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REGULATORY GUIDE

DIRECTORATE OF REGULATORY STANDARDS

REGULATORY GUIDE 5.8

DESIGN CONSIDERATIONS FOR MINIMIZING RESIDUAL HOLDUP OF SPECIAL NUCLEAR MATERIAL IN DRYING AND FLUIDIZED BED OPERATIONS

A. INTRODUCTION

Section 70.22, "Contents of applications," of 10 CFR Part 70, "Special Nuclear Material," requires, in part, that each application for a license to possess certain quantities[1] of special nuclear material (SNM) contain a full description of the applicant's procedures for control of and accounting for SNM which 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. Furthermore, Section 70.51, "Inventory and records requirements," requires, in part, that certain licensees conduct at specified intervals physical inventories of the SNM in their possession under license. The control of and accounting for SNM can be made more effective by minimizing the residual holdup after shutdown, after draindown, and after cleanout of the equipment used to process SNM, thereby reducing the component of uncertainty contributed by residual holdup to a physical inventory and lessening the severity of problems associated with determination of residual holdup. This regulatory guide describes acceptable design features and characteristics for minimizing the residual holdup of SNM in drying and fluidized bed operations after shutdown, draindown, or cleanout in order to facilitate material control and accountability procedures. These features and characteristics are not expected to interfere with process operations.

B. DISCUSSION

1. Background

Certain unit processes permit accumulation of sizable amounts of SNM which are referred to as residual holdup, or hidden inventory. A characteristic amount of this material that is difficult to locate, sample, identify, quantify, and analyze is held up in equipment for a given design, mode of operation, and type of process material. This holdup may be decreased as the status of the equipment changes progressively through the four stages consisting of operation, shutdown, draindown, and cleanout. Simultaneously, the number of sources of uncertainty and the levels of uncertainty in the physical inventory may be reduced.

The accumulation of SNM in process equipment in the form of residual holdup following shutdown, draindown, and cleanout could have adverse effects on a materials control program. Minimizing that quantity of material retained in process equipment enhances the effectiveness of a materials protection program in the following ways:

a. The quality of a physical inventory is improved by reducing uncertainty due to holdup. For example, the contribution of unmeasured holdup material to the category of material unaccounted for (MUF) may be lessened, and the influence of uncertainty associated with measured holdup on the limit of error on material unaccounted for (LEMUF) in a material balance may be lessened. Furthermore, the extent to which the uncertainty in holdup contributes to a physical inventory depends on the magnitude of the amount present and how precisely and accurately that amount is amenable to being measured. Therefore, reducing the quantity of holdup directly decreases the uncertainty contributed to a physical inventory.

b. A reduction in the quantity of holdup material that must be recovered following the three stages of shutdown, draindown, and cleanout of process equipment decreases the quantity of SNM susceptible to diversion during sampling, identification, and subsequent separation or recycle of this material as may be necessary to complete a physical inventory. A reduction

[1] This is a quantity exceeding at any one time 5,000 grams of contained uranium 235, uranium 233, or plutonium, or any combination thereof for use in activities other than the operation of a nuclear reactor licensed pursuant to 10 CFR Part 50 or as sealed sources.

in holdup also can enhance process operations by decreasing the extent and time of unit process interruptions for material accountability. For example, for a process amenable to dynamic inventory techniques, credibility in such a technique may be increased by reducing the detrimental effects of residual holdup on such an inventory.

c. The effort required to establish the presence of and to remove residual material for a physical inventory is reduced. Consequently, the amount of time and the number of people who need access to SNM are reduced. The opportunity for unauthorized individuals to gain access to SNM during this stage of a physical inventory also may be reduced.

This guide is addressed mainly to two unit processes–drying and fluidized bed operations. The unit drying operation is commonly applied to remove moisture, vapors, and/or solvent from a wet feed material to produce a dry solid product. A unit operation for dewatering slurries normally precedes drying. Commercial applications of fluidized beds are manifold. Generally, the fluidized bed is used for gas-solid, gas-gas, or gas-liquid contacting to effect dewatering, drying, calcining, chemical reaction, or particle coating. Frequently, shutdown and/or draindown of process equipment used for drying or fluidized bed operations results in a substantial quantity of residual material held up in the equipment. Consequently, design guidance is provided to facilitate minimizing holdup material in driers and fluidized bed equipment after shutdown and after draindown as well as after cleanout.

2. Holdup in Driers

A variety of driers is used in nuclear fuel fabrication. The holdup problems associated with each are peculiar to the state of the material being processed, the mode of operation, and particularly the specific type of drier.

With directly heated driers using a heated stream, fines may be entrained in the gas stream and must be collected in filters and recovered from the process. The entrainment contributes to holdup of fines in ductwork and filters. On the other hand, directly heated driers using infrared heat lamps are advantageous since entrainment then is minimal. Use of agitators in directly heated driers may be desirable from an operating standpoint However, driers with agitators are difficult to empty and clean.

Continuous driers are desirable for a high-throughput low-holdup operation. This arises largely from increased continuity of operation and increased uniformity of material handling. Continuous operations have the advantages of minimal physical handling as well as greater potential for process automation.

For certain processes, however, batch drying is advantageous. With individual batches it is possible to maintain batch identity. However, batch driers require more physical handling of material than continuous driers, may be difficult to automate, and may necessitate additional equipment cleanout between batches.

For directly heated fluid-bed driers and spray driers, there is a tendency for dry product to adhere to the walls and bottom of the drier, particularly if the product is very fine. Internal mechanical scrapers constitute an additional impediment to cleaning the drying chamber.

For indirectly heated driers in which the material being dried contacts a heated surface, sweep gas may be used to carry away the vapor from the drying solid. Unless the exit velocity of this vapor is low, some material will be entrained in the gas and may be retained in ducts. Also, for indirectly heated continuous screw conveyor driers, as the feed drys to an adhesive paste it has a tendency to cake and choke off the flow or to spill out of the drier. Furthermore, the screw conveyor is difficult to clean and tends to be a significant source of holdup.

Rotary driers have been used to combine a drying operation with a calcining operation in separately heated zones. An intermediate paste having a high bulk density and viscosity has a tendency to adhere to most materials which it contacts such as flight carriage surfaces. Such surfaces contribute to holdup by impeding material flow during emptying. Therefore, special attention may be necessary for cleanout or draindown. Directly heated rotary driers also may be accompanied by carry over of dust or ultrafine powder which becomes a form of holdup.

Woven metal belt driers have a high surface area and high porosity. Consequently, they may be a significant source of material holdup.

Batch pan driers are completely enclosed and usually are equipped with agitators which constitute a source of material holdup upon emptying. Agitators also cause more difficulty for a complete cleanout. Continuous driers with open static beds such as pans, boats, or trays do not contribute significantly to holdup unless they are accidentally tipped or the contents are otherwise spilled. Trays, pans, and boats also may be easy to empty and clean if necessary.

3. Holdup in Fluidized Bed Operations

Because of the numerous interrelated components of a fluidized bed operation that contact the process material, there exists a large number of locations where holdup may occur and numerous sources initiating its occurrence. However, holdup in fluidized beds commonly depends upon the size and growth of particles throughout the system. Beginning with the input, screw conveyors, pneumatic carriers, dip pipes, seal legs, injectors, or other means are used to introduce solids into the reactor proper. Difficulties with holdup arise and special techniques become necessary when solids are not free flowing, such as filtered precipitates and other moist solids. Since it is difficult by means of a screw conveyor to feed wet material to a reactor, it may be necessary to assist handling by wetting the material to attain a slurry consistency before feeding. If slurry consistency is undesirable for the material, the solid product may be recycled to mix with the feed to dry it and thereby achieve better handling qualities. Nonhomogeneous feed containing lumps of dry or semidry solids tend to compound the problem by agglomerating and fusing together instead of breaking apart. Agglomerates which are much larger than the original particle size subsequently tend to segregate out of the bed. After a period of time, the fluidized bed may become static, thereby necessitating shutdown and cleanout.

Liquid feed necessitates use of an injection nozzle and atomizing gas. The liquid input system consists of (1) a spray injection nozzle, (2) a liquid chemical injection system, and (3) a fluidizing gas system. Injection nozzles have been shown to be a source of localized cake formation and holdup. Furthermore, the area of the equipment directly across the fluidized bed opposite the nozzle also has been shown to be susceptible to cake formation. An additional consequence which further propagates holdup formation is interference of cake with normal operation. Agglomerates deposited at the bottom of the fluidized bed and on the gas distribution plate interfere with fluidization and may cause localized hot spots. Also, the product overflow tube may become blocked. Typical causes of this agglomeration are impurities in feed, fines from the recovery system, poor gas distribution, poor spray nozzle operation, generally poor fluidization, and other unfavorable operating conditions.

The fluidized bed chemical reactor system may consist of one of several configurations. A series of individual reactors as well as a single reactor with individual compartments have been used to provide multiple contacting stages. Unfortunately, multiple compartments as well as the series configuration provide multiple locations for holdup. In either case, a sufficient flow rate of gas is necessary to forestall plugging and channeling.

In general, process conditions influence the formation of holdup. Variables which may induce this formation are inlet gas composition and velocity, bed temperature and depth, and feed material temperature and consistency. The generation of fines especially is dependent on the operating range of process variables. Buildup of fines may cause bridging of solids in the reactor structure. In addition, deposition of substances on internal surfaces of the reactor structure and in connecting lines is sensitive to process variables such as temperature. Severe operating conditions such as temperature excursions are particularly conducive to severe segregation and packing of SNM against the base and interior walls. The existence of holdup may compound an excursion by its sudden release to the fluidized bed for reaction, which induces further excursion and additional resulting holdup by the mechanisms of packing and fusion.

Exiting material consists of product and offgases. Product may be batch removed by freely draining through a bottom outlet valve or by a screw conveyor. However, depending upon the characteristics of the particulate matter, solids may adhere to the walls or the gas distribution plate. If excessive caking occurs, larger agglomerates may form that do not drain through openings in the exit valve.

Other types of outlets for continuous product removal are: (1) a simple weir permitting overflow, (2) a flapper-type check valve to restrict gas flow through the exit, and (3) a seal leg with a solids flow control valve to equalize external and internal pressures. In each case, obstruction and accumulation as a result of inadequate design may result in large quantities of holdup material.

Offgases are discharged near the top of a fluidized bed reactor through a variety of components which are sources of holdup. These include cyclones for dust removal, carbon or sintered metal filters, and cold traps. Holdup in these devices occurs to such an extent that it is necessary to recover the solids which are carried by gases leaving the fluidized bed.

One of the advantages of utilizing a fluidized bed is its favorable heat transfer performance. Unfortunately from the viewpoint of minimizing holdup, heat exchanger tubes manifolded at the bottom and top or bayonets internal to the reactor are sometimes used. Such use should be avoided where possible since it aggravates the problems of holdup and cleanout.

In general, the absence of moving parts contributes significantly to effective cleanouts. For tall reactors, however, or for a mixture of fluidized solids with different characteristics, mechanical mixing may be utilized to reduce segregation. Without adequate mixing, agglomeration may occur because of particle fusion or poor dispersion of adhesive feed solids.

In contrast to particle growth, size reduction in fluidized beds contributes to the generation and subsequent deposition of fines. Major size reduction mechanisms in fluid beds are attrition, impact, and thermal decrepitation. All three mechanisms produce fines which may contribute to holdup, especially in filters or components downline from the fluidized bed reactor. Exceptionally fine particles may necessitate an offgas cleanup system on-line rather than a complete shutdown periodically. An alternative is to use an internal fines filter.

Instrumentation of fluid bed reactors largely consists of temperature and pressure sensors. Thermocouple wells and pressure taps are potential locations for retaining SNM during shutdown and draindown.

C. REGULATORY POSITION

For purposes of facilitating (1) control of SNM during processing or use, including shutdown, draindown, and cleanout, (2) determination of process losses by lessening the magnitude of the contribution of residual holdup to process losses, and (3) performance of a physical inventory, which may include an uncertainty component due to residual holdup, it is appropriate to minimize the amount of SNM retained inside equipment as residual holdup. The design of equipment used to carry out physical or chemical changes on SNM by drying or fluidized bed operations should include an evaluation of the desirability of incorporating features for purposes of minimizing residual holdup after shutdown, after draindown, and after cleanout. Appropriate features acceptable to the Regulatory staff for consideration include the following:

1. General Design

a. Surfaces are free from crevices, cracks, protrusions, and other irregularities that could entrap material.

b. Overlapping metal surfaces in contact with process material are sealed by welding; internal welds are ground flush with inner surfaces.

c. The internal angles and corners, particularly in tray driers, are rounded with a radius larger than a minimum radius, for example, one fourth inch.

d. Seams that promote corrosion are absent.

e. Materials of construction that contact SNM are compatible with the contents so that surfaces do not corrode, dissolve, or erode during operation or during contact with rinse solutions used for cleaning after shutdown.

f. Surfaces that contact SNM are selected, coated, polished or machined to prevent or resist the adherence of liquids and solids.

g. Structural integrity is adequate to resist formation of leaks, cracks, and crevices due to localized stresses such as thermal and vibratory stresses during operation.

h. Containers, for example, boats, pans, and trays, are constructed with adequate strength to preclude breakage and deterioration.

i. Trays in tray driers are designed not to tip and spill the contents during handling and operation. For example, when fully loaded, the distance of the center of gravity from any side is at least four times its distance from the bottom of the tray.

j. All equipment in which material is agitated, sprayed, or removed mechanically is enclosed with side walls, covers, or other means of containment to prevent spilling or release of the contents during operation.

k. The feed material is properly prepared to minimize the potential for holdup formation within a fluidized bed. Also, sizing operations prior to introduction of particles are evaluated.

l. The influence of operating variables such as gas flow rate and temperature is evaluated to reduce undesirable formation of holdup such as caking which may be induced by operating in an undesirable range of operating conditions.

2. Internal Design

a. Equipment has a minimum of internal components upon which process material can collect; equipment is free from internal structural supports, flanges, support rings, trays, or devices that are not essential to operation.

b. Racks, carriages, conveyors, guides, or drive mechanisms that are used to assist or direct the transport of trays through a tray drier are designed so that individual trays cannot be tipped or ride over one another. For example, for "walking-beam" drives, vertical travel is constrained to less than one-fourth the height of the tray to minimize the probability of tray override.

c. Mechanical agitators are designed to permit surfaces to drain freely and present minimum surface for collection of solids.

d. Sensing devices such as thermocouples are installed in a manner that minimizes the amount of solid material that can be retained by sensing devices.

e. Pressure taps projecting into the equipment have the capability for being gas purged.

f. Because of highly abrasive wear in fluidized beds and potential for SNM retention on horizontal elements and protection tubes, installation of internal elements are positioned, for example vertical, to reduce surface erosion and holdup. Examples of such elements may be sensing elements, bayonet heaters, mechanical mixers, and heat transfer fins.

g. Permanently mounted process equipment internals that cannot be removed for cleaning allow rinsings and normal contents of vessels such as fluidized bed driers to drain freely from the bottom of the equipment.

h. The height of the disengaging section above the expanded bed is adequate to reduce particle entrainment which contributes to holdup in the offgas recovery system for the fluidized bed operations.

i. Filters and/or cyclones are provided above the expanded bed to separate elutriated particulates, fines, and dust from the exhaust gases. These are designed to return accumulated solids to the bed; for example, filters are equipped with an automatic cyclic blowback feature, or an external bin is designed to accumulate solids.

j. Cyclones are equipped with suitable solids return lines that can be completely emptied for draindown of the reactor.

k. Flow control valves and spray nozzles for feeding solutions to the fluidized bed are designed and installed to minimize cake formation on the nozzle or within the equipment.

l. Components such as seal legs and valves having fixed openings are designed to minimize accumulation and obstruction by particulate matter.

m. Holes drilled in perforated support plates are conical to reduce the area of flat surfaces on which solids may stagnate and cake during reaction.

n. If the operation of the bed can result in the buildup of large particles that cannot be drained readily, the reactor is equipped with a gas-jet grinder.

o. The vessel for the fluidized bed has a tapered bottom to preclude the accumulation of material such as sintered SNM in corners at the bottom.

3. External Design

a. Clearance is provided to permit external use of nondestructive assay instruments or internal probes to detect the presence of or to identify the location of residual material not visually accessible.

b. The body of the fluidized bed reactor is equipped with vibrators or external impactors to reduce or prevent packing and adhesion of SNM.

c. Extended heat transfer surfaces, for example fins and tubes, for both heating and cooling are external to the fluidized bed containment structure. An alternate source of heat may be preheated inputs.

d. Fluidized bed structures are electrically grounded to prevent buildup of static charge which causes bed expansion and consequent occurrence of holdup.

4. Design for Cleanout Where Necessary

a. Driers are provided with access ports, removable covers, or removable sides for visual inspection of the internal surfaces.

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

c. Equipment is provided with fittings for connections for washdown and rinsing with liquids that will remove, dislodge, or dissolve all particulate process material, residual liquid, and condensed vapors that may remain on internal surfaces after the equipment has been shut down.

d. Provision is made for draining and collecting rinsings in which SNM may be entrained or dissolved.

e. If multiple stages in fluidized bed reactors employ horizontal surfaces such as perforated gas distributor plates, downcomers, flanges for segmentation, deflection baffles for mixing, and plate baffles for partitioning, these are accessible for cleanout.

f. Supplementary internal mechanical equipment not permanently mounted such as scrapers, agitators, rinsers, or atomizers inside equipment is capable of being disassembled and removed for cleaning and inspection.

g. A bottom outlet is provided to facilitate draindown and cleanout.

h. A gas plenum region or suitable packing material is used to prevent the bottom outlet from becoming encrusted, which may hinder the discharge of fluidized bed material during equipment draindown and cleanout.