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FIRE RISK ASSESSMENTS AT ROCKY FLATS PLANT

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INTRODUCTION

The Rocky Flats Plant (RFP) is a government-owned and contractor-operated facility, which is part of the nationwide nuclear weapons production complex managed by the U.S. Department of Energy (DOE). RFP is located in Colorado about 16 miles northwest of downtown Denver. The plant site encompasses about 10 square miles of federally-owned land with the major structures located within a half square mile section. The remainder of the land serves as a buffer zone between the processing facilities and the general public.

RFP was primarily involved with metal fabrication, assembly, and chemical processing associated with the nuclear weapons program and other work directly related to national defense. Activities included numerous metalworking, fabrication, and assembly shops; chemical recovery and purification processes; and associated quality control functions. This involved materials such as plutonium (Pu), enriched and depleted uranium, beryllium, and various alloys of stainless steel.

The hazards and associated risks from potential accidents involving the handling of fissile or other hazardous materials have been analyzed. One of the greatest hazards is that of fires due to the pyrophoric nature of certain forms of Pu. RFP has had a high frequency of small fires that did not result in the loss of confinement of radioactivity. However, two significant industrial fires involving Pu manufacturing occurred in 1957 and 1969. Lessons learned from these events resulted in substantial upgrading of fire prevention and fire protection programs, such as providing an inert atmosphere for operations that involved pyrophoric forms of Pu, eliminating combustibles inside gloveboxes and within the production areas, installing fire detection systems (e.g., contact heat detectors for storage locations, ambient atmosphere detectors inside gloveboxes), and installing fire suppression systems (e.g., wet pipe sprinklers for production areas and automatic deluge systems to protect exhaust high efficiency particulate air [HEPA] filter plenums). Additionally, administrative controls

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were enhanced (e.g., training, procedures, hot work permits) and response capabilities were strengthened (e.g., building fire brigades, full time onsite fire department).

The success and failure of these engineered and administrative controls were evaluated in the process of assessing risk from Pu fires to the public for the facilities' Final Safety Analysis Report (FSAR) required by DOE Orders 5481.1B (DOE, 1987) and 5480.23 (DOE, 1992). Since the FSARs were approved by DOE, additional fire risk assessments were performed which include: (1) an Unreviewed Safety Question Determination (USQD) addressing redundancy of glovebox heat detectors; (2) rebaselining risk estimates for resumption of Pu production operations; and (3) assessing the risk for thermal stabilization of Pu to support RFP's changing mission of decontamination, decommissioning, and environmental restoration. The probability of occurrence, radiological consequence, and risk of Pu fires were assessed using probabilistic risk assessment techniques.

FSAR FIRE RISK ASSESSMENTS

Fire risks were assessed for the FSARs by application of event tree analyses. Initiating event probabilities of occurrence and mitigating system (e.g., vital safety systems or administrative controls) failure probabilities (e.g., unavailabilities) were determined by fault tree analysis or statistical analysis of RFP incident or surveillance data. Methodologies were documented in the *Rocky Flats Risk Assessment Guide* (EG&G, 1992) which was developed from commercial nuclear reactor and chemical industry risk assessment techniques. Fire hazards and their controls were identified and grouped into categories that would be representative in terms of likelihood and consequences. Those potential fires which would result in negligible consequences, or whose probability of occurrence was not considered credible (i.e., $> 1 \times 10^{-6}$ /year) were screened from further evaluation. These grouped initiating events requiring further evaluation included fires initiated in similar processes in gloveboxes, fires in other inert atmosphere gloveboxes, fires in air atmosphere gloveboxes, fires in process rooms, fires in utilities areas, and fires on shipping and receiving docks. The success and failure of mitigating systems modeled included absence of combustible materials in gloveboxes and rooms to propagate a fire, confinement capability of gloveboxes, emergency responses by operators or the Building Emergency Support Team, emergency response by the RFP Fire Department, and suppression by the room wet-pipe automatic sprinklers. Other safety systems were assumed to function because including their failure would result in accident sequences with such low probabilities that they would not be risk significant. These systems included heat detection in gloveboxes, exhaust plenum automatic deluge systems, glovebox and room ventilation and filtration systems, and normal and emergency power, and room fire barriers to limit damage to one fire zone.

Accident sequences were defined by a particular path through the event tree based on either the success or failure of the mitigating systems. However, considering the uncertainty of the calculated probabilities, those sequences with a probability of occurrence greater than 1×10^{-8} /year were included if they increased the overall risk for the accident scenario by more than 10%. Those accident sequences which were determined to be credible were then analyzed for radiological consequences and risks.

Radiological consequences were determined by estimating an amount of material at risk as determined by the accident sequence, appropriate release fractions (i.e., fraction that becomes airborne due to the thermal stress and behavior of the form of Pu involved) which were based on experimental results or recommended in the literature, and applying leakpath factors from the glovebox. This initial source term

released to the room was used to assess risk to the workers, and was also modified by a leakpath factor from the building (e.g., two or four stages of high efficiency particulate air filtration) to estimate the building source term released to the environment. Mean dose to a hypothetical maximum offsite individual and health effects to the population were modeled with Gaussian dispersion methods based on a "star deck" of wind speed, stability class, and direction.

Mean doses and health effects were combined with the probability of occurrence of the accident sequence to establish a mean risk estimate. Accident sequence risks were summed to establish mean risk for the accident scenario and a composite risk estimate for all accidents. Distributions of radiological consequences were combined with the probability of occurrence to present risk curves. Risk comparisons were then made by comparing mean risks to risks from background radiation, and by comparing risk curves to those from the WASH-1400 Reactor Safety Study (NRC, 1975).

REDUNDANCY OF GLOVEBOX HEAT DETECTORS

Lack of redundant ambient atmosphere heat detectors was analyzed as part of a USQD risk assessment. The USQD process complies with DOE Order 5480.21 (DOE, 1991a) to assure that proposed changes to the facility and procedures are appropriately evaluated and approved. This process maintains the safety envelopes defined by the facilities' FSAR accident analysis. The current USQD approach used at RFP is based on the commercial nuclear power industry standard NSAC/125 (EPRI, 1989).

The USQD dealing with the lack of redundant ambient atmosphere heat detectors was initiated as the result of an audit that challenged the FSAR redundancy assumption of detector placements, and that some gloveboxes only had a single heat detector. Performance of the USQD risk assessment included an assessment of the availability of either single or redundant heat detectors by use of a fault tree analysis, evaluating both hardware failures and human errors during periodic surveillances.

Also questioned was the validity of using historical plant surveillance data in calculating the unavailability for ambient atmosphere heat detectors. This resulted in a re-evaluation of the unavailability for ambient atmosphere heat detectors using commercial industry failure rates and surveillance intervals as inputs to the fault tree analysis. A sensitivity analysis on the effects of having supervisory circuitry and other features were also modeled in the fault trees.

Results of the fault tree analyses were then incorporated into existing event tree analyses to determine the affect on the probability of occurrence and risk of accident sequences. The adjusted probability of occurrence and risk values were compared to the original values to see if significant changes had occurred.

Based upon the fault tree analyses and the dominant accident sequence probabilities of occurrence and risk estimates, it was concluded that an unreviewed safety question did not exist. This was because the revised risk estimates related to glovebox fires were bounded by risks from dock fires.

REBASELINING FIRE RISK ESTIMATES FOR RESUMPTION OF PU PRODUCTION OPERATIONS

Pu production operations at RFP were curtailed in late 1989 by DOE so that

interim authorization basis to allow resumption of Pu operations, several facilities' FSARs were reviewed. Several resumption teams were established to assess the safety of resuming Pu operations, and the adequacy of their safety analyses, Operational Safety Requirements, and vital safety systems. Specifically, Resumption Team 3, assessed RFP Pu operations to provide assurance that resumption of operations would be in a manner consistent with the approved radiological consequence safety envelopes. Other resumption teams and efforts concentrated on enhancing or establishing programs to effect a new safety culture consistent with commercial and government nuclear industry practices for power reactor facilities.

A risk assessment was performed in support of resuming Pu production operations. Part of this resumption effort involved the rebaselining of several Pu facility safety analyses. This effort included documenting the original FSAR risk assessment assumptions and calculations concerning fire risk estimates. If inconsistencies or errors were identified, risk estimates were rebaselined and a sensitivity analysis was performed to determine their impacts. Event trees were updated or new ones were developed to reflect changes in assumptions on accident progression and availability of more recent data on failure probabilities or initiating event probabilities of occurrence. Radiological source terms were revised to reflect changes in assumptions for the amount of material at risk, accident release fractions, and building leakpath factors. Radiological consequences and risks were analyzed with the MELCOR Accident Consequence Code System (MACCS) computer code (Chanin, 1990) to estimate impacts to the public.

The major changes to fire risk involved a significant increase in probabilities of occurrence for some fire scenarios. However, this did not substantially impact fire risks because of a substantial decrease in the probability of occurrence of a dock fire which was the dominant contributor to the overall fire risks. The revised risk curves were compared to the reactor accident risk curves from NUREG-1150 (NRC, 1990).

FIRE RISK ESTIMATES FOR THERMAL STABILIZATION OF PU

The latest fire risk assessment was performed in support of the changing mission for RFP to one of decontamination, decommissioning, and environmental restoration. An operation to support this mission is the thermal stabilization of Pu by electrical heating in an air environment to eliminate its pyrophoric hazards. Fire risks associated with this process, as well as other activities to maintain the buildings safety envelope, were assessed as an addendum to the rebaselining effort for the resumption of Pu production operations mentioned above.

Accident scenarios analyzed in the rebaselining for resumption of Pu production operations were assessed for applicability to the new mission. Fire scenarios analyzed originally considered to be applicable to the new mission were fire inside inert gloveboxes, fires in process rooms, and fires on docks. In addition to these fire scenarios, several additional fire scenarios were developed during the rebaselining of risk for resumption of Pu production operations. This included a fire in one and multiple gloveboxes either caused by loss of inerting or internal initiation of potentially pyrophoric plutonium.

The fire scenarios affected by the new mission were assessed for changes in the event tree logic, probabilities of occurrence, and mitigating system failure probabilities. This was performed for the risk-dominant fire scenarios determined in the rebaselining assessment.

Source terms for the fire accident scenarios were determined by updating those determined in the rebaselining assessment as necessary to accurately reflect the

circumstances associated with the new mission. Release fractions associated with the various materials were reviewed for applicability. Radiological consequences associated with the releases from various fire scenarios were calculated using the MACCS code.

Additionally, risk estimates and risk curves were presented. The most significant fire scenario in terms of risk to the public is due to an assumption that potentially pyrophoric plutonium would spontaneously ignite upon loss of power which results in loss of inerting, even though this has never occurred in the past. The mean risk estimates were demonstrated to be orders of magnitude below the quantitative safety goals promulgated by DOE (DOE, 1991b).

Radiological consequences and risk to co-located workers were assessed by modifying an atmospheric dispersion factor. Consequences were calculated for individuals gather outside of the facility and for individuals inside adjacent facilities for having an active ventilation system, or taking credit for emergency actions to reduce outside air intake. These assessments were used for on-site emergency planning purposes.

SUMMARY

Fire risks involving plutonium processed or stored at the RFP have been quantitatively analyzed for safety analysis reports. Operational Safety Requirements have been established on those mitigating systems (e.g., fire alarms, fire suppression systems, emergency response groups) that were credited in the risk assessment. These OSRs establish the minimum operating requirements and also mandate periodic surveillances.

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