceeded limits.				
Category	Mass violation	RC Category		P1/E3	
Root Cause Description	The primary cause of this infraction was a lack of attention to the task when personnel failed to check the NMSL before adding more material. A contributing factor was poor maintenance practice.				

Infraction	84-02	Date	1/24/84	Location	Bldg 771
Description	Open rasching ring tank left unattended by an inexperienced operator.				
Category	Unauthorized operation	RC Category		M7/P3	
Root Cause Description	Management failed to understand the nuclear safety implications related to inadequate training and qualification of personnel.				

Infraction	84-03	Date	1/30/84	Location	Bldg 771, Room 114
Description	Maximum container size violated on line 7.				
Category	Volume violation	RC Category		P1	
Root Cause Description	Operator failed to verify the correct pan size before using it, and thus caused NMSL to be exceeded.				

Infraction	84-04	Date	2/1/84	Location	Bldg 371
Description	Mass limit exceeded in the area				
Category	Other (Stacking violation)	RC Category		P1	
Root Cause Description	Complacency on the part of operator caused NMSL to be exceeded.				

Infraction	84-05	Date	1/30/84	Location	Bldg 776
Description	Mass limit exceeded in a transfer crate.				
Category	Mass violation	RC Category		P1	
Root Cause Description	Complacency on the part of personnel caused NMSL to be exceeded.				

Criticality Safety Procedural Infraction Database

Infraction	84-06	Date	2/2/84	Location	Bldgs 707,776,777,779
Description	HS&E Area Safety manager gave instructions to Production Control personnel which were in violation of established limits.				
Category	Unauthorized operation			RC Category	M3
Root Cause Description	Complacency on the part of the manager caused NMSL to be violated.				

Infraction	84-07	Date	2/6/84	Location	Bldgs 771, 707
Description	Castings were performed in all locations with unapproved tantalum screens.				
Category	Unauthorized operation			RC Category	M2
Root Cause Description	Supervision permitted the use of screens which were not listed in the Nuclear Material Safety Manual.				

Infraction	84-08	Date	2/6/84	Location	Bldg 707
Description	Depth limit exceeded in an oil pan for a lathe in box C60.				
Category	Volume violation			RC Category	P1
Root Cause Description	Complacency on the part of operators caused NMSL to be exceeded.				

Infraction	84-09	Date	2/8/84	Location	Bldg 771
Description	Two criticality drain lines were found obstructed with a screwdriver, broom handle, vial cap, punch, and a nut driver.				
Category	Other (Criticality drain violation)			RC Category	P2/M3
Root Cause Description	This infraction occurred due to a deliberate violation of a procedure. The fact that the material was not discovered for a considerable period indicates management complacency and poor maintenance practices.				

Infraction	84-10	Date	2/15/84	Location	Bldg 559
Description	Maximum container size violated in hood MH 11.				
Category	Volume violation			RC Category	P1
Root Cause Description	Complacency on the part of contractor personnel in observing posted limits.				

Criticality Safety Procedural Infraction Database

Infraction	84-11	Date	2/12/84	Location	Bldg 771
Description	Mass limit exceeded on line 3.				
Category	Mass violation	RC Category			P1
Root Cause Description	Complacency on the part of operators resulted in material exceeding the posted NMSL.				

Infraction	84-12	Date	2/20/84	Location	Bldg 707
Description	A casting was poured into the wrong mold.				
Category	Mass violation	RC Category			Pr3
Root Cause Description	Failure to establish procedures that would minimize human error caused this infraction.				

Infraction	84-13	Date	2/29/84	Location	Bldg 771
Description	Spacing requirements not maintained on a part carrier.				
Category	Spacing violation	RC Category			P1/P2
Root Cause Description	Operator complacency in the production process contributed to failure to use proper carrier. Operator failed to observe existing procedure.				

Infraction	84-14	Date	3/5/84	Location	Bldg 771
Description	Maximum container size violated in glovebox 40.				
Category	Volume violation	RC Category			P1
Root Cause Description	Operator failed to observe posted size limitation.				

Infraction	84-15	Date	3/16/84	Location	Bldg 771
Description	Improper transfer of solution resulted in mass limit being exceeded.				
Category	Mass violation	RC Category			M1/P2
Root Cause Description	Operators failed to follow proper practice. A contributing cause was the lack of a locking device on the fill valve. Management failed to think through and provide for the locking device of various valves in the tank system.				

Criticality Safety Procedural Infraction Database

Infraction	84-16	Date	3/30/84	Location	Bldg 771
Description	Spacing limits were violated for pans on line 3.				
Category	Spacing violation			RC Category	P3/M3
Root Cause Description	Operators lacked the necessary experience in conducting their assigned tasks. Supervision showed poor judgment in attempting to level the material in the pans.				

Infraction	84-17	Date	4/4/84	Location	Bldg 371
Description	Stacking and spacing requirements were violated during clean up of sludge.				
Category	Spacing violation			RC Category	P1
Root Cause Description	This infraction was caused by operator inattention.				

Infraction	84-18	Date	4/5/84	Location	Bldg 771
Description	Mass limit was exceeded in the feedhopper for line 3.				
Category	Mass violation			RC Category	M1
Root Cause Description	Management failed to consider, plan, and implement course of action and develop set of procedures for non-routine production conditions.				

Infraction	84-19	Date	4/16/84	Location	Bldg 771
Description	Spacing limits violated for pans on line 3.				
Category	Spacing violation			RC Category	P1
Root Cause Description	Operator complacency resulted in failure to observe NMSL.				

Infraction	84-20	Date	4/17/84	Location	Bldg 371
Description	Number of filters found in a box exceeded limits.				
Category	Mass violation			RC Category	M3/P2
Root Cause Description	Management failed to provide appropriate NMSL to accommodate the required activities in the box. The operators disregarded the NMSL that was then in effect for the box.				

Criticality Safety Procedural Infraction Database

Infraction	84-21	Date	4/24/84	Location	Bldg 559
Description	Number of vials exceeded established limits and were incorrectly stored.				
Category	Mass violation	RC Category			M1
Root Cause Description	Management failed to perceive potential conditions which led to lack of proper NMSL.				

Infraction	84-22	Date	4/27/84	Location	Bldg 559
Description	Mass limit exceeded in a burn pot.				
Category	Mass violation	RC Category			P1/M3
Root Cause Description	Operator complacency resulted in failure to observe NMSL. Management failed to adequately train personnel to observe posted safety limits.				

Infraction	84-23	Date	4/28/84	Location	Bldg 707
Description	Mass limit exceeded in a drum of wet combustibles.				
Category	Mass violation	RC Category			M5
Root Cause Description	Management failed to provide the necessary equipments and tools for performing work properly.				

Infraction	84-24	Date	5/7/84	Location	Bldg 371
Description	A plastic enclosure was constructed with inadequate criticality drain slots.				
Category	Volume violation	RC Category			P1
Root Cause Description	Operator complacency resulted in failure to observe NMSL.				

Infraction	84-25	Date	5/7/84	Location	Bldg 776
Description	Mass limit exceeded on a loading crate.				
Category	Mass violation	RC Category			P1/P5
Root Cause Description	Operator complacency resulted in failure to observe nuclear material safety procedure. Unclear labeling by the operators was a secondary cause.				

Criticality Safety Procedural Infraction Database

Infraction	84-26	Date	5/8/84	Location	Bldg 707
Description	Mass limit exceeded when manufacturing a briquette.				
Category	Mass violation	RC Category			P1
Root Cause Description	Operator complacency resulted in failure to observe NMSL.				

Infraction	84-27	Date	5/9/84	Location	Bldg 559
Description	Maximum container size violated in boxes E5, 15, 20, 21, 23, and 25.				
Category	Volume violation	RC Category			P1
Root Cause Description	Operator complacency resulted in failure to observe nuclear material safety procedure.				

Infraction	84-28	Date	5/17/84	Location	Bldg 371
Description	A plastic bag was found without drain slits.				
Category	Volume violation	RC Category			P3
Root Cause Description	Decon workers were not adequately trained.				

Infraction	84-29	Date	5/22/84	Location	Bldg 371
Description	Two 30-gallon plastic bags were found open.				
Category	Volume violation	RC Category			P1
Root Cause Description	Operator complacency resulted in failure to observe NMSL.				

Infraction	84-30	Date	5/24/84	Location	Bldg 707
Description	Material moved without approved limits into a newly constructed storage vault.				
Category	Mass violation	RC Category			M7/M3
Root Cause Description	Management failed to provide and verify the existence of specific NMSL for the new vault prior to loading the material in the vault.				

Criticality Safety Procedural Infraction Database

Infraction	84-31	Date	6/6/84	Location	Bldg 771
Description	Criticality drain was plugged with a sample holder.				
Category	Other (Criticality drain violation)			RC Category	P1
Root Cause Description	The storage of a sample holder in the opening to the wall-mounted criticality drain overflow was in violation of operating procedures and NMSL. This infraction was due to operator inattention to the task.				

Infraction	84-32	Date	6/7/84	Location	Bldg 371
Description	Number of containers in an airlock exceeded established limits.				
Category	Volume violation			RC Category	P5
Root Cause Description	The cause for this infraction was incomplete communication between the departing operator and the incoming operator.				

Infraction	84-33	Date	6/14/84	Location	Bldg 707
Description	Mass limit exceeded in a drum.				
Category	Mass violation			RC Category	M1/M3
Root Cause Description	Although following procedures, a reading over the limit was found on receipt at Bldg. 371. The failure and complacency by management in resolving a known problem area (no calibration of the instruments, no training courses, no accurate method of counting drums despite proposals for better methods) allowed this infraction.				

Infraction	84-34	Date	3/?/84	Location	Bldg 778
Description	During a test, security personnel violated handcarry limits.				
Category	Mass violation			RC Category	M2
Root Cause Description	This infraction was the result of an oversight by experienced supervisors. The reason for this oversight was failure by supervisors to check all plant policies and regulations that could apply to the intended task.				

Infraction	84-35	Date	6/22/84	Location	Bldg 776
Description	Mass limit exceeded on an oil slab cart.				
Category	Mass violation			RC Category	P1
Root Cause Description	The craftsman failed to ascertain that permission had been given to start the work. This was due to inattention to the task.				

Criticality Safety Procedural Infraction Database

Infraction	84-36	Date	6/23/84	Location	Bldg 776
Description	Mass limit exceeded while loading a crate.				
Category	Mass violation	RC Category			M3/M1
Root Cause Description	Management's failure to think through the task permitted this infraction (failure to calculate or add counts). A secondary cause was management's failure to provide a procedure that requires adding while performing the task.				

Infraction	84-37	Date	7/3/84	Location	Bldg 707
Description	Mass limit exceeded in a storage rack.				
Category	Mass violation	RC Category			P1
Root Cause Description	The operator causing this infraction failed to pay attention to the job.				

Infraction	84-38	Date	7/13/84	Location	Bldg 707
Description	Wrong mold was used in a casting.				
Category	Mass violation	RC Category			P1
Root Cause Description	The operator causing this infraction failed to pay adequate attention to the job.				

Infraction	84-39	Date	7/20/84	Location	Bldg 371
Description	Storage requirements violated; unauthorized shielding used.				
Category	Volume violation	RC Category			P1
Root Cause Description	The operators responsible for this infraction failed to pay attention to the job.				

Infraction	84-40	Date	7/21/84	Location	Bldg 771
Description	Plastic bags not slit as required for criticality safety.				
Category	Volume violation	RC Category			P2
Root Cause Description	Operators failed to follow procedure.				

Criticality Safety Procedural Infraction Database

Infraction	84-41	Date	7/25/84	Location	Bldg 771
Description	Maximum container size limits violated in a glovebox.				
Category	Volume violation			RC Category	P2
Root Cause Description	This infraction report deals with two infractions. Infraction A occurred during an operation that is unusual for this line and involved failure to follow a procedure. Infraction B was the result of failure to ascertain the contents of a wrapped bottle. Both incidents are due to failure by the operator to follow procedures.				

Infraction	84-42	Date	7/20/84	Location	Bldg 707
Description	The wrong mold was used in a casting.				
Category	Mass violation			RC Category	P1
Root Cause Description	This type of infraction is caused by operator complacency with regard to "checking and double checking."				

Infraction	84-43	Date	8/7/84	Location	Bldg 771
Description	Criticality safety drain slits not used in a plastic bag.				
Category	Volume violation			RC Category	P2
Root Cause Description	The taped and unslit bag represented a procedural violation.				

Infraction	84-44	Date	8/9/84	Location	Bldg 707
Description	Glovebox B70 was operated for some time without limits.				
Category	Unauthorized operation			RC Category	M7
Root Cause Description	Foundry Operations management took responsibility for failing to discover that the new chamber was not identical to the other chamber and had different limits. This infraction was a consequence of failure to recognize the potential for confusion when two things are similar but not identical.				

Infraction	84-45	Date	8/10/84	Location	Bldg 371
Description	Mass limit exceeded in furnace #10.				
Category	Mass violation			RC Category	P2
Root Cause Description	This infraction occurred as a consequence of operator failure to follow procedure.				

Criticality Safety Procedural Infraction Database

Infraction	84-46	Date	8/22/84	Location	Bldg 771
Description	More than one filter was removed at a time in lines 37 and 38.				
Category	Mass violation	RC Category			P3
Root Cause Description	The crewman removing the filters violated procedures. The root cause for this violation was non-retention of annual training on filter handling.				

Infraction	84-47	Date	9/5/84	Location	Bldg 559
Description	Mass limit exceeded in a sample vial.				
Category	Mass violation	RC Category			P2/M1
Root Cause Description	This infraction was the result of failure to follow procedure. However, the limits for the adjacent boxes C-4 and C-5 are different. Stronger procedures and other measures by management would prevent, or at least make more unlikely, violation of the limits.				

Infraction	84-48	Date	9/17/84	Location	Bldg 771
Description	Mass limit exceeded in glovebox 83.				
Category	Mass violation	RC Category			M1
Root Cause Description	Supervisory failure to implement a course of action (procedures) that ensures proper transfer of information from one employee to another made this infraction possible.				

Infraction	84-49	Date	10/12/84	Location	Bldg 707
Description	Mass limit exceeded in a 10 gallon drum.				
Category	Mass violation	RC Category			P2
Root Cause Description	This infraction occurred because the operators did not follow the NMSL.				

Infraction	84-50	Date	10/12/84	Location	Bldg 771
Description	Spacing requirements were not maintained in line 42.				
Category	Spacing violation	RC Category			P1
Root Cause Description	The primary cause for this infraction was inattentiveness by the operators.				

Criticality Safety Procedural Infraction Database

Infraction	84-51	Date	10/17/84	Location	Bldg 771
Description	Criticality safety drain slits were not used in a plastic bag.				
Category	Volume violation			RC Category	P1
Root Cause Description	This infraction was the result of inattentiveness by maintenance workers (failure to check and recheck area before leaving).				

Infraction	84-52	Date	10/26/84	Location	Bldg 707
Description	The wrong mold was used in a casting.				
Category	Mass violation			RC Category	P2
Root Cause Description	The two operators involved in this infraction failed to follow procedure.				

Infraction	84-53	Date		Location	
Description	Retracted.				
Category				RC Category	NA
Root Cause Description					

Infraction	84-54	Date	11/9/84	Location	Bldg 771
Description	Mass limit exceeded in a storage area.				
Category	Mass violation			RC Category	P1/M1
Root Cause Description	This infraction was primarily due to operator inattentiveness. However, a secondary cause is management's failure to devise a process and/or develop and implement a procedure that simplifies the process of receiving, storing and shipping.				

Infraction	84-55	Date	12/12/84	Location	Bldg 776
Description	An approved ingot was processed without limits being obtained from criticality engineering.				
Category	Unauthorized operation			RC Category	M3
Root Cause Description	A manager failed to obtain approval from criticality engineering for allowing the ingot to be processed.				

Criticality Safety Procedural Infraction Database

Infraction	84-56	Date	12/14/84	Location	Bldg 771
Description	Mass limit exceeded in glovebox 63.				
Category	Mass violation	RC Category			P1
Root Cause Description	This infraction is a result of failure to ascertain that the limits were not exceeded. The cause was complacency. The operators based their judgment of the contents over the past few months.				

Infraction	85-01	Date	1/10/85	Location	Bldg 707
Description	Mass limit exceeded in a twelve position button cart.				
Category	Mass violation	RC Category			P2/Pr3
Root Cause Description	The primary cause is failure of personnel to follow existing procedures. Inadequate procedures allowed such an infraction to occur and are a secondary cause.				

Infraction	85-02	Date	1/17/85	Location	Bldg 707
Description	Mass limit exceeded in a twelve position button cart.				
Category	Mass violation	RC Category			P2/Pr3
Root Cause Description	Same as 85-01.				

Infraction	85-03	Date	1/22/85	Location	Bldg 771
Description	The concentration of liquid transferred exceeded the discard level.				
Category	Mass violation	RC Category			P2
Root Cause Description	Operator failed to follow operating procedure. The laboratory analysis was not checked before transfer to ensure that the liquid waste is within the allowable safety limit (the procedure requires three personnel to check the solution).				

Infraction	85-04	Date	2/6/85	Location	Bldg 776
Description	Stacking limits violated.				
Category	Unauthorized operation	RC Category			E5/M1
Root Cause Description	This error occurred due to inadequate labeling. The box could be handled in accordance with the procedures without the operator being aware of the special nuclear materials safety limits labels on two sides. A more stringent procedure, requiring labeling on all sides, would have prevented this infraction. Management failed to provide such a procedure.				

Criticality Safety Procedural Infraction Database

Infraction	85-05	Date	2/22/85	Location	Bldg 771
Description	Mass limit exceeded in glovebox 49A.				
Category	Mass violation	RC Category		P1	
Root Cause Description	The cause of this infraction was operator inattention. This infraction occurred while under time pressure and under the additional pressure of training a new laboratory technician.				

Infraction	85-06	Date	2/27/85	Location	Bldg 559
Description	Mass limit exceeded in a sample vial.				
Category	Mass violation	RC Category		P2/Pr3	
Root Cause Description	PM-shift technician failed to follow procedure and instructions. However, the procedure controlling the complicated limits were also inadequate.				

Infraction	85-07	Date	3/16/85	Location	Bldg 371
Description	Mass limit exceeded in furnace TP-1.				
Category	Mass violation	RC Category		P1	
Root Cause Description	The charge limit is 3000 g. The furnace limit is 4000 g. The operator exceeded the charge limit. He conceded that he may have hurried. He considered the 4000 g limit but forgot about the 3000 g limit. Another operator was supposed to check the figures, but failed to notice the infraction. Both showed a clear lack of attention to the task.				

Infraction	85-08	Date	3/8/85	Location	Bldg 559
Description	Mass limit exceeded in glovebox C6.				
Category	Mass violation	RC Category		P2/P3	
Root Cause Description	Failure to check the amount of material in Box C-6 before moving in more material is a procedural violation. The two technicians involved had received instructions several times.				

Infraction	85-09	Date	3/24/85	Location	Bldg 776
Description	Mass limit exceeded in stacked drums.				
Category	Other (Stacking violation)	RC Category		P3/P2	
Root Cause Description	The operators, instructed to stack drums below 200 g, violated the 200 g limit. The primary cause for this particular infraction was failure to ensure that the operators understood the Nuclear Criticality Safety Limits. Secondary cause was a lack of attention to the task by the operators.				

Criticality Safety Procedural Infraction Database

Infraction	85-10	Date	4/1/85	Location	Bldg 371
Description	Mass limit exceeded in a 55-gallon drum.				
Category	Mass violation			RC Category	P1
Root Cause Description	The operators failed to check the drums for overweight (exceeding the limit of 500 g Pu/55-gal drum). They failed to check the drums out of complacency since very few drums over 500 g are picked up in Bldg. 371.				

Infraction	85-11	Date	4/10/85	Location	Bldg 771
Description	Two plastic bags did not have the required criticality safety drain slits.				
Category	Volume violation			RC Category	P1
Root Cause Description	It is assumed that this infraction is a result of complacency (the person who hung the bags was not found).				

Infraction	85-12	Date	4/12/85	Location	Bldg 559
Description	Mass limit exceeded in 2 sample vials.				
Category	Mass violation			RC Category	P2
Root Cause Description	The two vials with excess weight found in glovebox C29 were placed there by an operator in violation of existing procedures.				

Infraction	85-13	Date	6/10/85	Location	Bldg 371
Description	Mass limit exceeded in furnace #9.				
Category	Mass violation			RC Category	P1/M1
Root Cause Description	The operators erroneously registered the gross weight instead of the net weight. The cause for this infraction was inattention and failure to check the entries. Apparently, a procedure cautioning against erroneous entries and requiring a double check of the entries did not exist. This is a secondary cause.				

Infraction	85-14	Date	6/14/85	Location	Bldg 559
Description	Mass limit exceeded in a can packaged for shipment.				
Category	Mass violation			RC Category	P2/M1
Root Cause Description	The weight of a can containing Pu-oxide exceeded the 2000 g NMSL when it was in glovebox C-5. The cause was operator inattention and confusion about the different limits on glovebox C-22 and gloveboxes C-5 and C-6. The reason for this confusion is management failure to plan this process adequately.				

Criticality Safety Procedural Infraction Database

Infraction	85-15	Date	6/27/85	Location	Bldg 371
Description	Open plastic bag for 55 gallon drum did not have a drain slit. It was thought to be an infraction. However, there was found to be no piping above the bag that contained fissile material; therefore the violation was				
Category	NA	RC Category			NA
Root Cause Description	No root cause. Infraction retracted.				

Infraction	85-16	Date	6/27/85	Location	Bldg 771
Description	Solution transferred to tank 546 was above established limits.				
Category	Mass violation	RC Category			P1/M1
Root Cause Description	Fissile solution from the wrong pencil tank was transferred into Raschig ring-filled tank T-546 because an operator connected tubing to the wrong transfer line. A secondary cause was management's apparent failure to provide a procedure, which requires that connections be checked before a transfer begins (failure to plan the task to avoid potential infractions).				

Infraction	85-17	Date	7/1/85	Location	Bldg 771
Description	Spacing limits violated in line 13 (2 used filters).				
Category	Spacing violation	RC Category			P1/E2
Root Cause Description	The most probable cause for this infraction was identified as a failure by the operators to ensure that their activities do not cause any violations of posted NMSL. The infraction was possible because a used filter rack was not in a fixed position, i.e., equipment was improperly installed.				

Infraction	85-18	Date	7/11/85	Location	Bldg 664
Description	Mass limit exceeded in a filter crate.				
Category	Mass violation	RC Category			M1/M3
Root Cause Description	Violation of the DOT limit governing offsite shipment of crates was apparently possible due to a lack of procedures. Management failed to think through the task and provide adequate procedures.				

Infraction	85-19	Date	7/11/85	Location	Bldg 771
Description	Mass limit exceeded in a storage area.				
Category	Mass violation	RC Category			P1
Root Cause Description	The operator placed the overweight package on a rack, violating a NMSL because of lack of attention to the task.				

Criticality Safety Procedural Infraction Database

Infraction	85-20	Date	8/2/85	Location	Bldg 707
Description	Mass limit exceeded in the J10 burning chamber.				
Category	Mass violation	RC Category			M1
Root Cause Description	This infraction occurred because of failure of management to have old versions of the procedure destroyed.				

Infraction	85-21	Date	8/5/85	Location	Bldg 707
Description	Mass limit exceeded in box A40.				
Category	Mass violation	RC Category			Pr3
Root Cause Description	This infraction occurred because of an inadequate procedure.				

Infraction	85-22	Date	8/12/85	Location	Bldg 371
Description	Mass limit exceeded in glovebox 1.				
Category	Mass violation	RC Category			Pr3/E1
Root Cause Description	This infraction occurred because of an incomplete procedure, which neglected to instruct the operators and technicians to ensure that the airlock is empty before putting any material into it. A contributing factor was poor visibility (design).				

Infraction	85-23	Date	8/29/85	Location	Bldg 371
Description	Material stored in an unauthorized location.				
Category	Spacing violation	RC Category			M1
Root Cause Description	The experienced technician was aware that 55-gallon drums are not permitted to be stored under glovebox lines. He was not aware that 10-gallon drums are not allowed to be stored in this location. This infraction is the result of failure by management to establish refresher training sessions.				

Infraction	85-24	Date	10/3/85	Location	Bldg 374
Description	Material transfer made with solution concentration exceeding established limits.				
Category	Mass violation	RC Category			P2
Root Cause Description	Liquid waste above the Nuclear Material Safety Discard Limit was transferred to a criticality unsafe storage tank. The operating procedure was not followed since the transfer occurred before obtaining the required signatures.				

Criticality Safety Procedural Infraction Database

Infraction	85-25	Date	10/19/85	Location	Bldg 371
Description	Mass limit exceeded in furnace #6.				
Category	Mass violation	RC Category			P1/Pr3
Root Cause Description	The main reason for the overcharge of tilt pour furnace 6 was the use of a malfunctioning calculator. The malfunction should have been discovered by the operator since the calculator not only added improperly but also failed to clear. A secondary cause was the lack of a double check requirement.				

Infraction	85-26	Date	10/28/85	Location	Bldg 371
Description	Container volume exceeded in glovebox 9.				
Category	Volume violation	RC Category			M3
Root Cause Description	The operator was ignorant of nuclear material safety limits and physical layout and boundaries. He failed to read the nuclear materials safety limits. Inattention by management/supervisor made it possible for personnel to work in this area without having read the procedures.				

Infraction	85-27	Date	11/1/85	Location	Bldg 707
Description	Mass limit exceeded in sample vials.				
Category	Mass violation	RC Category			P1/P2
Root Cause Description	This infraction occurred due to failure of the operator to review the paperwork that thoroughly explained what was needed. This shows a lack of attention to the task and ignorance about the importance of safety limits.				

Infraction	85-28	Date	11/1/85	Location	Bldg 771
Description	Material transferred made with solution concentration exceeding established limits.				
Category	Mass violation	RC Category			P1/P5
Root Cause Description	Liquid exceeding the Nuclear Materials Safety Limits was transferred. The transfer occurred because the preceding transfer was incomplete. Valves were left in the incorrect position by operator leaving the area. The operator leaving the area also failed to notify the arriving crew of the incomplete status. Complacency by the crew and failure to communicate were the causes for this infraction.				

Infraction	85-29	Date	11/12/85	Location	Bldg 771
Description	Mass limit exceeded in the batching area of line 24.				
Category	Mass violation	RC Category			P1
Root Cause Description	The operator neglected to observe posted nuclear materials safety limits.				

Criticality Safety Procedural Infraction Database

Infraction	85-30	Date	11/20/85	Location	Bldg 371
Description	Container volume limit exceeded on glovebox 44.				
Category	Volume violation	RC Category			Pr3
Root Cause Description	The operators misinterpreted the limits they had read. The primary cause was unclear procedures/limits.				

Infraction	85-31	Date	11/27/85	Location	Bldg 707
Description	Mass limit exceeded on a parts carrier.				
Category	Mass violation	RC Category			P1
Root Cause Description	This infraction occurred because of operator inattention to the task.				

Infraction	85-32	Date	12/16/85	Location	Bldg 771
Description	Mass limit exceeded in a waste drum.				
Category	Mass violation	RC Category			P2/E3
Root Cause Description	This infraction report involves two infractions: (a) a violation of procedure (failure to separate the oxide from the filter pad) and (b) an electronic gram estimator that was out of calibration at the time of use. This can be attributed to inadequate calibration/maintenance intervals.				

Infraction	85-33	Date	12/19/85	Location	Bldg 779
Description	Container volume limit exceeded in glovebox 865.				
Category	Volume violation	RC Category			M1
Root Cause Description	The lead shields were not fabricated in accordance with the NML which required a maximum volume of 4 liters. This is indicative of management failure to adequately plan the work.				

Infraction	86-01	Date	1/14/86	Location	Bldg 771
Description	Number of containers in use exceeded limits.				
Category	Volume violation	RC Category			P1/M1
Root Cause Description	The primary cause for this infraction was violation of safety limits by the operator. However, due to the fact that these personnel worked at different areas with different limits, a secondary cause was failure by management/supervisors to coordinate the limits so that confusion is avoided.				

Criticality Safety Procedural Infraction Database

Infraction	86-02	Date	1/20/86	Location	Bldg 707
Description	Mass limit exceeded in a can stored on a 2- position can holder birdcage.				
Category	Mass violation	RC Category			M1
Root Cause Description	The cause for this infraction was the Medical Department's approval of a worker taking medication which could affect the performance of his duties. This judgment was erroneous as evidenced by the reversal of its decision after the infraction. This infraction is a consequence of lack of attention to the case, i.e., they failed to recognize potential side effects of the medication.				

Infraction	86-03	Date	1/24/86	Location	Bldg 771
Description	Mass limit exceeded in the incinerator glovebox of line 37.				
Category	Mass violation	RC Category			P2
Root Cause Description	The operators did not follow procedure, which required signing the Incinerator Material Balance Account sheet after completion of the dump. Since the error was discovered later when signing the sheet, the infraction would have been avoided by signing it in accordance with the procedure.				

Infraction	86-04	Date	1/31/86	Location	Bldg 707
Description	Mass limit was exceeded for the area and 4 cans were improperly spaced.				
Category	Mass violation/Spacing violation	RC Category			P1
Root Cause Description	Both weight and spacing limitations were violated because a worker failed to read the entire procedure. This infraction is a consequence of a worker's inattention to the task.				

Infraction	86-05	Date	2/1/86	Location	Bldg 707
Description	Mass limit exceeded in box B105.				
Category	Mass violation	RC Category			M3
Root Cause Description	The accumulation of scrap material in excess of the allowable limit and failure to immediately report the infraction was due to complacency by supervisors. They failed to ensure clean-up at the end of the shift.				

Infraction	86-06	Date	2/7/86	Location	Bldg 559
Description	Mass limit exceeded in a container of samples.				
Category	Mass violation	RC Category			P2/P1
Root Cause Description	The weight limit violation occurred because a technician failed to record salvaged metal material on the control card and a second technician failed to weigh the can before addition of metal. The second technician was unaware of an administrative weight limit. The primary cause was failure to follow procedure. Inattention to the task.(failure to read procedures) was a contributing cause.				

Criticality Safety Procedural Infraction Database

Infraction	86-07	Date	3/17/86	Location	Bldg 771
Description	Mass limit exceeded in line 3.				
Category	Mass violation	RC Category		P1	
Root Cause Description	Operators failed to observe NMSL when they added two cans to line 3 without observing that a mixed feed can was left in a batch can in the batching station.				

Infraction	86-08	Date	4/9/86	Location	Bldg 779
Description	Posted NMSL were altered and reposted without authority and approval from criticality engineering.				
Category	Unauthorized operation	RC Category		M3	
Root Cause Description	The manager failed to properly supervise his subordinates in requesting a change to the NMSL as recommended by criticality engineering. He further failed to pass along to his replacement the need for this change request.				

Infraction	86-09	Date	4/23/86	Location	Bldg 776
Description	Maximum container volume limit exceeded in glovebox 506.				
Category	Volume violation	RC Category		P3/Pr3	
Root Cause Description	This infraction was due to operator misunderstanding of procedures. The cause was inadequate training and unclear procedures.				

Infraction	86-10	Date	4/28/86	Location	Bldg. 771
Description	Plastic bag not slit in accordance with criticality safety procedures.				
Category	Volume violation	RC Category		M1	
Root Cause Description	Although the maintenance crew itself did not violate any procedures, they created a situation that lead to a violation. This indicates the lack of an appropriate procedure. Management/supervisors failed to establish procedures that would help avoid potential problems (e.g., unattended tools, leaving the work place without properly securing).				

Infraction	86-11	Date	5/3/86	Location	Bldg 771
Description	Spacing limit violated, mass limit exceeded also.				
Category	Mass violation/Spacing violation	RC Category		P1	
Root Cause Description	Operator inattention resulted in the placement of the drying pan next to an 8801 can, which violated spacing limitations set forth in the Nuclear Materials Safety Procedures.				

Criticality Safety Procedural Infraction Database

Infraction	86-12	Date	5/23/86	Location	Bldg 771
Description	Mass limit exceeded in a pan in glovebox D2.				
Category	Volume violation			RC Category	P1
Root Cause Description	Because of operator inattention, material was added to the operating line without placing the dry material in a dry pan into a 8801 can. This was a violation of the Nuclear Criticality Limits.				

Infraction	86-13	Date	6/2/86	Location	Bldg 707
Description	Five DJO parts had been processed in box B25A without approval.				
Category	Unauthorized operation			RC Category	Pr3/M6
Root Cause Description	This infraction was caused by inadequate procedures. The system for development of special order production "travelers" did not allow for or require review and approval of the actual document published; miscommunication easily occurred.				

Infraction	86-14	Date	6/23/86	Location	Bldg 771
Description	Mass limit exceeded in button produced on line 19.				
Category	Mass violation			RC Category	P1/E1
Root Cause Description	Excess material, left over from a previous run and mixed in with the next run, resulted in the production of two overweight buttons. The primary cause for this infraction was operator inattention to the task (failure to ensure that weight limits are not exceeded). A contributory factor was poor visibility, i.e., poor design.				

Infraction	86-15	Date	7/11/86	Location	Bldg 771
Description	Number of used filters in line 2 exceeded limits.				
Category	Mass violation			RC Category	P1
Root Cause Description	Operator inattention resulted in a NMSL violation when a fifth Ful-Flo filter was introduced into a glovebox that had a four filter limit.				

Infraction	86-16	Date	8/11/86	Location	Bldg 771
Description	Depth limit violated in a line 25 pan.				
Category	Volume violation			RC Category	P1
Root Cause Description	The primary cause for an overfilled pan was inattention of the operating personnel.				

Criticality Safety Procedural Infraction Database

Infraction	86-17	Date	8/11/86	Location	Bldg 707
Description	Mass limit exceeded in a chip can.				
Category	Mass violation	RC Category			P1
Root Cause Description	The operator failed to weigh the can before sending it to the Foundry. He failed to pay adequate attention to the task.				

Infraction	86-18	Date	8/12/86	Location	Bldg 707
Description	The cooling furnace box in box A35 contained a loaded crucible and mold. Limits allow only one or the other.				
Category	Mass violation	RC Category			M1
Root Cause Description	Management failed to provide a written procedure for tracking the locations of fissile material. Operators had been relying on word-of-mouth for the current location of the material.				

Infraction	86-19	Date	8/28/86	Location	Bldg 371
Description	Fissile material weight limits had been violated.				
Category	Mass violation	RC Category			M1
Root Cause Description	This infraction was a direct consequence of failure by management/supervisors to provide a procedure for the task of removing a crucible from the furnace and sending it to calorimetry.				

Infraction	86-20	Date	9/2/86	Location	Bldg 771
Description	After repair of equipment on shut down line 23, the previously empty container held fissile material.				
Category	Volume violation	RC Category			M3
Root Cause Description	Supervision failed to maintain control of the operation related to line 23. This increased to five the number of containers holding fissile material, a violation.				

Infraction	86-21	Date	10/9/86	Location	Bldg 777
Description	Pressure cooker left unattended on a transfer cart.				
Category	Other (Unauthorized procedure)	RC Category			Pr3
Root Cause Description	The operator was not aware that shipping containers are equivalent to approved shipping containers. The existing procedures were not clear enough to highlight the equivalency.				

Criticality Safety Procedural Infraction Database

Infraction	86-22	Date	10/12/86	Location	Bldg 771
Description	Mass limit exceeded in a free metal collection container.				
Category	Mass violation	RC Category		P1/Pr3	
Root Cause Description	The primary cause for this infraction was failure by the operators to check the net weight of free-metal. A contributing cause for this infraction was lack of a procedure for tracing the weight of free-metal in the line.				

Infraction	86-23	Date	10/27/86	Location	Bldg 771
Description	Spacing limits violated on line 15.				
Category	Spacing violation	RC Category		P1	
Root Cause Description	A dirty Ful-Flo filter cartridge was removed and placed on the flange of a digester (516A) in violation of spacing limits. This infraction occurred due to inattentiveness by the operator.				

Infraction	86-24	Date	10/27/86	Location	Bldg 771
Description	Plastic bag without criticality safety drainage slits.				
Category	Volume violation	RC Category		P1	
Root Cause Description	The infraction was due to operator inattention to the task.				

Infraction	86-25	Date	12/2/86	Location	Bldg 559
Description	Fissile material stored in a box without approved limits and was marked "no fissile material allowed."				
Category	Unauthorized operation	RC Category		P1	
Root Cause Description	Four vials were placed in a box clearly marked as "No Fissile Material," clearly violating procedure. The operator failed to be attentive to his task.				

Infraction	86-26	Date	12/5/86	Location	Bldg 779
Description	Mass limit exceeded in a 1-gallon container.				
Category	Mass violation	RC Category		P1	
Root Cause Description	The Nuclear Materials Safety Procedure was violated by packing 937 g Pu in a 1-gallon paint can (outer container) when only 50 g are allowed. The recent shipments were all small analytical samples and operators did not think that a higher mass of plutonium oxide required a different outer container. This violation was due to operator inattention.				

Infraction	86-27	Date	12/11/86	Location	Bldg 707
Description	A briquette weighing more than the allowed limit was formed.				
Category	Mass violation			RC Category	M1
Root Cause Description	Management failed to provide a written procedure for this task which required verification that the containers are empty before reuse. Prior material remained in the can and the NMSL was exceeded.				

Infraction	87-01	Date	1/19/87	Location	Bldg 559
Description	The mass of fissile material exceeded the stated NMML for operation in the glovebox.				
Category	Mass violation			RC Category	P1
Root Cause Description	Failure of two operators to follow instructions in the proper use of balance cards, and failure to maintain an accurate material balance card. The card was modified to reflect an incorrect material balance when a container could not be found.				

Infraction	87-02	Date	2/6/87	Location	Bldg 707
Description	Mass limit exceeded in the box A45 furnace.				
Category	Mass violation			RC Category	P1/Pr3
Root Cause Description	Operators failed to verify that the furnace was empty. A full ingot was produced before the start of another pour. The procedure did not clearly specify the actions to be taken before loading the furnace.				

Infraction	87-03	Date	2/5/87	Location	Bldg 771
Description	Mass limit exceeded in a waste drum.				
Category	Mass violation			RC Category	P1/P2
Root Cause Description	Failure of operator to follow procedure which requires double verification of assay results.				

Infraction	87-04	Date	3/4/87	Location	Bldg 707
Description	Number of parts exceeded limits in box B70.				
Category	Mass violation			RC Category	P1/Pr3
Root Cause Description	Operator incorrectly read the weight. The complexity of the traveler card may have contributed to this infraction. However, even though the parts traveler may have been complex, the operator should have noted the difference between the weight of the two parts.				

Criticality Safety Procedural Infraction Database

Infraction	87-05	Date	3/5/87	Location	Bldg 371
Description	Mass limit exceeded in glovebox 70.				
Category	Mass violation	RC Category		P1/Pr3	
Root Cause Description	Two crucibles placed in maintenance box. One crucible still had 2754 g of Pu. The established limit was 1000 g. The operator thought the limit was 3000 g. He also overlooked the presence of the second crucible. A written procedure was not available.				

Infraction	87-06	Date	3/20/87	Location	Bldg 707
Description	Two approved assemblies found on table 19; limited to 1.				
Category	Mass violation	RC Category		P1/M3	
Root Cause Description	Personnel error caused two pits to be placed on pumpdown table. Management's decision to remove test units from the cart to keep production moving contributed to the mistake.				

Infraction	87-07	Date	4/8/87	Location	Bldg 707
Description	Limits not available for a Pu melting operation in progress.				
Category	Unauthorized operation	RC Category		M1	
Root Cause Description	Management failed to plan for the work. Adequate limits were not established for this special foundry operation.				

Infraction	87-08	Date	4/10/87	Location	Bldg 771
Description	Unsampled solution transferred to a tank due to improper valve lineup.				
Category	Unauthorized operation	RC Category		P1/E1	
Root Cause Description	Drain valve was locked in the open position, allowing 40 liters of unsampled liquid to be drained to a tank. Operator failed to visually verify valve position. A contributing factor was that the design of the valve stem-type locking device made it difficult to observe the valve position.				

Infraction	87-09	Date	4/13/87	Location	Bldg 771
Description	Spacing limits violated on line 5 (used filter cartridge).				
Category	Spacing violation	RC Category		P1	
Root Cause Description	Operator failed to properly space Ful-Flo filters.				

Infraction	87-10	Date	4/14/87	Location	Bldg 771
Description	Maximum container volume limit exceeded in MT-5.				
Category	Volume violation			RC Category	P1
Root Cause Description	A cake pan was used to blend material. The cake pan size caused the one-liter volume to be violated. The operator failed to realize that use of this pan was limited to non-fissile material.				
Infraction	87-11	Date	4/20/87	Location	Bldg 707
Description	Mass limit exceeded on a part carrier.				
Category	Mass violation			RC Category	M1/P1
Root Cause Description	Management failed to provide a scale to facilitate the determination of the weight to be loaded in the carrier. Operator loaded material in parts carrier in excess of the weight limit.				
Infraction	87-12	Date	4/23/87	Location	Bldg 771
Description	Mass limit exceeded in a waste drum.				
Category	Mass violation			RC Category	M1/M7
Root Cause Description	Because the uranium content of two drums was not taken into account, the 1000 g limit was exceeded. The package counter was not calibrated to read uranium, only plutonium. Management failed to plan the activity and did not understand the complexity inherent in the process.				
Infraction	87-13	Date	4/23/87	Location	Bldg 771
Description	Containers improperly stored.				
Category	Volume violation			RC Category	P1/E1
Root Cause Description	Operators or maintenance personnel, through carelessness, removed the lid from a stainless steel pump transfer container. This container was located under lines containing fissile material; thus, the 4-liter volume rule was exceeded. A contributing factor was the ease with which the cover could be removed. A lock was installed to prevent cover removal.				
Infraction	87-14	Date	5/4/87	Location	Bldg 707
Description	Mass limit exceeded in chainveyor system.				
Category	Unauthorized operation			RC Category	M3/P2
Root Cause Description	Supervisor did not read the temporary limit prior to loading the carrier. The operator allowed a new parts container to be loaded with 100-200 g of Pu in violation of a temporary limit established for test purposes to disallow fissile material.				

Criticality Safety Procedural Infraction Database

Infraction	87-15	Date	5/26/87	Location	Bldg 371
Description	Unauthorized shipping container transported on a flatbed cart.				
Category	Unauthorized operation			RC Category	P1
Root Cause Description	An unapproved 2-liter container was loaded on to a flatbed cart. The operator did not make herself aware of the NMSL prior to loading the container.				
Infraction	87-16	Date	6/21/87	Location	Bldg 707
Description	Mass limit exceeded in gloveboxes B25B and B80.				
Category	Mass violation			RC Category	P1
Root Cause Description	Two thermalcycle unit gloveboxes were found to contain 4 parts in one chamber in excess of the allowed 2 parts. Operator knew the NMSL but was hurrying to finish the work.				
Infraction	87-17	Date	7/8/87	Location	Bldg 707
Description	Mold configuration not in accordance with prints.				
Category	Unauthorized operation			RC Category	M3/M1
Root Cause Description	Ingot received from rolling mill over the allowable thickness in one area, because of failure to use a mold clamp as required by NMSL. Management failed to confirm that the established limit was in accordance with the new procedure.				
Infraction	87-18	Date	7/29/87	Location	Bldg 771
Description	A protective covering over a sump pump was left off during pump replacement. Since the pit had unsafe dimensions and fissile material was located in piping above the sump, a criticality infraction occurred.				
Category	Volume violation			RC Category	M1
Root Cause Description	The maintenance supervisor involved failed to think out the potential problem associated with the installation of the new pump.				
Infraction	87-19	Date	8/4/87	Location	Bldg 707
Description	Spacing requirements violated between birdcage on chainveyor 7-51.				
Category	Spacing violation			RC Category	M1
Root Cause Description	The conveyor line was not checked by the production supervisor.				

Criticality Safety Procedural Infraction Database

Infraction	87-20	Date	8/13/87	Location	Bldg 771
Description	Max container size limit violated.				
Category	Volume violation			RC Category	P2/P1
Root Cause Description	The operator did not follow the approved procedure. Contributing to the infraction was the inattention of the operator to proper work practices.				

Infraction	87-21	Date	8/18/87	Location	Bldg 771
Description	Used Ful-flo filter cartridge stored in an unauthorized area.				
Category	Unauthorized operation			RC Category	P1
Root Cause Description	Through carelessness, an operator moved a dirty Ful-flo filter to a batching area location in violation of the NMSL.				

Infraction	87-22	Date	8/27/87	Location	Bldg 776
Description	Improper stacking.				
Category	Other (Stacking violation)			RC Category	P1
Root Cause Description	Operators were hurrying to complete the work and, through carelessness, did not check drum content before stacking. One drum contained 211 g of fissile. The limit for stacked drums is 200 g.				

Infraction	87-23	Date	9/9/87	Location	Bldg 371
Description	NMSL exceeded in a 55-gallon drum.				
Category	Mass violation			RC Category	P1
Root Cause Description	The NMSL of 1000 g was violated when a package of fissile material was loaded in the wrong drum. Operators did not match drum control card with package.				

Infraction	87-24	Date	9/9/87	Location	Bldg 707
Description	Inclined trough at scrap shearer contained more fissile material than allowed by NMSL.				
Category	Mass violation			RC Category	P3
Root Cause Description	Operators were confused regarding how to handle a full ingot. One operator was in training for this operation and was not able to estimate the amount of scrap material. The other operators (there were two more) were not sure if the NMSL applied to the scrap shearer.				

Criticality Safety Procedural Infraction Database

Infraction	87-25	Date	10/9/87	Location	Bldg 707
Description	Mass limit exceeded on 4 part carrier.				
Category	Mass violation	RC Category		P1/M3	
Root Cause Description	Management failed to post carrier limits. The operator did not know the carrier limit and violated the NMSL. He further did not know other limits posted for the machines routinely used by him.				

Infraction	87-26	Date	10/13/87	Location	Bldg 771
Description	Improper spacing - 2 Pu buttons loaded into line 30 with no spacing.				
Category	Spacing violation	RC Category		P1	
Root Cause Description	Through carelessness, an operator incorrectly placed two cans containing buttons in the same bag.				

Infraction	87-27	Date	11/5/87	Location	Bldg 707
Description	Improper spacing of two fissile PC parts.				
Category	Spacing violation	RC Category		P1/M1	
Root Cause Description	Worker failed to take note of labeling that would have told him that the bags contained fissile material. Supervision allowed congestion in the area. This indicated poor work planning and contributed to the probability of the infraction.				

Infraction	87-28	Date	11/4/87	Location	Bldg 771
Description	Drums exceeded Pu NMSL of 500 g by 323 g.				
Category	Mass violation	RC Category		P1	
Root Cause Description	Resin not properly eluted (washed) before its removal from the line. Operator failed to gram estimate the package before placing it in the drum.				

Infraction	87-29	Date	11/16/87	Location	Bldg 771
Description	NMSL exceeded.				
Category	Mass violation	RC Category		P1/P4	
Root Cause Description	Operators were not properly using equipment to gram estimate each package. In addition, the operators failed to remove only dry filters from the line, thus increasing the error when using the gram estimator.				

Criticality Safety Procedural Infraction Database

Infraction	88-01	Date	2/1/88	Location	Bldg 771
Description	NMSL for glovebox filters exceeded.				
Category	Mass violation			RC Category	P1
Root Cause Description	Operators improperly stacked HEPA filters one on top of another.				

Infraction	88-02	Date	2/24/88	Location	Bldg 771 line 17
Description	NMSL exceeded when five 2-liter bottles were placed in an area where only 4 were allowed.				
Category	Mass violation/Volume violation			RC Category	P1
Root Cause Description	Operators made a mistake while rushing to complete work. Poor attitude evident.				

Infraction	88-03	Date	2/26/88	Location	Bldg 771
Description	NMSL exceeded when two full cartons of PuF4 were placed in the vicinity of an additional carton containing floor sweepings.				
Category	Mass violation			RC Category	M3/P1
Root Cause Description	Supervisors permitted poor housekeeping conditions in a glovebox and allowed an inadequate shift turnover. Operator inattention during shift turnover was evident.				

Infraction	88-04	Date	3/1/88	Location	Bldg 559
Description	NMSL exceeded when an evaporator apparatus containing a 7.5 liter reservoir was placed in a hood having a volume limit of 4 liters.				
Category	Volume violation			RC Category	M1/M3
Root Cause Description	The operator failed to note the volume restriction and failed to recognize that the reservoir was a container. Management was responsible for this infraction because it permitted fissile material in a cold hood for the convenience of work operations. It took over 3 months to discover the infraction even though routine inspections of the hood had been conducted.				

Infraction	88-05	Date	3/7/88	Location	Bldg 371
Description	Improper stacking of drums.				
Category	Other (Stacking violation)			RC Category	P1
Root Cause Description	Incorrect drum labels led to the improper stacking of two drums. One drum having the correct drum label was stacked even though it exceeded the 200 g weight limit. This indicated that operators were inattentative to the drum nuclear materials values and failed to check the values prior to stacking the drums.				

Criticality Safety Procedural Infraction Database

Infraction	88-06	Date	3/10/88	Location	Bldg 771
Description	Solution transferred to tank and maximum allowed concentration exceeded.				
Category	Mass violation	RC Category		P2/P1	
Root Cause Description	Operator failed to follow procedure; this led to obtaining incorrect sample values of the solution because of improper mixing. In addition, the feed evaporator settings were incorrect; these settings should have been checked by the operators but were not.				

Infraction	88-07	Date	4/14/88	Location	Bldg 771 line 3
Description	NMSL exceeded.				
Category	Mass violation	RC Category		P1	
Root Cause Description	The operators failed to thoroughly check a line during a shift change; this resulted in three filters being present in an area where only two were allowed.				

Infraction	88-08	Date	4/23/88	Location	Bldg 707
Description	NMSL exceeded.				
Category	Mass violation	RC Category		P1	
Root Cause Description	Operator improperly loaded a parts handler. This resulted in the NMSL of 3000 g being exceeded.				

Infraction	88-09	Date	5/17/88	Location	Bldg 771
Description	NMSL exceeded. Five containers were found in a section of Line 25; only four were permitted.				
Category	Volume violation	RC Category		P1/P3	
Root Cause Description	Operator overlooked a screening container because he did not understand that the screening container should be counted in the NMSL.				

Infraction	88-10	Date	5/10/88	Location	Bldg 771
Description	Glovebox contained two filters; only one allowed by NMSL.				
Category	Mass violation	RC Category		P1/Pr1	
Root Cause Description	This infraction appears to have been caused by the failure to post criticality limits. However, this type of infraction is recurring and indicates a lack of attention to detail. Proper handling of filters should be understood by the operators without the need to post specific limits.				

Criticality Safety Procedural Infraction Database

Infraction	88-11	Date	5/20/88	Location	Bldg 559
Description	Criticality safety drain covered.				
Category	Unauthorized operation			RC Category	M1/M3
Root Cause Description	The fact that this infraction was not found in over two months indicates a problem with management complacency. Supervisors failed to plan maintenance activities to avoid covering up the drain.				

Infraction	88-12	Date	5/20/88	Location	Bldg 771
Description	55-gallon drum exceeded weight limit.				
Category	Mass violation			RC Category	P1/P3
Root Cause Description	A count of 132 g incorrectly listed as 32 g. An inexperienced operator did not have good working habits of checking and rechecking paper work. Two operators failed to double check each other.				

Infraction	88-13	Date	6/1/88	Location	Bldg 559
Description	Volume restriction in glovebox violated.				
Category	Volume violation			RC Category	M7/P1
Root Cause Description	An error by an unidentified person caused this infraction. That person used a container that had been clearly marked " Do Not Use." Supervisors had monitored compliance with the sign for two months but failed to remove the container or to take timely action to change the glovebox limit to permit its use.				

Infraction	88-14	Date	6/10/88	Location	Bldg 707
Description	Two extra parts were loaded into glovebox, causing violation of weight limit.				
Category	Mass violation			RC Category	P1
Root Cause Description	The operator failed to verify the identity and weight of each of a total of five parts before he loaded the parts into the glovebox.				

Infraction	88-15	Date	6/7/88	Location	Bldg 707
Description	Material in catch pan exceeded weight requirement of NMSL.				
Category	Mass violation			RC Category	Pr3
Root Cause Description	The procedure did not require a Pu weight check before burning out crucibles and funnels.				

Criticality Safety Procedural Infraction Database

Infraction	88-16	Date	3/21/88	Location	Bldg 776
Description	Material shipped to Bldg 371 exceeded weight limit of 200 g; incorrectly assumed dry limit vice liquid limit.				
Category	Mass violation	RC Category		M3/Pr3	
Root Cause Description	The supervisor and the operators did not understand that RTVs are to be considered wet and thus permitted the NMSL to be exceeded by 200 g. The procedure for handling the RTVs was unclear.				

Infraction	88-17	Date	7/1/88	Location	Bldg 371
Description	Process vent system valves not locked in closed position as required by NMSL.				
Category	Other (Procedure violation)	RC Category		M1/Pr3	
Root Cause Description	Operating supervisor was not aware of the requirement to lock the valves in the closed position because the requirement was not specified in the vent system operating procedure.				

Infraction	88-18	Date	7/8/88	Location	Bldg 707
Description	Three carriers containing rings cut from three items exceeded the weight limit.				
Category	Mass violation	RC Category		M1/Pr3	
Root Cause Description	Engineering supervisors permitted the issuance of an engineering order to cut the items that did not require a ticket, thus the item weights were not provided. This is the third instance of such an occurrence in the past year. In addition, supervisors did not provide scales in the glovebox to weigh the material before and after machining.				

Infraction	88-19	Date	7/8/88	Location	Bldg 707
Description	Number of parts placed on table exceeded the limit..				
Category	Unauthorized operation	RC Category		P1	
Root Cause Description	This infraction is indicative of operator inattention to detail.				

Infraction	88-20	Date	7/14/88	Location	Bldg 771 rm 149
Description	Line 23 drain line taped incorrectly, which could restrict flow of liquid.				
Category	Other (Criticality drain pan violation)	RC Category		P1	
Root Cause Description	Operator error caused by inattention to detail.				

Criticality Safety Procedural Infraction Database

Infraction	88-21	Date	7/28/88	Location	Bldg 371
Description	Waste drum exceeded mass limit of NMSL.				
Category	Mass violation			RC Category	M1/Pr3
Root Cause Description	Operations management failed to require drums to be measured after splitting and failed to recognize that splitting could result in an imbalance of material among the drums. Procedure for allotment of the grams of Pu to drums after splitting was found to be inadequate.				
Infraction	88-22	Date	8/8/88	Location	Rolling operations
Description	Ingot not rolled to required thickness.				
Category	Mass violation			RC Category	M3/Pr3
Root Cause Description	The engineering drawing did not have a specified working tolerance. The dimension sheet did not specify whether the stated dimensions were a minimum or a maximum. As a result, incorrect verbal instructions were given by a supervisor to the operator to roll the ingot thicker than allowed.				
Infraction	88-23	Date	8/31/88	Location	Bldg 707 Mod. A
Description	Exceeded NMSL for number of castings allowed.				
Category	Mass violation			RC Category	M3/P5
Root Cause Description	Supervision failed to provide for a proper shift turnover. No log book was kept. This resulted in a failure to adequately communicate that there already was a casting on the furnace floor.				
Infraction	88-24	Date	9/12/88	Location	Bldg 771
Description	NMSL violated by introducing material 378 g greater than allowed.				
Category	Mass violation			RC Category	P5
Root Cause Description	An excessive amount of feed was introduced into the south section of line 3 due to the failure of two chemical operators to communicate the correct staging sequence for the feed.				
Infraction	88-25	Date	9/14/88	Location	Bldg 771 to Bldg 774 Transfer
Description	Fissile content not sampled prior to transfer.				
Category	Unauthorized operation			RC Category	P2
Root Cause Description	The procedural requirement to check valve position at the beginning of each shift was violated by the operators. In addition, the vent method used did not comply with the procedure.				

Criticality Safety Procedural Infraction Database

Infraction	88-26	Date	10/14/88	Location	Bldg 771
Description	Exceeded NMSL (unusual occurrence report being prepared).				
Category	Mass violation	RC Category			P1/E3
Root Cause Description	A 55-gallon drum was found to contain more than 500 g of fissile material because the operator failed to performance check the gram estimators, and they were not operating properly.				

Infraction	88-27	Date	11/3/88	Location	Plant Site
Description	Ten-gallon shipping containers had unapproved spacer rings.				
Category	Unauthorized operation	RC Category			M3
Root Cause Description	Temporary safety limit to allow 8-inch spacers expired in 1987. Management did not comply with the requirement to remove these spacers from service. This failure allowed loss of control of perhaps 100 8-inch spacers on site.				

Infraction	88-28	Date	11/3/88	Location	Bldg 559 Box C-27
Description	NMSL exceeded.				
Category	Volume violation	RC Category			P1/P5
Root Cause Description	The NMSL required a lazy susan to be present in a glovebox. The operators did not install the lazy susan since they felt that the installation was optional. Poor communication was evident.				

Infraction	88-29	Date	11/4/88	Location	Bldg 771
Description	Improper bagging of filters resulted in exceeded NMSL.				
Category	Mass violation	RC Category			P2
Root Cause Description	The operator failed to follow procedure.				

Infraction	89-01	Date	1/4/89	Location	Bldg. 371
Description	Improper stacking of drums.				
Category	Other (Stacking violation)	RC Category			P1
Root Cause Description	This infraction is attributed to operator carelessness.				

Criticality Safety Procedural Infraction Database

Infraction	89-02	Date	5/2/89	Location	Bldg 707
Description	55-gallon drum exceeded NMSL.				
Category	NA			RC Category	NA
Root Cause Description	No root cause. Infraction retracted.				

Infraction	89-03	Date	5/3/89	Location	Bldg 559
Description	55-gallon Drum exceeded NMSL.				
Category	NA			RC Category	NA
Root Cause Description	No root cause. Infraction retracted.				

Infraction	89-04	Date	5/9/89	Location	Bldg 707
Description	Three loaded parts carriers violated NMSL of one parts carrier in glovebox. There was also a violation of a spacing requirement.				
Category	Mass violation/Spacing violation			RC Category	P1
Root Cause Description	Operator carelessness.				

Infraction	89-05	Date	4/28/89	Location	Bldg 777 Glovebox 362
Description	Use of unauthorized pans resulted in violation of NMSL.				
Category	Volume violation			RC Category	M3
Root Cause Description	Management complacency allowed the use of unauthorized pans in a glovebox for over 20 years.				

Infraction	89-06	Date	5/2/89	Location	Bldg 371 to Bldg 374
Description	Fissile concentration exceeded NMSL.				
Category	Mass violation			RC Category	M3/P2
Root Cause Description	The transfer of waste from Bldg 371 to Bldg 374 was authorized by a supervisor in violation of procedure.				

Criticality Safety Procedural Infraction Database

Infraction	89-07	Date	5/4/89	Location	Bldg 707
Description	55-gallon drum exceeded NMSL.				
Category	Mass violation	RC Category		Pr2/P3	
Root Cause Description	Inexperienced operator did not correctly use gram estimator. There was no procedure available for the proper use of the gram estimator.				

Infraction	89-08	Date	5/24/89	Location	Bldg 777
Description	NMSL violated when someone placed 28 kg of material on the bottom shelf of a cart.				
Category	Mass violation	RC Category		P1	
Root Cause Description	Operator carelessness.				

Infraction	89-09	Date	5/30/89	Location	Bldg 779
Description	The 200 g glovebox limit was exceeded.				
Category	Mass violation	RC Category		P1	
Root Cause Description	An operator incorrectly identified a transfer of 117 g of SNM as 17 g. Placing the additional material in the glovebox caused the NMSL to be exceeded.				

Infraction	89-10	Date	6/15/89	Location	Bldg 881
Description	The stacking of two of four crates containing uranium in excess of the Low Specific Activity violated the NMSL.				
Category	Other (Stacking violation)	RC Category		P5/P3	
Root Cause Description	Carpenters were unaware of the special handling requirements associated with the four crates. The carpenters also stated that no one advised them of the NMSL posting. Such postings are not normal in Bldg 881. It appears that the training given the carpenters may not have been adequate.				

Infraction	89-11	Date	7/3/89	Location	Bldg 771
Description	A 30-gallon trash bag was placed under a criticality drain inside a plastic house in violation of a NMSL.				
Category	Volume violation	RC Category		P1	
Root Cause Description	Operator carelessness.				

Criticality Safety Procedural Infraction Database

Infraction	89-12	Date	7/3/89	Location	Bldg 776
Description	Five drums were transferred to be counted without verifying the exact amount of material contained in each drum. As a result, each drum exceeded the 1000 g limit.				
Category	Mass violation			RC Category	P1
Root Cause Description	Operator carelessness.				

Infraction	89-13	Date	7/10/89	Location	Bldg 569
Description	One drum found to exceed weight limit by 66 g.				
Category	Mass violation			RC Category	P1
Root Cause Description	The operator did not indicate the weight of Pu in a drum on the Nuclear Material Drum Transfer Receipt, although the appropriate values were listed on the drum. Discrepancy was found upon receipt at transfer point.				

Infraction	89-14	Date	Unknown	Location	Unknown
Description	No report for this infraction issued as of 8/14/89.				
Category	NA			RC Category	Not determined
Root Cause Description	Not determined				

Infraction	89-15	Date	7/19/89	Location	Bldg. 777
Description	Pan used to store tools and miscellaneous items in glove box exceeded the pan depth of 2-inches.				
Category	Volume violation			RC Category	P1
Root Cause Description	Operator carelessness				

APPENDIX H

DEFINITIONS AND EXPLANATIONS OF TERMINOLOGY

Definitions are important in this assessment for two reasons. First, even within the relatively small nuclear industry there is a range of understandings and usages for some of the fundamental terminology. Consequently, it is often more difficult than one might expect for new avenues of communication to be opened among the various nuclear industrial facilities, laboratories and educational institutions, regardless of how many years they have been working on similar tasks. Therefore, one purpose of these definitions is to support a frame of reference so this report can be understood within the nuclear community.

Second, of course, the Team is concerned about communicating fully with the general public and their elected officials so that whatever concerns remain after reading this report will, at least, not be based on misunderstandings. This aspect of the communication problem is the most troublesome since many readers may have no frame of reference from which to judge the various levels of concern which are reflected throughout this report, much less understand the technical jargon that "insiders" often use too freely. Unfortunately, it is not possible in a report such as this to provide a complete course in nuclear engineering.

To assist the public to a reasonable extent, however, the Team has attempted to provide some perspective in the various sections of the report. Nevertheless, it is possible that misunderstandings will still need to be resolved. Although it is likely that a few definitions and discussions will be of only minor help in this regard, the reader should persist in the effort to understand this report. Readers with questions should feel free to contact the Team for clarifications.

The reader will notice that the words and phrases defined below are not presented in alphabetical order. Here they are presented in "logical order" so those that are interdependent might be better understood. This avoids having to stop in the middle of one definition to read another, and it also has the complementary effect of encouraging the reader to study all of the definitions.

CRITICALITY

The most important word needing a clear definition for this report is *criticality*. Criticality is achieved in a nuclear assembly which contains fissionable material when a *chain reaction* can be maintained. A chain reaction can maintain itself in steady state, that is at a constant energy-producing level, when the number of fissions per second is kept constant. The number of fissions, in turn, is controlled by the amount of fissionable material and the number and energy level of neutrons present in the assembly. Neutrons can only do five things in the volume of the assembly:

1. They can be *scattered* upon collision with any of the nuclei that make up the assembly thus changing their energy and their direction.

2. They can *leak* out, never to return, and thereby be unavailable for further interaction in the assembly volume.
3. They can be *reflected* back into the assembly after having scattered and leaked out from materials outside the assembly.
4. They can be *captured* by a nucleus, creating a new nucleus, and thus are effectively removed from the process.
5. They can cause *fission* through capture by a fissile nucleus that then quickly breaks into parts consisting of various fission fragments and more neutrons.

Nuclear fissioning releases a large amount of energy, most of which is the kinetic energy of the fission fragments themselves. This is the energy that turns into heat and runs a nuclear power plant. Each fission produces neutrons, anywhere from one to five per fission event. These neutrons can sustain the chain reaction as discussed above. Most of these neutrons are produced instantly, at the time of the fissioning event. A small fraction, however, are "delayed neutrons," produced by the decay of fission fragments seconds after the fissioning event. It is these delayed neutrons that allow for the controlled power increases at nuclear power plants.

If conditions are right, one of those neutrons will cause another fission, while the remaining neutrons will either be captured by other nuclei and not result in fission or will leak out of the assembly volume. However, if the leakage or capture of neutrons is increased, the chain reaction stops, and the system shuts down. Providing sufficient leakage and/or capture to a assembly containing fissile material (such as plutonium) is the key to keeping the assembly from going critical. *Separation* of fissile materials by additional distance or by additional materials that absorb neutrons will decrease the *reactivity* of the assembly. An assembly in this condition below criticality is referred to as being "sub-critical."

CRITICALITY EVENTS

If an assembly is just critical (in steady-state) and the neutron leakage or capture is decreased by moving the fissile materials *together* or removing other materials that absorb neutrons, more neutrons are available for fissioning (since less are captured or leaked from the system, the system reactivity increases) and the system becomes supercritical. The chain reaction, instead of just maintaining itself, increases with each new neutron and fission generation. The resulting power increase will be relatively slow if the leakage or capture decreases are small enough for the delayed neutrons to dominate the power rise. If, however, the decrease in the leakage or capture is large enough, the neutrons produced instantly at fission can control the power rise, resulting in a very rapid increase in fissioning with a corresponding doubling of the power in fractions of a second. Fortunately, such an excursion usually will shut itself down rapidly since the heat produced will expand the assembly, thereby increasing neutron leakage. Such an event is referred to as a "prompt criticality" event.

For accidental criticality events (usually prompt critical events), typically 10^{17} fissions take place before the system shuts down. This value was determined to be typical by the Team based on reports of actual criticality accidents occurring over the last 45 years (see below). Typically there is a "fission spike" which may be followed by a fluctuation in power or secondary spikes for critical solutions (liquids as opposed to solids). The energy released in such an event is about 3,000 BTUs or the amount of energy needed to heat 30 pounds (about 4 gallons) of water from 50 degrees Fahrenheit to 150 degrees Fahrenheit.

Nuclear weapons are designed to overcome the natural tendency of plutonium assemblies to shut down. It is a major engineering challenge to design and build a device which produces the large amounts of energy of a nuclear weapon. For a device with a yield equivalent to 1 kiloton of TNT (a very small nuclear weapon), more than 10^{23} fissions are necessary, over a million times as many as occur in a typical criticality accident. An accident at Rocky Flats Plant could not come close to the yield from a small nuclear device. Nor could it come close to the fission product yield from a typical (1,000 megawatt, electric) nuclear power plant. It takes less than one thousandth of a second of operation for such a nuclear power plant to produce the same amount of fission products as a typical criticality accident.

HISTORY OF CRITICALITY ACCIDENTS

Since 1945 there have been at least 35 significant criticality accidents throughout the world where the power level of fissile systems rose uncontrollably due to unplanned or unexpected events involving additions of *reactivity*. Reactivity increases cause more fissions to occur and eventually lead to a condition of criticality. The systems involved in accidents included working reactors, experimental critical assemblies, and systems found in fissile-material processing plants similar to Rocky Flats Plant. There were seven accidental criticalities at processing facilities in the United States between 1958 and 1978.^{1,2}

There were some events during and just after World War II and later between 1958 and 1962. The last criticality accident at a nuclear material processing plant in the United States occurred in 1978. Typical fission yields from these events range from 10^{15} to 10^{19} fissions with most having around 10^{17} . Experience from past criticality accidents led to the issuance of ANSI-ANS 8.1 (see Section 5.1 of this report). The most serious criticality safety risks, based on these accidents, is from liquid solutions and large diameter vessels.

¹ Stratton, William R., "A Review of Criticality Accidents," Los Alamos Scientific Laboratory, LA-3611, September 1967.

² Knief, Ronald A., Nuclear Criticality Safety: Theory and Practice, 1985, American Nuclear Society (Chapter 3).

PROBABILITY OF ACCIDENTAL CRITICALITY

The *probability* of a criticality accident, as quoted in the Safety Analysis Reports (SARs) for the various buildings at Rocky Flats Plant, ranges from one event in one thousand years to one event in one hundred thousand years for each year of future Rocky Flats Plant operation. The validity of these estimates is discussed in the body of this report (see Section 5.4). The probability of an criticality accident is small.

CONSEQUENCES OF CRITICALITY ACCIDENTS

The consequences of criticality accidents at processing plants like Rocky Flats Plant can be divided into four groups: (1) damage to equipment and buildings; (2) loss of fissile material; (3) radiation exposures and other injuries to workers located near the event and (4) consequences to the public. The Team did not find evidence at Rocky Flats Plant of a criticality accident, however, the seven criticality events that have occurred at other U.S. processing plants resulted in no significant damage to equipment or buildings and in no loss of fissile material.

The seven criticality accidents resulted in two deaths of workers and 19 significant overexposures of workers to radiation. For a criticality event occurring in a solution of plutonium and producing 10^{17} fissions, the range of a lethal dose of radiation (>400 rem) is about 10 feet. There would be about 10 rem of exposure at 100 feet. Clearly, unless they were far from the event or shielded, a criticality accident poses a significant potential hazard to workers.

The seven events in U.S. processing facilities between 1958 and 1978 resulted in virtually no exposure to the public. This is not unexpected because the public is far removed (relative to the range of the radiation) from processing facility sites so that the burst of radiation from a criticality event (gamma rays and neutrons) would be of no consequence. In addition, the amount of fission products from a criticality accident would be very small (see Section 2.2). It is very unlikely that a criticality accident would produce enough energy to disperse fission products to the general public.

ACCIDENT

For the purposes of *this* report, an accident is an unintended criticality event. The Team has tried to always use the words *criticality* and *accident* together in this report in order to avoid confusion with procedural infractions and incidents where no damage or harm is done. Also, while it is true that significant criticality accidents would generally involve a *significant* amount of reactivity above the criticality condition (prompt critical, as described above), the Team searched for evidence or indications that *any level* of criticality occurred.

INCIDENT

An incident is an error which did not cause damage or injury, but which *could* have resulted in an accident if not discovered in time and corrected. Generally, the error would be made in an actual activity performed rather than in a recording or documentation process; however, improper measurements or recording of plutonium quantities are considered to be incidents. The loss or the accumulation of fissile materials in unknown or uncontrolled locations or configurations are also incidents.

DESIGN

Engineering designs are arrangements of equipment in systems in a manner which will support the performance of a specified function. Included in the "systems" are appropriate operating procedures and maintenance strategies that are intended to anticipate and minimize as many potential problems as possible which may occur over the life of the project. Often it is the concept of "design life" that causes confusion since initial designs may be adequate over a short life span but inadequate for a longer or an open-ended life span. Also, the longer the design life, the more difficult it becomes to anticipate or identify those problems which may only become evident after a number of years of experience. In addition, designs sometimes become obsolete as either better systems evolve or objectives (standards) change. Process evolution may change the way in which a function is performed. Importantly, it is necessary in nuclear facilities to understand the reason for all design features so that they will not be neglected in later modifications.

CONFIGURATION MANAGEMENT

As problems are identified or as objectives are changed, the basic design may be modified many times. Often these modifications are gradual and address only a small percentage of the design features and do not warrant a continuous update of all of the affected documentation. Nevertheless, the number of these minor changes increases over the years and may cause confusion as to the current status of the system if the documentation of the design has been allowed to become fragmented and difficult for plant engineers to identify with confidence. This possibility has led to the need for *configuration management*, where formal efforts are made to maintain design documentation current and to ensure that changes are made in a controlled manner. Configuration management is not easily imposed on a design in mid-life since the current configuration must be known in order to be managed, and this depends on everything that has happened over the years.

DESIGN BASIS

It is increasingly necessary to describe an engineering design configuration in terms of its design basis documentation. The design basis is simply a compilation of all of the objectives and requirements of the design, along with its related assumptions and limitations. It is a complete description of the system, including all of the calculations needed for selection of the piping, components, instrumentation, and the support of the system. The design basis documentation of an entire facility

or plant either exists in a useful format or it does not. It is of little value, for example, to define a design basis for only one system if the interacting systems are not also defined. While a configuration document describes "what and where," a design basis document tells "why." This is not the same as a safety analysis report which is often limited to defining the boundaries around "how." A comprehensive safety analysis report, however, can be an important component of the design basis documentation. Without formal design basis documentation, configuration management documentation has no purpose or meaning.

SURVEILLANCE

Surveillance is any activity that is done to verify that a system or plant design is functioning in accordance with its design basis. Included in these verifications are actual tests of the system or its components as well as inspections by persons who know what the design basis requires. A surveillance may also be visual observation of personnel performing work in order to assure the proper use of procedures. Of course, a test or an inspection can be performed without an awareness of the person performing it as to the design basis, but such surveillance efforts must originate from an understanding of the design basis, otherwise they are not appropriate monitors of complex or potentially hazardous engineering systems or plants.

ASSESSMENT

The Criticality Safety Assessment Team was assembled in order to determine the validity of public concerns regarding criticality safety at the Rocky Flats Plant. By using the word "assessment," the Team separated itself from other types of appraisals and inspections which are routinely done in the nuclear community. This report, then, concerns an assessment of a range of activities and designs associated with criticality safety at the Rocky Flats Plant.

INDEPENDENT ASSESSMENT

DOE ORDER 4700.1 provides useful guidance on *independent* assessments: "An assessment, made outside the normal advocacy chain, of a project's status or condition.... These independent evaluations must be based on knowledge of the actual project and related institutional matters." The Team was independent, it was selected by SCIENTECH with no input from DOE, its charter was written by SCIENTECH without deletion by DOE, the members took time to develop knowledge of the plant, and the Team provided plant managers and DOE officials the opportunity to confirm facts that were observed. Readers who question the independence of the Team are provided enough information in this report to do their own assessment, which the Team would like to have the opportunity to critique in turn.

RECOMMENDATIONS

When the Team lists areas where significant improvements in criticality safety are possible, a recommendation is made. Recommendations are considered to be mandatory in this report. They are "good engineering practices" which can be

expected to have beneficial results if addressed. They reflect experience and knowledge as to how to correct the types of problems noted during the assessment. Action on recommendations, including funding actions required of DOE, should be taken expeditiously.

SUGGESTIONS

The Team has made suggestions in areas where the need for improvement should be evaluated and further action taken based on the results of that evaluation. This is an important definition in the current report since much of what is done at the Rocky Flats Plant is unique, and it would be inadvisable for the members of the Team to classify everything as recommendations when there might be several ways to meet the same objective or where the Team is not entirely sure based on information in hand that a problem actually exists in a particular area.

MEASUREMENTS: LOWEST LEVEL OF DETECTION

Some of the public concerns regarding criticality safety at the Rocky Flats Plant involve measurements of radioactive materials in the environment. Modern technology has made it increasingly possible to not only detect lower and lower levels of radiation, but it is also making it much easier to find and identify smaller and smaller quantities of specific elements, radioactive or not.

As explained by the Alliance for a Clean Rural Environment (ACRE) in one of its fact sheets, only 20 years ago laboratories were only able to measure quantities of materials in terms of parts per million. Now they can do it in parts per quadrillion. Thus, science continues to "discover" the presence of "new" materials where they are not expected. The problem, of course, is that it is now much more difficult to determine by measurements alone whether something has actually changed in the last 20 years or if the data would have been the same if laboratories had this advanced measuring capability back then.

The Team, thus, would caution against trying to reach conclusions simply based on measurements in the environment. The discussions and conclusions in this report discredit reports that something was found in the environment that would indicate that a criticality accident occurred. In fact, in Section 2 the argument is made that the detection of cesium and strontium in the environment is not a good indicator of the occurrence of a criticality accident since such an accident could have occurred and *had* no measurable impact on the environment. Even if the fission product materials from a criticality accident were released and measured, they would not necessarily be discernible from radioactive fallout or even natural levels of radioactive elements. Thus, even with the availability of modern technology, the Team found it necessary in this assessment to search well beyond the simple "evidence" provided in the news media.

RESIDUE

Residues are materials which are left over from fabrication or processing activities. At Rocky Flats Plant, the term refers to such materials only if they have an economic recovery value above a specified limit. Residues containing plutonium are retained at the plant in drums, awaiting processing to extract the plutonium. For certain residues being retained at the plant, the technology or equipment for economic extraction may not be in place, so some residues have been stored at the Rocky Flats Plant on a semi-permanent basis, pending the availability of the needed recovery capabilities. While stored at the plant, residues are of a criticality safety concern in that drums must each contain only a small amount of plutonium so that they may be stored near each other and not cause a criticality event even if unusual incidents or accidents occur.

WASTES

Those materials which are to be discarded due to their lack of economic recovery or recycling potential are referred to as waste. There are six basic types of waste, but some materials may be included in more than one of the categories (mixed wastes). They may also be in either solid or liquid (also called aqueous) form. Waste materials containing plutonium are stored at the plant in drums until an offsite radioactive waste disposal facility agrees to receive them for disposal. The six types of waste are:

TRANSURANIC (TRU)	Refers to elements heavier than uranium; in this report, it refers to waste materials with plutonium activity greater than 100 nCi/gram and less than the economical recovery limit
MIXED TRU	Same as TRU, plus hazardous contaminants (Note: more than 95% of Rocky Flats Plant TRU is mixed TRU)
LOW LEVEL (LLW)	Less than 100 nCi/gram of plutonium activity and/or other radioactive contaminants
MIXED LLW	Same as low level, but (chemically) hazardous materials are included
HAZARDOUS	Contains chemically dangerous materials but no radioactive contaminants
SANITARY	Solid and liquid waste containing no hazardous or radioactive contaminants

APPENDIX I

PERSONNEL CONTACTS AND BRIEFINGS

The Team received a number of briefings. Some of these were routine orientation briefings about the various departments and buildings at the Rocky Flats Plant. Additional briefings and interviews were conducted at the specific request of Team members. The various managers and technical people who were involved in presenting information to the Team were forthcoming and open. Most were eager to discuss their recent accomplishments in correcting deficiencies that were identified during previous inspections and assessments, and some discussed their own initiatives for improvements. Necessarily, however, this report focuses on issues that are directly related to criticality safety and the public concerns in this area of which the Team is aware.

The information and opinions expressed by each person were taken seriously. It was not sufficient to determine if the information is right or wrong. It was necessary to understand the source of the concern in order to provide an effective recommendation.

<u>Name</u>	<u>Organization</u>
S. Anderson	Health Physics
J. A. Behanna	Safeguards Measurement
C. Beutler	Acting Manager, Facility Engineering
S. Blush	Office of the Secretary, DOE Headquarters
J. C. Bretzke	Manager, Bldg. 771
J.M. Brooks	Industrial Hygiene
G. J. Carnival	Nuclear Materials Safeguards
K. Chandler	NDA, Bldg. 371
L. Couldren	Dosimetry
D. Cox	771 Incinerator Design
E. Crusan	Radiation Instrumentation
N. M. Daugherty	Environmental Management
C. Delforge	Operations Health Physics
S. W. DeWitt	771 Operations - 1st Shift
L. DiGiallonardo	Operations Manager; Foundry, Machinery & Assembly
V. Digman	Manager, Assay Operations
B. Douglass	Safeguards Planning and Assessment
S. Doty	Nuclear Materials Accountability
B. Duran	NMC
D. D. Dutcher	Maintenance 559/707/750
A. Eden	Manager, Plant & Utilities Engineering
R. J. Erfurd	Director, HS&E
N. Esquibell	Bldg. 371
R. Falter	771 Operations Manager
D. W. Ferrera	Acting Director, Support Operations
T. L. Foppe	Safety Analysis
F. J. Fraikor	Technical Training
K. J. Freiberg	Manager, Maintenance Department
A. Garcia	Filter System Maintenance Foreman
Gessell	EG&G, Idaho
J. Giacomini	Nuclear Materials Accountability
J. Gilmer	Nuclear Materials Accountability
E. S. Goldberg	Acting Manager, RFO
T. D. Gray	771 Maintenance Manager
T. C. Greengard	Manager, Environmental Restoration
A. Hazle	Colorado Department of Health
M. Hickey	Safety Review Group
R. B. Hoffman	Information Security
D. Hunter	Bldg. 881 Manager
G. S. Hyatt	Special Projects
E. H. Ideker	Director, Production Operations
R. Johnson	Bldg. 444 Manager
W. J. Kimmett	Final Product Acceptance
W. Kirby	Quality Assurance

Name**Organization**

A. Kirk	Machinery Foreman, 707/777
M. Lammering	Chief, EPA Radiation Programs Branch, EPA
J. M. Langsted	Manager, Operational Health Physics
W. Lawton	HVAC Engineer
B. R. Lewis	Environmental Management
G. McCain	Manager, Bldg. 776 Maintenance
J. D. McCarthy	Manager, Nuclear/Industrial Safety
N. McGuire	DOE/RFO
J. McKamy	Safeguards Measurements
K. B. McKinley	Manager, RCRA/CERCLA Program
R. Miles	Critical Mass Lab
D. Minshall	TV reporter, Denver, CO
M. M. Moomey	Library
J. Morrison	Safety Review Group
N. Muillo	Rocky Flats Project Coordinator, EPA Region VIII
R. J. Nau, Jr.	Manager, Bldg. 776; Nuclear Safety Committee Chairman
D. Norton	Bldg. 776, HS&E Area Engineer
K. Ortiz	Photo Archives
F. Padghan	Photo Archives
M. A. Paliani	Librarian
J. K. Patterson	Bldg. 881, Alternate Manager
K. Peters	Nuclear Materials Accountability
G. L. Potter	Manager, Radiological Health
T. Putney	NMC Foreman
R. E. Quale	771 Utilities Manager
G. E. Reed	Utilities (PSZ)
R. E. Richardella	Manager, HS&E Engineering
V. Risner	Manager, Criticality Engineering
R. M. Rogers	Radiation Monitoring
D. J. Sanchini	President, Rocky Flats Plant
C. Sandt	Machinery Foreman, 707/777
R. J. Schassburger	DOE/RFO Acting Branch Chief, Safety & Health
K. Schirk	Utility Manager (PSZ)
S. Sergeson	Project Manager, Bldg. 881 renovation
L. C. Smith	Self-Improvement Programs
W. Smith	R&D Machinist, Bldg. 881
J. Stone	Former RI Employee
D. Sweet	800 Area HS&E Engineering
C. Waggoner	NMC Crew Leader
J. D. Weaver	HS&E Area Management
W. F. Weston	Director, Plutonium Operations
C. L. Wilson	Security Operations
S. Wing	Manager, Bldg. 777 Support
J. Wu	Critical Mass Lab
R. D. Wyant	Safeguard Dev Plan Asses
F. T. Zurey	Proc & Equipment Engineering

APPENDIX J

LIBRARY-SEARCH KEYWORDS USED

The Criticality Safety Assessment Team was briefed on the classified and unclassified computer database information available in the Rocky Flats Plant Library. The Team requested and received subject printouts for the keywords below and identified a number of documents which were subsequently reviewed in order to be assured that an criticality accident has not occurred at Rocky Flats Plant.

1957 Fire	Keno
1969 Fire	Lessons
881	Maintenance
Accident	Manage
Alarm	Management + Review
Alleg	Material + Balance
Benelux	MBA
Ce/Sr	NDA
Cesium	Offsite
Conveyer	Operation
Crit	Organize
Design + Changes	Overpress
Destruct	Process + Safety
Drum + Safety	Quality + Engineering + Safety
Drum + Meas	Quality + Engineering
Duct	Renovate + Build
Duct + 707	Replacement
Engineer	Residue
Environment	Residue + Drum
EPA	Residue + Storage
Exposure	Risk
Filter	Safety + Analysis
Fire	Scans
Fissile + Material	Shield
Fission	Shielding
Flood	Strontium
Flyover	Training
Gamma + Scans	Union
Glove Box	Waste + Storage
Health + Physics	Unplanned
Incident	Unusual
Incinerate	Waste + Storage
Inert	

APPENDIX K

KENO COMPUTER CODE

The KENO code is a Monte Carlo code that is used to calculate the effective multiplication rate (k_{eff}) of an assembly containing fissionable material. It was originally developed at Oak Ridge National Laboratory (ORNL)^{1,2,3} and has evolved through a series of progressively more powerful and/or efficient codes into the versions KENO IV and KENO VA (the latter is occasionally described as KENOSA) currently available for use at Rocky Flats. A brief description of these codes is given in Attachment 1, which has been abstracted from training materials.⁴

In practice, the use of KENO requires a specification of a geometrical configuration, a distribution of materials throughout that geometric configuration, and a set of neutron cross sections that describe the interactions between neutrons and the various materials (this list of specifications is not exhaustive). At the Rocky Flats Plant, the Hansen-Roach set of 16 energy group cross sections (an internationally recognized set of data⁵) is the only set that is used, although R. E. Miles has considered the introduction of other sets (e.g., 123 energy group cross sections). The KENO code has been extensively validated^{6,7,8,9} for use on critical assemblies under a wide variety of geometric and material specifications by comparison of KENO results with actual experimental data. The Critical Mass Laboratory at Rocky Flats Plant has been used⁹ for some of these validations, particularly for circumstances like those to be found at the plant. The Critical Mass

¹ G. E. Whitesides, "The Development of KENO, A Multigroup Monte Carlo Criticality Program," Proc. Livermore Array Symp., CONF 680909, Lawrence Radiation Laboratory, September, 1968.

² E. C. Crume, Jr., "Some Considerations in Regard to the Development and Use of the KENO Program," *ibid.*

³ G. E. Whitesides and N. F. Cross, "KENO, A Multigroup Monte Carlo Criticality Program," CTC-S, Union Carbide Corporation, Computing Technology Center, 1969.

⁴ Introductory KENOSA Class.

⁵ G. E. Hansen and W. H. Roach, "Six and Sixteen Group Cross Sections for Fast and Intermediate Critical Assemblies," LAMS-2543, Los Alamos Scientific Laboratory, 1961.

⁶ G. R. Handley and C. R. Hopper, "Validation Checks of the "ANISN" and "KENO" Codes by Correlation with Experimental Data," Union Carbide Corporation, Y-1858, Nov. 20, 1972.

⁷ Jordan, Landers and Petrie, "Validation of KENO V.a, Comparison with Critical Experiments," ORNL/CSD/TM-238, December, 1986.

⁸ Handley, Masters and Stachowiak, "Validation of the Monte Carlo Criticality Program KENO IV and the Hansen-Roach Sixteen-Energy-Group Cross Sections for High-Assay Uranium Systems," Union Carbide Corporation, Y-2234, April 1981.

⁹ Internal Letter from R. E. Miles to N/IS File: Validation of KENO IV and KENOSA codes on the IBM 3090, Nov. 10, 1988.

Laboratory also reproduces annually⁹ a set of KENO calculations to provide assurance that no alterations in the code or data have occurred (except for those specifically authorized).

It must be observed, however, that almost none of these comparisons has involved subcritical assemblies. Because all of the situations arising in the production and experimental facilities at Rocky Flats Plant are intended to be subcritical, with a margin of safety, there is room for concern that KENO is being appropriately used at this facility. (See Attachment 2 for a discussion of this issue.)

Configuration control of KENO is obtained by a designation of the code, and its data sets, as "protected," so that Information Systems Management (ISM) does not permit alterations unless they come from Robert E. Miles, who has been delegated (by name, not by title) the sole authority to make such alterations.¹⁰ ISM then maintains copies of both the old and the new versions, so that the ability to reproduce earlier calculations is not lost.

When it is desired to introduce a new activity at Rocky Flats Plant, or to modify an old one, an engineering job order is prepared by the appropriate engineer. The criticality engineer assigned to the involved area reviews this order, prepares the necessary geometrical and materials input, and runs the KENO VA calculations. Both the geometrical and the materials inputs are analyzed and several calculations are performed with a variety of inputs, in order to take account of uncertainties (e.g., just where in a 55-gallon drum is the fissionable material located, what comprises and how solidly packed is the nonfissionable material, etc.) as well as a number of abnormal situations (e.g., unexpected flooding, collapse of supports intended to separate different pieces of fissionable material, etc.).

The analysis, calculations, and results, are documented in a bound notebook, kept by the criticality engineer and turned over to the Manager, Criticality Engineering if the criticality engineer departs from the group; that Manager maintains a file of the old notebooks. (The Team scanned one such notebook; its contents were considered to be satisfactory to determine what calculations were done.) The documentation is quite sufficient to provide traceability from the job order through the analysis and calculations to the posted criticality limits in the plant. If it were desirable at a later date to duplicate an earlier calculation, or to perform an additional calculation on a minor modification of the data, this could be done with relative ease. The results of the criticality engineer are then reviewed, and in some cases double-checked, by another criticality engineer, and proposed criticality limits are reviewed by Health Physics and Operations personnel. If necessary, the entire process is iterated until agreement is reached on a procedure that is acceptable to all involved groups, or the new or modified activity is abandoned.

New criticality engineers are required to have a degree in nuclear engineering, chemical engineering or physics, but are not required to have any specific experience with KENO, with criticality calculations in general, or with processes or

¹⁰ Internal Letter from J. D. McCarthy to N/IS File: "Use of KENO IV and KENO5A for Critical Safety Evaluations," Nov. 11, 1988.

experiments similar to those done at Rocky Flats. Training, both in classroom and in on-the-job settings, is conducted at Rocky Flats by the more senior criticality engineers. Much of this is done while the new employee is waiting (in some cases more than a year) for his Q-clearance. After a certain minimum (about 2 years) of training and on-the-job experience, a criticality engineer can be certified. At present only the manager and one other person are certified.

Based on the Team's review of the use of KENO at Rocky Flats Plant, it is suggested that:

- 1. The Department of Energy provide resources (money, equipment, etc.) to enable the Critical Mass Laboratory to design and carry out subcritical experiments that could be used to validate the KENO code under circumstances relevant to Rocky Flats Plant needs.**
- 2. Up-to-date sets of cross sections, which reflect the current state-of-art, be made available for use with KENO at Rocky Flats Plant.**

APPENDIX K - ATTACHMENT 1

INTRODUCTION TO KENO

1. How do the KENO IV and KENO VA codes work?

These codes solve for the quantity or quantities of interest (generally the neutron multiplication value) using the Monte Carlo method. This method involves mathematically tracing paths of individual neutrons, collision by collision, until they are lost by absorption or leakage. The fate of the neutron after each collision is determined by the probability distribution functions that are formed from the neutron cross section data. Random numbers are used to statistically sample these distribution functions. The procedure may be described as follows:

- A random number is generated and used to select a neutron location (several options are available).
- A random number is generated and used to select a neutron energy, from a fission energy spectrum.
- A random number is generated and used to select a neutron direction.

Another random number is generated and used to select the distance of travel before collision using the macroscopic total cross section for the medium. If the neutron crosses a boundary within this distance of travel, then the distance of travel is refigured using the total cross section for the next medium. If the neutron crosses the outer boundary of the system (neutron leakage) it is lost from the system and tracking is terminated.

At the site of a collision another random number is generated and used to select the type of interaction (absorption, fission, elastic, or inelastic scattering). If absorption occurs, tracking is terminated; if fission occurs, further tracking is also terminated, but another random number is needed to determine the number of neutrons produced in that fission. In addition, the fission location is saved to be used as a location for a source neutron for the next batch. A scattering collision requires the selection of a new random number to be used to select the emergent neutron energy and direction according to the cross section data.

All neutrons in a batch are tracked until they are lost by leakage or absorption. A value of k_{eff} for the batch is calculated as the ratio of the total number of fissions produced to the number of source neutrons. This process is repeated for 60-100 batches, and the final k_{eff} is the average of the k_{eff} s for the individual batches.

The above Monte Carlo procedure is referred to as an analog Monte Carlo simulation since the calculations follow the physical events of neutron scattering, absorption, and leakage just as they would be expected to occur in the system being modeled. Most Monte Carlo codes including KENO depart from this direct

simulation in order to reduce the variance of the estimate of k_{eff} for a given amount of computer time.

The most common variance reduction technique is the use of statistical weights. In this method, each neutron is assigned an initial weight of 1.0. If this neutron is absorbed, its weight is reduced but tracking continues. Likewise, if it causes a fission reaction its weight is increased and tracking continues. In this method, tracking can only be terminated if the neutron leaks from the system or its weight falls below some level. In this case, Russian roulette is played and if it loses at this game, tracking ceases; if it wins, its weight is increased and tracking continues. Variance reduction techniques such as this must be set up so as not to bias the calculation.

Theoretically, a Monte Carlo code such as KENO or KENO VA can use point cross section data and cross section sets containing 100 or more groups with no increase in running time over that obtained using the Hansen & Roach 16 group set. A Monte Carlo code uses cross section data as probability distribution tables and the size of these tables has no significant effect on the computer running time.

2. What does KENO calculate?

The main objective of the KENO code is to determine the neutron multiplication rate for an isolated system. It can also be used to compute other quantities they may be of interest such as: neutron flux as a function of position and energy; fission densities as a function of position; neutron leakage, absorption, and fissions as a function of energy; and neutron lifetimes and generation times.

Even if only the neutron multiplication rate k_{eff} is of interest, it is important to understand the significance, implications, and uses of these other data. The neutron fluxes, fission densities, etc., reported by KENO are based on a neutron emission rate of one neutron per second.

3. How should KENO results be interpreted?

The neutron starting distribution can have a profound and, in some cases, a disastrous effect on the accuracy of KENO calculations. In situations where there are known hot spots, the user should intentionally drive the fundamental mode by starting a large percentage of the neutrons at those locations. In general, the user should always make a judgement as to the locations of these hot spots and choose a starting distribution which will drive the fundamental mode. The concept of "neutron importance" can also provide guidance in selecting a starting distribution. Interior regions of fissile material are generally more important than exterior regions and reflector regions. Therefore, in selecting a starting distribution, more neutrons should be started in interior array units than identical exterior array units.

Notwithstanding these efforts to drive the fundamental mode, it is still necessary to carefully inspect the KENO results to assure that the Monte Carlo calculation has converged to the appropriate k_{eff} value.

The actual k_{eff} for the system being analyzed should be determined from an analysis which verifies that all regions containing fissile material have a "reasonable" fission density and that the fission density as a function of energy group is as expected; the neutron leakage and absorption sums to approximately 1.0; the chosen neutron start distribution has converged to the fundamental mode; the selected average k_{eff} has a small standard deviation; and the distribution of individual k_{eff} values has a near-normal distribution.

APPENDIX K - ATTACHMENT 2

VALIDATION OF KENO FOR USE AT ROCKY FLATS PLANT

Extensive comparisons have been made between the results of KENO calculations and experimental data for a wide variety of critical experiments^{6,7,8,9}. On the basis of these comparisons, the Team concludes that a KENO prediction that $k_{\text{eff}} = k_0 + 0.015$ is reliable when the absolute value of $k_0 - 1$ is less than 0.03, if KENO is used with the Hansen-Roach set of 16 energy group cross sections for geometrical and material specifications like those typically encountered at Rocky Flats Plant. The Team was unable to find a basis for this conclusion if $k_0 = 0.8$, or 0.9, or even 0.95, although the Team agrees that its reliability improves as k_0 increases to 1.

It is certainly true that the basic laws of physics are the same for subcritical and critical assemblies and that Monte Carlo codes, such as KENO, simulate these basic laws. On the other hand, the comparisons referred to in the preceding paragraph test not only the physics built into the code, but also the code logic (or architecture), the various numerical analysis tricks employed to replace continuous variables (e.g., energy, direction) with discrete variables, the cross section data and other input values, and the interpretation of the output values.

The Hansen-Roach cross sections are obtained by averaging a more detailed set of cross sections over an assumed neutron energy spectrum that is regarded as typical of (at least some) critical assemblies. One can, therefore, expect these cross sections to be valid when the actual and assumed neutron energy spectrum do not differ very much. There is no reason to believe (or not to believe) that the neutron energy spectrum in a subcritical assembly is necessarily close to the spectrum assumed for the Hansen-Roach cross sections. This issue is to some extent addressed at Rocky Flats Plant. Several different cross section sets for Th-232, U-233, U-235, U-238, Pu-238, Pu-239 and Pu-240 are listed, and the users must specify (in the so-called mixing table) which set is to be used. In a typical application, the users will run KENO with several different sets of data for one or more of these nuclides and will base their conclusions on the worst case.

The detailed cross sections used to calculate the Hansen-Roach cross sections were the best available at the time (late 60's). Considerably more extensive and accurate data are now available as the result of the ENDF program at Brookhaven. It would be desirable to base whatever few group cross section sets are used at Rocky Flats on the most recent versions of these ENDF data, and for the Critical Mass Laboratory to carry out at least a few subcritical experiments with geometrical and material specifications similar to actual production and/or experimental situations.

APPENDIX L

EMPLOYEE CONCERNS PROGRAM

The Team requested and reviewed all available records of Occupational Safety or Health Complaints that were submitted to the Department of Energy Area Office by Rocky Flats Plant employees who had concerns about criticality safety issues. The purpose of this review was to determine whether any of these complaints indicated the occurrence of an actual criticality accident or a situation with a high likelihood of resulting in a criticality accident.

The Team reviewed sixteen employee complaints in detail. A summary of the Team's findings for each complaint is provided below. Table L-1 summarizes the characteristics of the complaints. The majority of the complaints were filed with regard to Building 771. Several complaints involved repeat concerns, especially violation of Procedure 9969; nevertheless, in the review of these files, the Team found no evidence or indication that a criticality accident at Rocky Flats Plant had occurred. Also, no incident having a reasonable possibility of involving a criticality accident was found in this review.

In general, the complaints appear to have been responded to in a timely manner, and appropriate action was taken by plant managers. In several cases a complaint was filed only after the complainant(s) felt that they did not receive an adequate and timely response from their supervisors when they used less formal approaches.

Evaluation of Responses to Employee Complaints

Complaint #2 628-74-2. by phone April 23, 1974

An "imminent danger" complaint regarding Tank 953 in Building 771 was filed because of a Raschig-ring void in the tank. Although the Raschig-ring void was a serious infraction, no imminent danger existed since the tank was empty at the time of the complaint. However, the potential for a criticality accident may have existed previously or could have developed if no action had been taken.

From the records reviewed (in particular the memo from N. R. Glover, Chief QA and Safety Branch to B. W. Colston, Area Manager, Rocky Flats Area Office, dated May 1, 1974) it appears that a similar incident had happened in 1973.

Safety Concern #74-73. dated October 17, 1974 and Complaint #5 628-74-7. dated October 25, 1974

A concern was expressed about material being stored in the East Hall of Building 771 that had not been assigned a plutonium value. Without a value, it is not known how much plutonium is in the container. Also, it was charged, that management did not adhere to the agreement in Safety Concern #74-34.

The supervisor's response to this complaint was that the maximum plutonium content of residues stored in the East Hall can be "fairly accurately estimated" based on operating experience and that a study is underway as to whether a portable counter

can be used to determine the plutonium content of packages. This response was not satisfactory to the complainant.

The complainant then filed Complaint #5 628-74-7 on October 25, 1974. The complaint charged dangerous storage of plutonium material and "Knowingly failing to follow prescribed procedures with respect to handling and storing of nuclear materials."

The Team concludes that this matter did not involve any imminent danger of criticality.

Complaint #6 628-74-8, dated on or about November 3, 1974

The complainant was concerned about an insufficient number of Raschig rings found in a tank in violation of Procedure 9969. Management did not believe that the condition of an imminent criticality danger existed.

The Team believes that the investigation was performed in a timely and adequate manner.

Complaint #12 628-75-1, dated January 13, 1975

The complaint stated that Pu material was "dangerously stored," in violation of prescribed procedures and a previous complaint involving storage of unmarked and unknown quantities of plutonium. The complaint also asserted that permission to call nuclear safety was refused.

During the investigation, it was admitted that a criticality safety procedural violation had occurred.

The documentation of this complaint is poor and somewhat confusing. A memo to the United Steelworkers of America by the Area Manager states that the denial charge was based on a misunderstanding among the complainants and that the container was "safely stored according to prescribed procedures."

The reviewed material does not indicate any imminent danger of criticality. The responses occurred in a timely manner.

Complaint #17 628-75-6, dated February 28, 1975

The complaint questioned the integrity and safety of the method for testing the plant neutron criticality alarm (NCA) system. The complainant made seven recommendations with regard to the NCA system.

Dow Chemical Company, the plant contractor at that time, sent a reply to the DOE office (then ERDA) on March 7, 1975, which was forwarded to the complainant on March 28, 1975. On April 17, 1975, the complainant, joined by others, sent their comments on the Dow letter to Dow and added four new recommendations related to the NCA system. Of the seven responses by Dow to the recommendations, the complainants accepted three, partially accepted one, did not accept two, and one was clarified and apparently accepted. All decisions in Dow's letter of March 28, 1975 were upheld in a letter, dated May 2, 1975, from Dow to the complainants. Of the

additional four recommendations by the complainants, three were rejected, and one was deferred for measurements (related to the db-level of criticality alarms).

The Team found that the responses were adequate and that no criticality accident was involved.

Complaint #18 628-76-1, dated July 19, 1976

The complaint concerned procedural violations associated with tank inspections (Procedure 9969 and previous Safety Concerns 74-56 and 75-71). The complaint apparently was triggered by a spill of oily carbon tetrachloride on July 15, 1976, when the last bolt on a bottom inspection port flange was removed. The complainant was not involved in that operation, and the Raschig ring crew insisted that the complainant did not speak for them. The Raschig crew leader said that "he and others on the crew goofed by not checking a site gauge on the tank before removing a flange and asserted that there were probably also some flaws in the governing procedure."

The investigation of the complaint included interviews with the complainants, the ring crew and supervision, and health and safety personnel. Several safety-related documents were reviewed, and it was found that the procedures were not adequate and were not being followed properly. The Team concludes, however, that no imminent danger of criticality existed.

Letter to W.M. Lamb, Area Manager, ERDA Rocky Flats Plant, dated September 30, 1977 (Complaint #21 628-77-3)

This letter was a follow-up on Complaint #17 628-75-6.

The complainant stated that several items listed in the earlier complaint have yet to be properly resolved or completed. He also stated that Health Sciences and Radiation Instrumentation management have "reneged on one important item which was supposedly settled by mutual agreement...."

The answers provided appear to be satisfactory and in compliance with the earlier agreement between the complainant and Rockwell.

Complaint #52 628-84-3, dated May 18, 1984

The complainant charged that a requirement in DOE Order 5413.1 to furnish a "place of employment free from recognized hazards that are causing or likely to cause death or serious physical harm to employees" was being violated. The complaint stated that a plastic room (pen) had been built with no criticality drains and that management did not respond to this problem in an adequate and timely manner.

The investigation report of May 22, 1984 responded to the request for investigation. From the material available, the Team concludes that the complaint was responded to in a timely and adequate manner.

Complaint #54 628-84-5, dated October 29, 1984

Complainant stated in a phone call that he is filing an imminent danger complaint verbally. The complaint was about personnel leaving plutonium in gloveboxes

sometimes stacked "2 to 3 high in cans." It appears that the complaint was filed after the supervisors and others would not talk to him about the situation ("I have been ignored").

In a letter, dated December 3, 1984, Rockwell was asked to perform an audit of their glovebox housekeeping program and to document the audit. In its response (January 17, 1985), Rockwell stated that no nuclear materials safety limits were violated and that emphasis will be given to good housekeeping in gloveboxes.

There was no danger of criticality (an NMSL was not violated). The responses to the complaint were prompt and adequate.

Complaint #62 628-85-5, dated December 17, 1985

The complainant reported that maintenance personnel drained cooling water of unknown plutonium concentration into a 55-gallon drum. He also stated that a sampling of this water a week earlier showed a very low concentration. The draining operation had been authorized by the Safety Department.

The complainant's concern was expressed to his supervisor before writing the complaint. The supervisor's answer that he did not feel that anything could be done was unsatisfactory to the complainant.

The complaint was investigated and it was found that the system containing the water to be drained had not been opened between the time the sample was taken and the time the system was drained. For this reason permission to drain the system had been given.

The complaint did not involve any danger of criticality. With the exception of the supervisor's response, the complaint was investigated and settled in a timely and adequate manner.

Complaint #92 628-86-29, dated September 4, 1986

The complainant was concerned about potential violations of criticality limits at a furnace. The investigation showed that Criticality Engineering had evaluated the situation and allowed continued operation at that particular furnace. The complaint was filed because the complainant was not aware of Criticality Engineering's approval. This was due to insufficient communication.

No criticality limits had been violated. The complaint was settled in a timely and adequate manner.

Complaint #101 628-86-38, not dated (probably October 9, 1986)

The complainant charged that organic material floating on top of the aqueous solution shipped from Building 771 to 774 could contain high levels of plutonium and/or uranium. Consequently, when received in the "critically unsafe tanks in Building 774 it could cause a criticality." The complainant attached to the complaint an additional list of alleged discriminatory actions against him and letters of commendations for his work.

The investigation revealed no accumulation of fissile material in the affected tanks. However, further precautions were deemed necessary and 12 action items were identified.

The Team finds that no criticality limits were exceeded and that no danger to the health and safety of the workers existed.

Complaint #125 628-87-13. dated April 21, 1987

The complainant was concerned about the policy of Criticality Engineering where they "are not concerned about how many containers are present in any one line at a time as long as they are empty. This practice should cease and desist immediately in order to prevent a major incident from happening."

The investigation involved a physical examination of the gloveboxes, interviews with operators, a quantitative analysis of the probability of accidentally filling too many empty containers. The quantitative risk analysis showed that the likelihood of an accidental criticality of empty containers (in the worst configuration) is $1.7 \times 10^{-10}/\text{yr}$. Although this number may include significant uncertainties, the Team concurs that this particular criticality problem does not involve a significant risk. Any probability less than $1.0 \times 10^{-6}/\text{yr}$ is considered to be insignificant.

During the investigation, it was noted that control limits would not prevent the intentional creation of a critical configuration (intentional filling of empty containers). Also, the procedures state that empty containers "should" be turned over. Replacement of "should" by a requirement was suggested.

The investigation was performed in an adequate manner. However, it took from April 21, 1987 to September 1988 to close out the matter by letter to the complainant. Although there was no danger of accidental criticality during this period of time, this became clear only during the investigation in July 1988.

Complaint #141 628-87-29. dated November 10, 1987

The complaint stated that the floor area under the feed hopper in line 16, Room 114, Building 771 was accumulating a large amount of material. On November 10, the Operations Manager told the Technical Foreman to monitor the line for material buildup on the floor of the glovebox and to remove immediately any material found. The line was shut down for cleanup after the evening shift. Just before shift relief and after startup in the morning, it was found that the auger was leaking. At shift relief the offgoing foreman told the crew leader to shutdown, which occurred at 8:30 am.

The day shift people were concerned about a potential criticality accident and thought management was unresponsive because of production pressure, so they filed this complaint. When management wanted to restart the line about 4 pm, DOE asked that the line stay shut down since nobody appeared to know the cause for the leak.

After inspection, the leak was sealed and a temporary NMSL was written limiting the allowable depth of material in the glovebox floor to less than 2." The line restarted on November 12, 1988. It continued to run without leakage.

During the investigation, another concern was uncovered: the Criticality engineer was not immediately notified because "supervision already knew about the leak" and "they feared retribution for talking to safety personnel."

The incident posed a potential health hazard and resulted from operational problems but was no immediate criticality concern. The response by management was in general timely but not adequate since management tried to restart the line prematurely because of production pressure. Only DOE intervention prevented them from doing so.

Complaint #142 628-87-30, dated November 18, 1987

Several complainants filed a joint complaint that uncertified chemical operators perform operations that were previously performed by certified experimental operators. Apparently, no investigative action occurred until January 9, 1988, when one complainant called to find out what was happening with the complaint and to state that a criticality is imminent because of the resin being used in special recovery.

On a return call, a co-complainant stated that he "knew no criticality was imminent" but that there was a dangerous situation.

During the investigation it was found that there is "some indication of the uncertified operators doing unsupervised work" and that "supervision of uncertified operators may not always be present."

In a June 1988 letter to the complainants, it was stated that the resin has been used at other sites and "has proven reliable." It was also stated that uncertified workers can work under supervision of certified operators. The file was closed in February 1989, more than a year after the complaint.

There is no indication that there was the imminent danger of a criticality. Violation of supervisory duties did occur. The response of the investigation was slow, taking over a year to close-out the complaint.

Suggestion No. 84234, dated February 25, 1988 and Complaint #152 628-88-9, dated April 1988

Suggestion 84234 was filed under the Employee Suggestion Program. It was suggested that the radiation detectors should be self testing. The concern was regarding the reliability of the detectors, which were tested only once a month. Also expressed was a concern about personnel exposure from the use of a radioactive source (Cf-252) for the monthly tests. The Cf source is carried around outside its normal storage container. On April 21, 1988 the employee filed Complaint 152 628-88-9 because he felt that his suggestions were disapproved without a careful evaluation.

The Team found that the referenced letter of disapproval dismissed the suggestion in a cursory manner and was based primarily on costs and the expectation of an increased number of false alarms.

On June 2, 1988, an investigation was started in response to the complaint. This investigation closed on June 29, 1988. The proposed actions included installation of a

low-level alpha source for continuous detector testing and training of Radiation Instrument Technicians in the handling of sources.

The Team found that the complaint was handled in a diligent manner. The improvement suggested by the complainant was implemented despite a high reliability record for the detectors.

Building	Date	Complaint No.	Summary of Complaint	Summary of Response
771	4/23/74	2 628-74-2	Raschig-ring void in Tank 953 (repeat).	The level of solution in the tanks limited; further improvements considered and pursued.
771	10/25/74	5 628-74-7	Material being stored that has not been assigned a plutonium value.	Enforcement of prescribed procedures and avoidance of verbal orders when special handling is required.
771	11/2/74	6 628-74-8	Insufficient number of Raschig rings in a tank in violation of Procedure 9969 (discovered during installation of a port).	Installation of additional viewing ports; implementation of additional administrative controls.
771	1/13/75	12 628-75-1	Plutonium stored improperly; procedures not followed; workers claimed they were not allowed to contact nuclear safety personnel.	Nuclear safety personnel were not contacted due to misunderstanding between complainants. Stored material was found to be in accordance with procedures.
771	7/19/76	18 628-76-1	Procedural violations associated with tank inspections (Procedure 9969). Spill of oily carbon tetrachloride.	Improvement of procedures and in training.
771	12/17/85	62 628-85-5	Draining of cooling water of unknown plutonium concentration.	A sample had been taken a week before drain operation. The system had not been opened between taking the sample and draining.
771	11/10/87	141 628-87-29	Large amount of material was accumulating under feed hopper in line 16; the NMSL does not address dirty oxide on the floor.	A leak was detected and sealed; a temporary NMSL was written. Other problems were discovered during the investigation.
771	11/18/87	142 628-87-30	Uncertified chemical operators performing operations that should be performed by certified experimental operators.	DOE sent directive to Rocky Flats Plant management to correct problem.
771, 774	10/9/86	101 628-86-38	Organic material floating on top of aqueous solution shipped from Bldg. 771 to 774.	Twelve action items were identified as a result of this complaint.
707-778	2/28/75	17 628-75-6	The integrity and safety of the method for testing the plant neutron criticality alarm (NCA) system was questioned.	Action on eleven identified issues were initiated.
779	10/29/84	54 628-84-5	Improper handling of plutonium in glovebox line.	Rocky Flats Plant management was directed to provide special attention to glovebox housekeeping.

Building	Date	Complaint No.	Summary of Complaint	Summary of Response
371	5/18/84	52 628-84-3	Complaint included that a plastic room was built without criticality drains and management did not respond timely and adequately.	Improved training. The investigation of the complaint was expanded to include other areas as well.
371	9/4/86	92 628-86-29	Potential violation of criticality limits at a furnace.	The complainant was not aware of Criticality Engineering's approval due to insufficient communication to the workers.
All [1]	9/30/77	21 628-77-3	Several items in response to Complaint 17 628-75-6 have yet to be properly resolved or completed.	The status on each item was reported.
All [2]	4/21/87	125 628-87-13	Concerned about the number of empty containers present in a line.	A physical examination and a risk assessment was performed. It was shown that the likelihood of criticality is less than 1E-6/year.
All [16]	4/21/88	152 628-88-9	Concerned about the reliability of radiation detectors and the health hazard associated with carrying Cf 152 sources for tests.	The improvements suggested by the complainant were implemented.

NOTES:

- [1] With the exception of Buildings 771-774
- [2] Where criticality can occur
- [3] All production areas on plantsite

APPENDIX M

REFERENCES

Date (YYMMDD)	Author/Source	Document Title
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(NOTE: Undated documents are at the end of the list.)

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APPENDIX N

ACRONYMS AND ABBREVIATIONS

ACNFS	Advisory Committee (to the DOE) on Nuclear Facility Safety
ACRS	Advisory Committee (to the NRC) on Reactor Safeguards
ALARA	As low as reasonable achievable; a standard nuclear facility requirement to have a formal program to minimize personnel exposure to radiation; the elements of time (planning), distance and shielding are considered
Am	Americium; Am-241 is a decay product of plutonium-241, an isotope produced with plutonium-239. Americium-241, therefore, is found in Rocky Flats Plant systems that process plutonium.
ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
avg	Average
BTU	British thermal unit, a measure of energy or heat
CDH	Colorado Department of Health
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERN	European Organization for Nuclear Research, Geneva (Conseil Européen pour la Recherche Nucléaire)
Cf	Californium
cfm	Cubic feet per minute
CFR	Code of Federal Regulations

Ci	A curie; a measure of radioactivity of a material, equivalent to one gram of radium-226 or 3.7×10^{10} disintegrations/second
cps	Counts per second, used as a relative measure of radioactivity as read on a radiation detector
CSU	Colorado State University
db	Decibel - a measure of sound intensity
DE	Department of Energy, used on contact codes
DOE	U.S. Department of Energy
DOP	Diocetylphthlate; a filter efficiency test material
EDL	Economic discard limit
EG&G	A corporation; contractor to DOE
EH	U.S. Department of Energy, Office of Environment, Safety and Health
ENDF	A computer database developed by Brookhaven National Laboratory
ERDA	Energy Research and Development Administration; predecessor to DOE
EPA	U.S. Environmental Protection Agency
F	Fahrenheit, temperature scale
FSAR	Final Safety Analysis Report
FWHM	Full width at half maximum
GB	Glovebox
HEPA	High efficiency particulate air (filters)
HLW	High-level waste
HPGE	High purity germanium (crystal used as sensor in a gamma radiation energy spectrum analyzer used in NDA)

HS&E	Health, Safety, and Environment Department at the Rocky Flats Plant
HVAC	Heating, ventilation, and air conditioning
ICRP	International Commission on Radiation Protection and Measurements
ID	Identification
ISM	Information Systems Management
JHH	A Jomar Corporation radiation detector model prefix
k_{eff}	A measurement of criticality; if an assembly of fissile material has an effective k factor (k_{eff}) of 1.0 then it is critical - producing a constant number of fissions (power); if k_{eff} is greater than 1.0 (supercritical) the number of fissions per second is continually increasing; if k_{eff} is reduced to below 1.0 (subcritical), the number of fissions will decrease to some level of subcritical neutron population that is dependent on a non-fission source of neutrons, which causes some fissioning but not enough to support a continuously increasing level of fissioning
KENO	A computer code used in the calculation of criticality levels of fissile materials
keV	Thousands of electron volts; a measure of the energy level of an atomic particle or gamma (photon) energy
kg	Kilogram - a thousand grams (about 2.2 pounds)
km	Kilometer - a thousand meters (about 0.6 of a U.S. mile)
λ	Lambda; an exponential decay factor in units of inverse time; used in calculation of activity levels, which are time dependent due to natural decay (decrease in remaining numbers of atoms)
LLD	Lowest level of detection (see Appendix H)
LLNL	Lawrence Livermore National Laboratory

LLW	Low-level waste (See Appendix H)
LTA	Less than acceptable
MBA	Material balance area
mg	Milligram - one thousandth of a gram
mm	Millimeter - one thousandth of a meter
mrem	Millirem - one thousandth of a REM
n	Nano (10^{-9}) - e.g., nCi = 1×10^{-9} Ci
NaI	Sodium iodide (crystal sensor used in certain radiation detectors)
NDA	Nondestructive assay (for this report, identification of radioactive elements using radiation detectors)
NMC	Nuclear Material Control; part of the Rocky Flats Plant organization
NMSL	Nuclear material safety limit
NRC	U.S. Nuclear Regulatory Commission
OD	Outside diameter (of a pipe or ventilation duct)
OJT	On the job training
ORNL	Oak Ridge National Laboratory
p	Pico (10^{-12}) e.g., pCi = 1×10^{-12} Ci
PRA	Probabilistic risk assessment; a detailed, mathematical evaluation of risk
Pu	Plutonium
PuF ₄	Plutonium Fluoride
QA	Quality Assurance (Quality Engineering and Controls at Rocky Flats)
r	Radius (distance)
RCRA	Resource Conservation and Recovery Act

rem	Radiation effective man - a quantity of radiation dose that is based on the biological effects of radiation damage caused by different types of radiation
RFO or RFAO	Rocky Flats Area Office, Department of Energy
RFP	Rocky Flats Plant
RI	Rockwell International, the contractor/manager
SAAM	Selective alpha air monitor
SAR	Safety Analysis Report, a comprehensive documentation of design and operational safety characteristics
SCIE	SCIENTECH, Inc.; part of a report code
SGS	Segmented gamma scanner
SNM	Special nuclear material, such as uranium or plutonium, used in the assembly of nuclear weapons
sq	Square
SS&G	Sand, slag and crucible
TA-55	A facility at Los Alamos National Laboratory for processing and research on plutonium
Th	Thorium
TNT	A powerful explosive (trinitrotoluene); chemically $\text{CH}_3\text{C}_6\text{H}_2(\text{NO}_2)_3$
TRU	Transuranic, referring to elements heavier than uranium (waste material - see Appendix H)
U	Uranium
μ or u	Micro (10^{-6}) - e.g., $\mu\text{Ci} = 1 \times 10^{-6} \text{ Ci}$
VAC	Vacuum
WG	Water gauge; a scale for measuring small pressure differences, such as in ventilation

systems, by comparing with the height of a column of water (or differences in the heights of columns of water) supported by the (air) pressure in the system relative to some reference pressure (such atmospheric pressure); usually given in inches of water

WIPP

Waste Isolation Pilot Plant