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REDEFINED CRITICALITY RISK CATEGORIES FOR FIRE FIGHTING

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INTRODUCTION

Following the investigation and recommendations of the serious Rocky Flats Plant fire on May 11, 1969, a review was made of the fire fighting philosophy in Atomic Energy Commission installations. After the review and with the knowledge gained from the fire, project action was taken to install automatic water sprinkler systems in several facilities where, in the past, the use of water generally was considered a last resort in fire control. Since automatic sprinklers supply an unknown volume of water to the system as compared to manually controlled sprays, the criticality control parameters in a number of locations required review.

Current Atlantic Richfield Hanford Company fire fighting policy divides fissile material processing locations into four categories; A, B, C, and D depending upon the criticality risk involved.(1) In "D" areas, the direct use of water for fire fighting or the introduction of water from fire fighting activities in adjacent areas has been excluded except as a last resort. Many areas in the plant have been defined Category D. Since some of the "D" areas are confined within fragile or combustible barriers, rubber gloves, and plastic bag ports, which are likely to be destroyed or damaged by fire, the exclusion of water from automatic sprinklers cannot be guaranteed.

This document provides the basis for revising operating instructions and the concomitant revisions in specifications, standards, and operating procedures. The document redefines the four fire fighting categories to better differentiate between categories particularly under the special conditions imposed by automatic sprinkler systems.

SUMMARY

The fire fighting Categories B, C, and D are redefined to clearly qualify the risks of criticality by using, as a criterion, the number of independent errors or failures required before a criticality can occur. The new category definitions are as follows:

Category A. The addition of water to the facility or area cannot cause a criticality because the quantities of fissile materials are too small.

Category B. Fissile materials are regulated such that, in addition to a fire, consequential conditions, and the automatic use of water; three or more additional independent errors or failures are necessary to cause a criticality.

Category C. Fissile materials are regulated such that, in addition to a fire, consequential conditions, and the automatic addition of water; two additional independent errors or failures are necessary to cause a criticality.

Category D. Fissile materials are regulated so that fire and its worst consequential conditions alone, or the addition of water alone, will not cause a criticality, but a combination of the two may.

After the installation of automatic fire prevention sprinkler systems, fire along with possible breaching of combustible barriers and the automatic release of water shall be considered as one "error" (deviation from normal operation). To comply with the present AEC requirement[2] of a system remaining subcritical with one error or failure, Category D areas shall remain subcritical under the above conditions. In addition, to comply with the present ARHCO philosophy of a system remaining subcritical with two error or failures in unshielded areas[3,4], Category D areas shall not be allowed in unshielded locations.

DISCUSSION

The criticality prevention aspects of any process, operation, or area are normally analyzed by a Criticality Prevention Engineer in response to a Request for Criticality Prevention Analysis or when reviewing a minor revision in a specification. The analysis considers all credible changes in process and failure possibilities. These include the worst foreseeable combination of fissile material (type and quality), fissile material density, diluent composition and distribution, geometry, reflection, interaction, and measurement uncertainty. It is mandatory that criticality not occur under the worst foreseeable conditions following one credible equipment failure or human error[2] but where people are working in unshielded proximity to fissile material, it has been ARHCO's practice to be subcritical with two independent failures or errors.[3,4] Where additional factors of safety can be assured with no or minimal inconvenience to operations, these may also be recommended. The term "error" as used in criticality prevention analyses may include not only human error but all other abnormal operating conditions such as fires, equipment failures, water addition, etc.

Compliance with the policy that no one error or failure shall cause a criticality is necessary in assessing fire fighting risks. The risk that a criticality could be caused by adding water to chemical processing facilities varies from zero to high, depending upon the quantity, form, and packaging of the fissile materials present. For fire fighting purposes, chemical processing facilities have been divided into four categories, depending on the criticality risk involved. These have previously been defined as follows:[1]

Category A. Probability of Criticality if Water is Added Zero.
The addition of water to the facility cannot cause criticality because the quantities of fissile materials present are too small.

Category B. Probability of Criticality if Water is Added Minimal. The likelihood of criticality resulting from fighting a fire with water is very small. While fissile materials are normally present in quantities exceeding a minimum critical mass, the fissile materials are in a form, in packaging, or so stored that criticality is practically impossible.

Category C. Finite. Under some foreseeable conditions, the addition of water could cause criticality. This category embraces two types of areas:

1. Those process areas in which fissile materials are normally present in quantities exceeding a minimum critical mass; the fissile materials are normally held in such a manner that the addition of water would not cause criticality.

2. The personnel working areas immediately surrounding Category D facilities.

Category D. High. Fissile materials are normally present in a configuration that could be made critical by the addition of water, or the configuration is very likely to be changed by fire such that the addition of water could cause criticality.

Categories A and B above are easily distinguished, "A" by limited mass, and "B" by sufficient regulations to prevent criticality. Categories C and D are not as easily distinguished and should be defined in terms of errors or failures required for criticality. Revised definitions for three of the four fire fighting categories have been developed to more clearly qualify the risk of criticality using as the criterion the number of independent errors or failures permitted before a criticality can occur. The new category definitions are as follows:

Category A. The addition of water to the facility or area cannot cause a criticality because the quantities of fissile materials are too small.

Category B. Fissile materials are regulated such that, in addition to a fire, consequential conditions, and the automatic use of water; three or more additional independent errors or failures are necessary to cause a criticality.

Category C. Fissile materials are regulated such that, in addition to a fire, consequential conditions, and the automatic addition of water; two additional independent errors or failures are necessary to cause a criticality.

Category D. Fissile materials are regulated so that fire and its worst consequential conditions alone, or the addition of water alone, will not cause a criticality, but a combination of the two may.

After the installation of automatic sprinkler systems, ARHCO's existing safety philosophy that requires a subcritical condition following the two worst independent and credible errors or failures in an unshielded area should be maintained. Presently, all existing Category D areas are unshielded and many are enclosed by fragile or combustible barriers including rubber gloves and plastic bag ports. When the barrier around a Category D area is fragile or flammable, breaching of the barrier along with automatic and unlimited water entry, either directly or indirectly, cannot be considered impossible. Therefore, fire and/or breaching of the barrier and/or water entry is (are) considered one error, and to be consistent with the "two error subcritical" philosophy a second credible error or failure, such as double batching or change in spacing shall not cause a criticality in unshielded areas. Therefore, all existing Category D unshielded areas should be reclassified "C". Some of the areas can be reclassified "C" by Criticality Prevention Specification change only. Other "D" areas will require physical modification and/or administrative changes to enable reclassification to "C" before the automatic sprinkler system becomes operational.

In recommending modifications of areas to cause a lower criticality probability, it is recognized that water has different potential effects depending upon the form of fissile material. Following the Rocky Flats Plant fire, the investigators determined that:[5]

a. The plutonium was confined to the burned out conveyor-boxes in well-defined piles after the use of forty to one hundred thousand gallons of water in the fire fighting efforts using both water fog and direct solid streams.

b. The use of water apparently caused a rigid oxide crust to form over the burning metal preventing the spread of loose oxide during fire fighting efforts.

c. Except for one metal ingot that was washed out of a hood, less than one half of a minimum critical mass of plutonium was found in the water and on the floors outside the hoods and conveyors after the fire, even though most of the hood panels had been destroyed.

d. Where the metal was contained in covered containers, it did not burn.

e. There were no explosions resulting from adding water to burning plutonium.

A series of experiments has recently been performed to determine the mobility and final geometry of several plutonium compounds during and following a simulated fire fighting situation utilizing automatic sprinklers.[6] Plutonium compounds in open containers were flushed out until a 1/2 to 2-inch water layer prevented further transport. The protective water layer thickness depended upon the water droplet size, velocity at impact and the density of the plutonium compound. The displaced solid compounds readily flowed with the water but rapidly settled out into a uniform thin layer that was not remixed by normal sprinkler action after the protective water layer exceeded 1/2 inch. If the mixtures do not flow into restricted volumes or water layers greater than 2.5 inches, the system will remain subcritical.

Therefore, it can be concluded that when metal or powder masses are properly sized, contained, and spaced; the addition of unlimited water by the automatic sprinklers will not change the mass, nor significantly alter the moderation, geometry, or spacing. The containers, however, must be of such size and shape that a double batch in the container will not be critical with the inleakage of water and/or with water surrounding the container, if water flooding is possible.

In automatic sprinkler areas where fire, breached barrier and automatic water addition are possible, the leakage of stored concentrated fissile solutions is of concern. The minimum critical plutonium concentration and mass on a hood floor is substantially reduced when the concentrated plutonium solution (450 g/l allowed by CPS) is diluted with water to approximately 17 g/l at a depth of about 9 inches. The final geometry of liquid will be a slab and will fit the shape of the container, thus the safety of a fissile solution system must be controlled by limiting the solution shape or height following accidental leakage and water addition or by limiting the stored mass to less than a minimum critical mass.

The safest method of criticality prevention in solution storage hoods of this type is to limit the solution to a safe depth under worst foreseeable conditions following two errors or failures. For example, this precludes a criticality even if all tanks in a hood rupture or a manifold which is open to all tanks leaks or there is a combination of a broken tank and a manifold open to all tanks. If a drain is used to prevent liquid buildup in the hood, it must be open and free of obstructions at all times, have a capacity to handle expected incoming water rates, and drain the effluent into a criticality safe configuration.

A second, but less desirable method, of criticality prevention would be to limit the mass allowed in each tank or hood. Most of the solution storage hoods, however, contain multiple tanks which are connected to a common manifold. It is normal practice to circulate the contents of several tanks through this manifold for mixing; therefore, a manifold rupture could drain the contents of more than one tank to the hood floor. In this case, the combined mass being circulated should be limited to a subcritical mass or only one manifold valve should be open at one time. In most operations, this restriction would drastically limit the storage capacity and flexibility of the hood.

The new definitions of fire fighting categories clearly indicate the differences among the categories. Upon the installation of an automatic sprinkler system, the new definitions clearly show that Category D locations should be eliminated in unshielded areas and where necessary one of the above methods of accommodating the addition of essentially unlimited amounts of water can be safely used.

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