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REGULATORY GUIDE

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REGULATORY GUIDE 5.42

DESIGN CONSIDERATIONS FOR MINIMIZING RESIDUAL HOLDUP OF SPECIAL NUCLEAR MATERIAL IN EQUIPMENT FOR DRY PROCESS OPERATIONS

A. INTRODUCTION

Paragraph (b) of Section 70.22, "Contents of Applications," of 10 CFR Part 70, "Special Nuclear Material," requires, among other things, that each application for a license to possess at any one time more than one effective kilogram of special nuclear material (SNM) contain a full description of the applicant's program for control of and accounting for SNM that will be in his possession under license, including procedures for controlling SNM during its processing or use in the facility and procedures by which process losses are determined. Section 70.51, "Material Balance, Inventory, and Records Requirements," indicates that certain licensees must conduct their nuclear material physical inventories in compliance with specific requirements.

The control of and accounting for SNM can be made more effective by reducing residual holdup in process equipment following draindown and cleanout. Such a reduction would lessen the severity of the problems associated with determining the residual holdup component of a physical inventory and would reduce the uncertainty component contributed by residual holdup.

The purpose of this guide is to call the attention of individuals who participate in equipment design and layout and in measurement control to the utility and significance of reducing residual holdup. This guide, therefore, is intended for plant managers, designers, operators, material control personnel, and others at the decision-making level who include safeguards as an integral part of their professional activities.

This guide describes design features acceptable to the Regulatory staff for minimizing the residual holdup of SNM after draindown or cleanout of equipment used in dry process operations.[1] The design features noted will facilitate physical inventory measurements and reduce material balance uncertainties. They are not expected to interfere excessively with process operations. In particular, this guide is applicable to (1) gas handling, (2) glovebox operations, (3) calcining, (4) dry solids transfer, (5) dry blending and classification, (6) packed bed conversions, and (7) comminution.

B. DISCUSSION

1. Background

Past experience and current observation of process operations used in various systems indicate that the publication of general guidelines for equipment design could assist in achieving the degree of material control and accounting needed for satisfactory protection of SNM. Sizable amounts of SNM accumulate as deposits during material processing or draindown. For certain process steps, modes of operation, and types of material, the quantity of the accumulated deposit may reach a steady state that fluctuates around some characteristic amount. In other instances, a deposit may continue to accumulate as the process continues to operate and may not become apparent until draindown or cleanout. In either case, the quantity of SNM in residual holdup following draindown often is difficult to determine with sufficient precision and accuracy to meet material

[1]Regulatory Guide 5.8 addresses drying and fluidized-bed operations for purposes of minimizing residual holdup of SNM. Regulatory Guide 5.25 addresses residual holdup problems unique to equipment used for wet process operations.

unaccounted for (MUF) and limits of error of MUF (LEMUF) requirements. Appropriate design could increase the effectiveness of draindown and assist in reducing residual holdup and the consequent need for determining the retained SNM. Good design also should improve the capability for any needed cleanout following draindown.

Minimizing the quantity of material retained in equipment after draindown generally enhances the effectiveness of a material protection program in the following ways:

a. Quality of Physical Inventories

Reducing the quantity of residual holdup that is not amenable to measurement improves the quality of a physical inventory.[2] The extent to which the measurement of the residual holdup contributes to the quality of a physical inventory depends on the amount of holdup and the uncertainty of the measurement method.

b. Susceptibility and Accessibility of SNM

If the quantity of residual holdup remaining after draindown and/or cleanout of equipment is reduced, less SNM is accessible and susceptible to theft or diversion during the sampling, identification, and evaluation necessary to complete a physical inventory. Lessening the effort necessary to remove and/or evaluate residual holdup reduces the amount of time SNM is accessible, the number of people who need access to it, and the opportunity for unauthorized individuals to gain access to SNM during a physical inventory.

2. Unit Operations

This guide deals with the reduction of residual SNM holdup during a physical inventory in seven process operations common to dry chemical processing. These operations are described in the following paragraphs.

a. Gas Handling

Gas-handling operations considered here include handling of (1) process gases and (2) carrier gases that may contain suspended SNM particles. The transfer of UF_6 from shipping containers to process vessels is the most common example of the handling of gaseous SNM in a fuel conversion facility. Offgases from activities such as drying, calcination, pneumatic solids transfer, and fluidized-bed reactions contain SNM in particulate form; the use of filters, cyclones, and scrubbers to remove these particulates from the gas streams should be considered.

[2] Regulatory Guide 5.13 addresses the subject of conducting physical inventories of nuclear material.

b. Glovebox Operations

Gloveboxes are used principally for handling materials containing uranium-233 or plutonium.

c. Calcining

Calcining is applied to dried solids that have been produced in a precipitation step. For example, plutonium oxalate is calcined to plutonium oxide. The oxide product from the calciner may be subjected to comminution and/or blending before it becomes feed for the fabrication of fuel. Some equipment can be used to perform both drying and calcining simultaneously. Certain types of scrap or waste may be calcined as part of the recyling or recovery of its contained SNM.

d. Dry Solids Transfer

Dry solids are transferred in a number of fuel conversion or fabrication steps. For example, dry ammonium diuranate (ADU) powder formed during the drying of the filter cake from an ADU precipitation process is transferred to a calcining furnace for conversion to uranium dioxide. Similarly, dried mixed plutonium-uranium oxides formed by coprecipitation are transferred to the next process step. SNM oxide powders are transferred to blenders and to fuel pelletizing equipment.

e. Dry Blending and Particle Classification

Blending and classifying are commonly utilized in various chemical conversion and fuel fabrication processes. Examples include the ammonium diuranate or fluid-bed processes for uranium conversion; the conversion of mixed uranium-plutonium nitrates to mixed uranium-plutonium oxides; and the fabrication of spherical particles by spheroidizing and particle coating.

Dry particulate materials may be blended to produce a uniform mixture of two or more materials having different chemical compositions, particle sizes, shapes, surface areas, or other properties.

Classification can be used to produce a controlled particle size distribution or shape for materials to be blended or for materials that have been blended just prior to fabrication.

Blending and classifying may be performed as separate or combined operations.

f. Packed Bed Chemical Conversions

Packed bed conversions can be used for converting a solid uranium compound to a metal or to another solid compound by a controlled exothermic batch reduction process. For example, this type of operation is used for the reduction of uranium tetrafluoride to uranium metal with magnesium or calcium metal. Compounds of other metals may be added to effect a coreduction that yields an alloy product. Packed bed operations may also be used for the reaction of uranium dioxide with carbon or graphite to produce uranium carbides.

g. **Comminution**

Comminution is applied to dried or calcined oxides in order to obtain a powder suitable for fabrication into desired fuel shapes. It also may be applied to dried cake or to solid scrap (which is being prepared for recycling) from a fabrication process.

The product of comminution is a fine, free-flowing powder with a fairly uniform particle size distribution. The comminution equipment is selected so as to control particle size and surface area of the powder and to obtain the desired pelletizing and sintering properties.

Ball mills or rod mills may be used to combine blending with a comminution step.

3. Holdup in Gas Handling

The holdup problems in equipment for handling gases fall into the following two general categories:

a. Those problems related to the storage and transfer of UF_6, including the prevention of condensation of UF_6 in transfer lines by heating, the removal of as much gas as possible from the containers by heating and purging, and the accurate measurement of the residual "heel" in the container.

b. Those problems related to SNM particulates entrained in gaseous waste streams, including the deposition and accumulation of particulates in ducts, filters, cyclones, and scrubbers.

4. Holdup in Gloveboxes

Holdup problems in gloveboxes are related to the type of operations and to the degree of leak-tightness of the process equipment installed within the glovebox. Equipment that is totally and reliably enclosed and is essentially automatic in normal operation contributes negligible holdup to gloveboxes. Problems of holdup arise during maintenance or other nonroutine operating periods when process containments are breached.

Some operations, such as those in which dry solids are loaded into and discharged from equipment units, may inherently permit the escape of SNM to the glovebox environment. Examples of this type of operation are comminution, blending, and agglomeration where quantities of fine powder can escape and accumulate on glovebox internal surfaces and all equipment surfaces.

5. Holdup in Calcining

Holdup occurs in calcining when powder sticks to rough surfaces or is trapped in crevices. The powder may become entrained in gas streams and be deposited in ductwork and filters. Material can also be inadvertently spilled into inaccessible locations within the calciner during operation. The fact that the calcined powder usually has a high bulk density helps to reduce dusting in handling.

Direct heating in calciners using a heated gas stream can cause dust particles to become entrained in the gas stream. Indirect heating and direct radiant heating, on the other hand, do not normally contribute to holdup.

Cylindrical rotating-retort calciners are particularly desirable for high-throughput, low-holdup operation. These calciners, which may be operated continuously, have the advantages of minimum physical handling of product and great potential for automation. However, the presence of lifting bars or flight carriages in these calciners makes them more difficult to drain down or clean out for a physical inventory of SNM.

A batch or semicontinuous operation with trays of material traveling through an indirectly heated muffle-type calciner has comparatively little holdup, unless the trays are accidentally tipped and the contents spilled into the calciner as a result of mechanical malfunction of the tray conveyer systems. This problem can be greatly reduced by the use of covered trays.

6. Holdup in Dry Solids Transfer

Dry powders usually are moved from one process step to another by manual, mechanical, or pneumatic means. The manual method involves loading a container at the discharge point of equipment for one unit process and moving it by hand to the charging position of the equipment of the next unit process. This technique is generally employed when relatively small quantities of material are involved. When properly designed, the containers used to manually transfer dry solids can be cleanly emptied except for the small amount of material that clings to the inner surface. This residual material can easily be removed by brushing, vacuuming, or dissolution.

Mechanical conveyors have broad application in the chemical industry, but are not generally used for transfer of material containing SNM. Screw and belt conveyors have been used in some operations for moving large quantities of ADU powders. Holdup problems with mechanical conveyors generally arise as a result of material adhering to the surfaces of screws, idlers, bearings, and belts. Because the screw cannot sweep the interior of the transfer tube completely, significant residual material may remain held up in a screw conveyor. In all mechanical conveyors, dusting can be a problem.

Pneumatic conveyors constitute a relatively simple way to move large quantities of dry solids. In this operation, solid particles suspended in air are transferred by the bulk movement of the air. Holdup problems are fewer than with mechanical conveyors since the transfer lines can be kept smooth and free of obstructions. Even though dusting constitutes a problem with pneumatic conveyors, the quantity of material remaining after draindown is normally small and cleanout can be achieved by sending brushes through the lines or by flushing with cleaning solutions.

7. Holdup in Dry Blending and Classifying

Several factors contribute to holdup in blending and classifying equipment. One problem arises when dry particulate material of irregular shape and size collects and becomes packed in lines and in internal recesses of equipment. This is most likely to occur if fine particles are present. Irregularly shaped particles may become trapped in screens. Spherical particles generally flow freely and drain readily from equipment. Ultrafine powder must be handled carefully to reduce dusting.

Mechanical batch-type blenders with internal agitators contribute to significant material holdup since any material that collects around the mechanical agitator and drive mechanism is difficult to remove. Unless sealed covers are provided, material can be dispersed as airborne fines.

Holdup problems are minimal in batch-type blenders with smooth internal surfaces, no internal moving parts and designs that permit charging and discharging by gravity. The simple V-cone blender with a full-diameter cover is an example of this type of blender; it is most difficult to prevent holdup in the gasket area. Dust accumulations on the surfaces of a V-cone blender can easily be removed with a brush or wipe.

Pneumatic batch-type blenders are equipped with feed and recirculation piping that extends the surface area to which material can adhere. This piping system makes pneumatic blenders particularly difficult to clean. Although these blenders may be designed to discharge by gravity, a holdup problem can result if a line becomes plugged or packed with material that is not detected upon draindown.

Some operations combine comminution with blending to reduce the size of particles while performing a mixing operation. Ball or rod mills may be used for this, but the large surface areas of such mills may result in significant material holdup after emptying. The design of this equipment makes it especially difficult to clean.

Blending may also be done by splitting and recombining of controlled quantities of material. This gravity-flow operation may include mechanical agitation of the flowing stream with an impeller or gas jet. The principal source of material holdup in splitters is the accumulation or caking of material on ledges and in recesses in the equipment. Plugging is a problem in the extensive piping or tubing used with multiple splitters. For this reason, mechanical vibrators are used to keep material flowing in lines.

The sieves, screens, and air classifiers used to classify dry particles contribute to some holdup of SNM. Particles that are trapped and held up in screen openings are difficult to remove and may require some mechanical cleaning. Material is held up in the piping used with air classifiers. Unless screens or sieves and air classifiers are completely enclosed and sealed, dusting can result in a significant holdup of material.

Mechanical vibrators that are used to classify spherical particles are easily cleaned and usually have no significant holdup problems.

8. Holdup in Packed Bed Conversion Operations

The holdup problem that normally occurs with packed bed conversion operations is caused by the SNM that is unreacted or occluded and remains in the slag. This holdup material may be accounted for by nondestructive analysis (NDA) or by being recovered in normal recycle or scrap-recovery operations.

Occasionally, the refractory lining between the packed bed and the steel containment shell for uranium metal reduction is porous or thin, permitting molten uranium to contact the shell. This results in a "blowout" and the release of uranium metal outside the containment shell. Spills of this sort can result in significant holdup of SNM in auxiliary equipment.

Some ceramic particles from the carbide conversion process adhere to or react with the walls of the graphite crucible. This holdup material, which cannot be recovered by a simple draindown or cleanout operation, contributes to MUF until the crucible is evaluated or processed for recovery of SNM, but its contribution is normally small.

9. Holdup in Comminution Equipment

Nearly all flow of material through comminution equipment is by gravity. Equipment is normally capable of being drained down with a minimum of holdup. Holdup of SNM in comminution is most likely to occur in the form of airborne particles that leak from equipment or that escape during transfer and handling and collect in ventilation ducts, filters, or on the surfaces of equipment and gloveboxes.

If gyratory or jaw crushers are used in the comminution operation, some holdup may occur on the corrugated surfaces of the jaw faces.

When SNM consists of hard friable ceramic sinter cake or fused particles, equipment such as rotary hammer mills may be used for comminution. The irregular surfaces of breaker plates, rotating mechanical discs and hammers, and screen bars in this equipment contribute to holdup and make draindown and cleanout difficult.

C. REGULATORY POSITION

To facilitate the measurement and/or recovery of residual special nuclear material held up in process equipment and to improve the accuracy and reliability of a physical inventory, the amount of residual SNM held up in equipment should be minimized. The design of equipment used to carry out physical or chemical changes on special nuclear material by dry process operations, including gas handling, glovebox activities, calcining, dry solids transfer, dry blending and classifying, packed bed conversion, and comminution, should incorporate features that minimize residual holdup.

Some appropriate equipment design features and characteristics whose use is acceptable to the Regulatory staff for this purpose are described in the following paragraphs. These features should be implemented to the extent practicable. Implementation also should be consistent with other quality assurance, health, and nuclear safety codes and standards that may be applicable.

1. General Design

a. Inside surfaces of equipment and gloveboxes should be free of crevices, protrusions, and other irregularities that could entrap material.

b. Inside surfaces of equipment and gloveboxes that contact SNM should be selected, coated, polished, or machined to prevent or resist the adherence of powders or other dry particles.

c. Where possible, the lower portions of vessels such as blenders and storage bins should be of conical shape and fitted with bottom outlets to facilitate material draindown and cleanout.

d. Overlapping metal surfaces in contact with process material should be avoided except where sealed by welding; internal welds should be ground flush with inner surfaces. Possible exceptions are gasketed openings such as inspection and cleanout doors or ports.

e. The internal angles, corners, and recesses of gloveboxes and equipment should be designed and constructed to permit complete draindown or cleanout.

f. Seams that promote corrosion should be avoided.

g. Materials of construction that contact SNM in any form should be selected so that surfaces do not corrode, dissolve, or erode during operation or during contact with rinse solutions used for cleaning. Materials for construction of jaw faces, wear bars, or breaker plates of comminution equipment should provide maximum resistance to pitting or erosion.

h. Structural integrity should be adequate to resist the formation of leaks, cracks, and crevices due to thermal, vibratory, or other stresses. Transfer and instrument lines should be designed and installed so as to minimize mechanical stresses on interconnected equipment.

i. Operating variables such as material flow rate, moisture content, particle size, and vessel geometry should be evaluated and selected to reduce undesirable formation of holdup (e.g., caking or sticking).

j. Process units should be closely coupled and sized with minimal intervening holdup bins and containers, consistent with good engineering design.

2. Internal Design

a. Equipment should have a minimum of internal components upon which process material can collect.

b. Sensing devices such as thermocouples or other detectors should be installed in a manner that minimizes the amount of solid material that can be retained on their surfaces.

c. Permanently mounted process equipment internals that cannot be removed for cleaning should be designed and installed in a manner that minimizes holdup in the equipment during draindown and permits cleanout if necessary.

d. The inner surfaces of ducts in which deposition of particulates can occur should be smooth and free of recesses or other irregularities. Vessels and transfer lines in which condensation of vapors can occur should be heated and/or insulated.

e. Provision should be made for heating and purging UF_6 cylinders and transfer lines to permit maximum removal of the gas.

f. Pneumatic conveyors should be fabricated without internal obstructions to the flow of air and suspended solids. Charging and emptying ports should be designed to minimize dusting and holdup of material at these points.

g. Trays that are used to transport material through batch or semicontinuous muffle-type calciners should be designed so that they cannot be tipped over or their contents spilled during handling or normal operation. When a tray is fully loaded, the distance of the center of gravity from any side should be at least four times its distance from the bottom of the tray. Racks, carriages, conveyors, guides, or drive mechanisms that are used to assist or direct the transport of trays should be designed so that individual trays cannot be tipped or caused to ride over one another.

h. The use of blenders with internal mechanical agitators should be avoided. If agitators are used, they should be designed to permit areas to drain freely and to present minimum surface for the collection of solid particles.

i. Containment retorts or crucibles for packed-bed conversion should be designed without recesses, internal flanges, or other uneven surfaces that would interfere with the normal discharge of the bed material after conversion.

3. External Design

a. Visual access should be provided to surfaces or spaces where material is likely to accumulate. Alternatively, clearance should be provided so that either external use of nondestructive assay instruments or internal probes can be used to detect the presence of SNM or to identify the location of residual material not visually accessible.[3]

b. Dusting should be controlled and contained at the charging and discharging ends of mechanical or pneumatic conveyors. Pneumatic systems should be leaktight, and appropriate cyclones and filters should be used at the discharge end to separate solids from the carrier gas. In mechanical systems, the conveyor bodies should be enclosed to reduce the dispersement of airborne SNM material.

c. Equipment should be arranged so that the routes of solids conveyors are as short as practical and have the smallest number of bends and interconnections.

d. Exhaust ducts should be provided on all equipment in which waste gases are generated (e.g., hoods, gloveboxes, and pneumatic transfer equipment). The pressure inside exhaust ducts carrying SNM particulate should be sufficiently negative to prevent the loss of material by leakage to surrounding areas.

e. When large quantities of SNM particulates are carried by exhaust gas streams, suitable devices (such as cyclones) should be employed to separate the bulk of such solids from the gas streams. Prefilters at the exit point in gloveboxes or enclosed equipment and final filters prior to release should be used to remove particulates from exhaust gases. If measurable quantities of SNM in fine particulates or vapors pass through a final filter, a suitable wet scrubber should be installed in the exhaust system to remove them. When wet scrubbers are used, consideration should be given to installing suitable reheaters to prevent the corrosion of gas exhausters due to condensation.

f. Devices for measuring differential pressure should be installed around filters to indicate the accumulation of material containing SNM.

g. Drive motors and gear boxes for any solids conveyor should be mounted external to the conveyor, and the drive shaft should extend through a suitable leak-tight seal. Bearings for drives and idlers should be protected against the entrance of solids.

h. Conveyor enclosures should be equipped with vibrating devices to reduce the quantity of solids adhering after a normal draindown.

i. External surfaces of equipment installed inside gloveboxes should be smooth and free of crevices, cavities, and openings. Drives and power trains for process equipment should be located outside gloveboxes, with appropriate seals for drive shaft penetrations through glovebox walls.

j. Provision should be made for charging and discharging of dry particulate material in the calcining operation by use of enclosed charge and discharge lines. Continuous calciners should be equipped with externally mounted vibrating mechanisms to ensure uniform flow of material throughout the calciner and to prevent the formulation of areas in which the material accumulates.

k. Completely enclosed charge and discharge lines, ventilated hoods, or gloveboxes should be provided for all charging, discharging, or handling of SNM for blending, classifying, and comminution equipment. An exception may be material of a particle size or flow characteristic such that no fines are released during handling. All openings, covers, or mechanical drive penetrations for blending, classifying, and comminution equipment should be sealed during operation to prevent the spillage or release of SNM.

l. Piping or tubing that is external to blending or screening equipment and that may become plugged internally with particulate material should be equipped with externally mounted vibrating mechanisms to ensure a uniform flow of material and should be removable for inspection and cleaning.

m. Retorts or containment shells used for packed bed operations such as uranium metal reduction should be adequately sealed to prevent the loss of SNM as vapor during the reduction process. The materials used for the construction of the containment shells for uranium metal reduction should be compatible with the external furnace preheat atmosphere and with the insulating material (refractory lining) used to separate the packed bed from the retort so that the shells will not corrode or warp during operation.

4. Design for Accommodating Cleanout

a. Equipment such as calciners and gloveboxes should be provided with access ports, removable covers, or removable sides to allow visual inspection of the internal surfaces.

b. Access ports or removable panels should be provided to facilitate cleaning of internal surfaces by appropriate methods such as brushing, vacuuming, washing, scraping, or rinsing to remove, dislodge, or dissolve SNM particles.

c. Equipment should be provided with fittings as connections for washdown and rinsing of internal surfaces of vessels and pipes. Air, steam, water, or appropriate chemical solutions may be used to dislodge, dissolve, or otherwise remove particulate process material, residues, and condensed vapors remaining on internal surfaces of the equipment.

[3]Regulatory Guide 5.23, "In Situ Assay of Plutonium Residual Holdup," provides additional methods and procedures

d. Provision should be made for flushing and draining and for removing and collecting any of the various rinses in which SNM may be entrained or dissolved. Removal of material from blenders, calciners, comminution equipment, or other equipment should be facilitated by designs that permit disassembly. Also, flush distribution devices should be connected at high points in the transfer lines or upper zones of equipment and should be designed and arranged to allow flushing media to contact the interior surfaces and cavities of the process equipment and of auxiliary devices inside the equipment. Valves should be installed at appropriate locations in the system for complete draining.

e. Supplementary mechanical equipment not permanently mounted should be capable of being disassembled and removed for cleaning and inspection.

f. Provisions should be made to permit verification that all material has been removed from enclosed transfer lines or from other equipment such as blenders enclosed in gloveboxes.

g. Filter media should be removable or capable of being backpurged while in position. Removable filter media should be treated by leaching or by combustion and leaching for the recovery and determination of SNM. The design of cyclones should permit cleanout of residual solids and powders.

h. Ducts should be fabricated so as to be easily disassembled. For example, taped joints may be used to facilitate disassembly.

i. The normal contents and all rinse solutions from rotary retort-type calciners that contain lifting bars or flight carriages should drain freely by gravity from the bottom of the calciner.

j. Containment shells or crucibles should be designed with openings or access for thorough mechanical cleaning such as brushing or scraping to remove or dislodge all solid particles of SNM that may remain on internal surfaces after the equipment has been emptied.

k. Mechanical equipment, jaw faces, and breaker plates should be capable of being disassembled and removed from crushers, disintegrators, or pulverizers for cleaning and inspection.

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants and licensees regarding the Regulatory staff's plans for utilizing this regulatory guide.

This guide reflects current regulatory practice. Therefore, except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described herein will be used by the Regulatory staff in evaluating all license applications docketed after publication of this guide.