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POWDER HANDLING FOR AUTOMATED FUEL PROCESSING

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POWDER HANDLING FOR AUTOMATED FUEL PROCESSING

ABSTRACT

Installation of the Secure Automated Fabrication (SAF) line has been completed. It is located in the Fuel Cycle Plant (FCP) at the Department of Energy's (DOE) Hanford site near Richland, Washington. The SAF line was designed to fabricate advanced reactor fuel pellets and assemble fuel pins by automated, remote operation. This paper describes powder handling equipment and techniques utilized for automating powder processing and powder conditioning systems in this line.

POWDER HANDLING FOR AUTOMATED FUEL PROCESSING

INTRODUCTION

The Secure Automated Fabrication (SAF) line was designed and built by Westinghouse Hanford Company for the Department of Energy at the Hanford site near Richland, Washington. The SAF line was designed to fabricate advanced reactor fuel and fuel pins for the Fast Flux Test Facility. Its highly automated and remote operation features will provide significant improvements in reducing personnel radiation exposure and increased productivity. Equipment and control innovations will enhance product quality, safety, and special nuclear material (SNM) accountability.

Automating a breeder fuel fabrication facility presented unique design requirements. Innovative equipment designs are used throughout the SAF line to meet these requirements. This paper describes UO_2, PuO_2, and mixed uranium-plutonium oxide (MOX) feed powder handling criteria and equipment designs in the powder processing systems.

DESIGN BASIS

The process flow diagram for the SAF line is shown in Figure 1. Using a cold press and sinter process, UO_2, PuO_2, and MOX powder will be processed into fuel pellets. These pellets will then be chemically and physically inspected and loaded into fuel pins with other fuel pin components. Nominal batch size will be 70 kilograms, with a throughput capacity of six metric tons of mixed oxide fuel per year.

The primary design considerations for the SAF line, aside from throughput, were reduction of radiation exposure to workers, enhanced safeguards, improved product quality, achieving near real-time accountability of SNM, and increased productivity. The facility was to process recycled plutonium with a maximum 20 percent ^{240}Pu isotopic content. Protection against radiation and thermal conditions generated by this material was to be provided.

SECURE AUTOMATED FABRICATION

PROCESS FLOW DIAGRAM

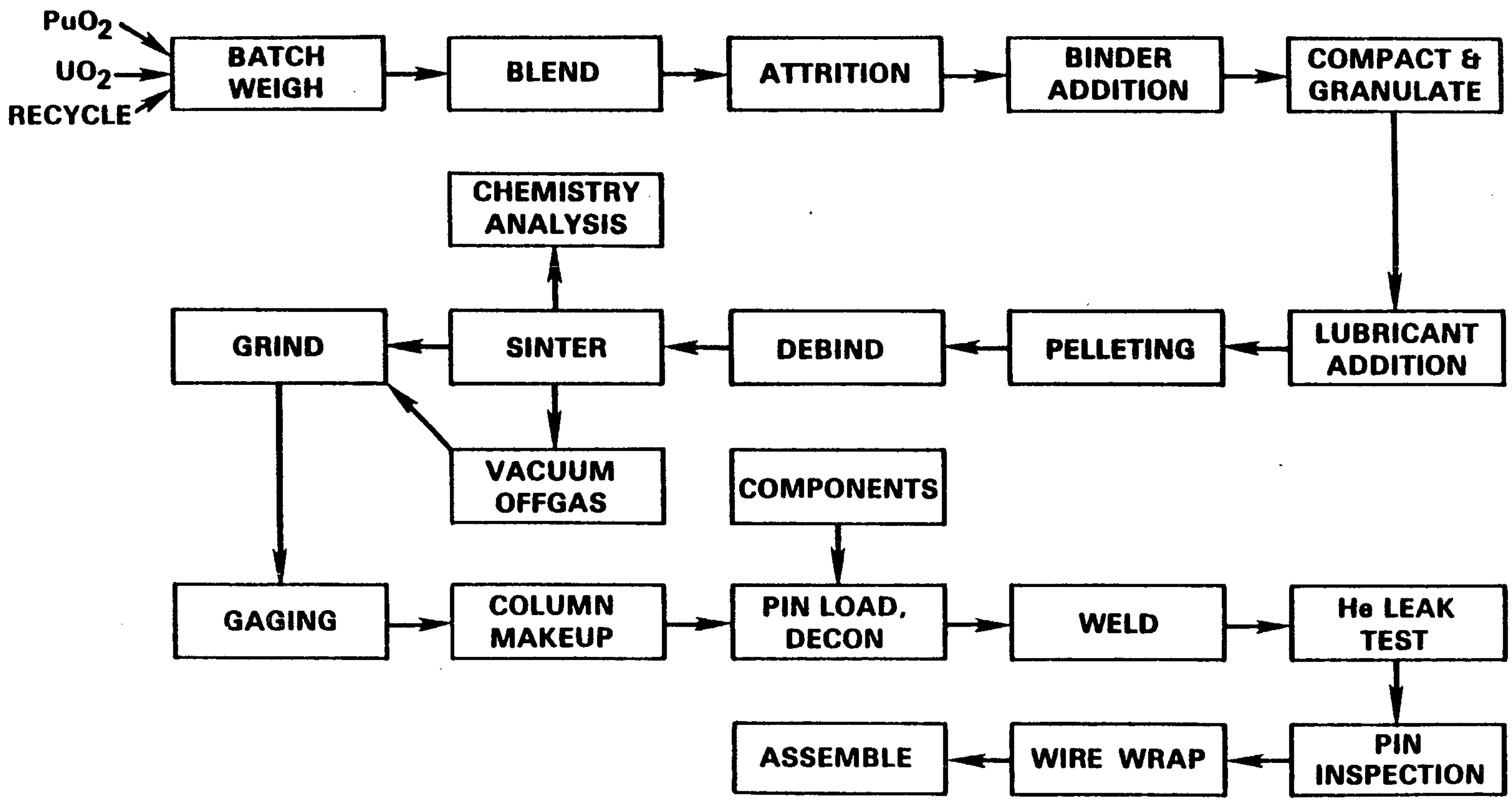

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Figure 1: SAF Process Flow Diagram

SAF LINE CONFIGURATION

To meet design criteria, the SAF line is fully automated. This includes automation of data acquisition for processing, process certification, and accountability, as well as automated equipment operation. The SAF line layout on the 70-ft level in the Fuel Cycle Plant (FCP) is shown in Figure 2. Powder Operations, Pellet Operations, and Pin Operations are the major process areas. All fuel processing and fuel handling equipment is located inside gloveboxes which provide plutonium confinement. Most enclosures are interconnected by transport systems which allow remote transfer of fuel material from one process step to the next.

A multi-level control system has been installed to provide remote, automated operation as well as local control for maintenance and upset recovery operations. Remote controls are located in the shielded control room. These include the computers and control racks required for automatic sequencing of equipment. A central supervisory control console integrates operations. It coordinates timing among systems and acquires data for process control and nuclear material accountability.

POWDER HANDLING

In powder operations, feed powders of UO_2, PuO_2, and MOX are batched, blended, and conditioned into lubricated granules. The granules provide a free flowing feed material for pelleting operations.

Specific powder processing steps are:

1) Feed powder receiving, fissile (PuO_2, MOX) and fertile (depleted UO_2)
2) Vee-shell macroblending of feed powders
3) Jet milling to reduce particle size and microblend
4) Adding and blending a dry, powdered binder
5) Slugging powder with a compaction press

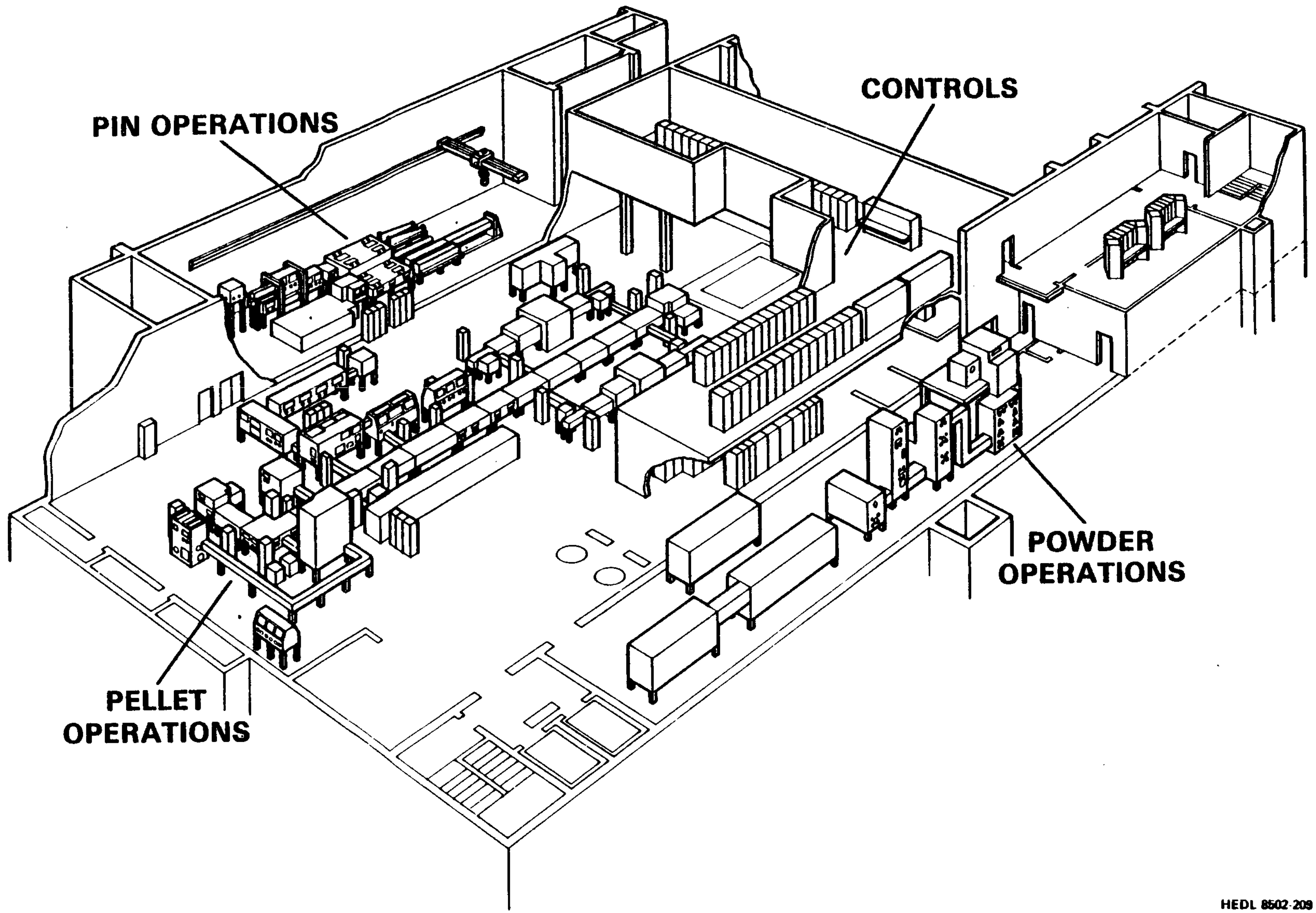

Figure 2: SAF Line Layout

6) Granulating slugs and sieve sizing granules
7) Adding and blending a dry, powdered lubricant

These process operations are divided into two major process systems; namely, Powder Receiving and Preparation and Powder Conditioning. Powder Receiving and Preparation includes operations through jet milling. The remaining operations are in Powder Conditioning.

Equipment used for each processing operation was selected because it had previously proven its dependability and effectiveness in manual production of breeder reactor fuel. This selection eliminated uncertainty in the processing operations themselves. However, powder handling between process operations, which in other breeder fuel fabrication facilities were manual, had to be automated. To automate this process and meet design criteria, innovative designs and testing were required.

Powder handling includes transfer and storage of powder between process operations. Major design considerations for powder handling equipment were radiological safety, criticality control, equipment dependability, and process dependability.

POWDER TRANSFER

Where possible, powder transfers are gravity feed. This simplified control system and equipment designs. Interfaces between operations requiring material metering are controlled by belt feeders or rotary feeders. Material is elevated for gravity feed in canisters or by pneumatic transfer. These handling techniques are described below.

Gravity Feed

Gravity feed is used to transfer powder between powder receiving subsystems, batching, V-shell blending, and jet milling operations. It is also used for powder and granule transfers in compaction and granulation operations. The Powder Receiving and Preparation system is illustrated in Figure 3. Primary design concerns were free powder flow with no bridging or hold up, dust-free transfers, and dependability of valves. Bridging and hold up could not be tolerated because they would disrupt automatic equipment function. Radiological safety and real-time accountability would also be affected by these problems. Transfers must be essentially dust free to prevent build up of fine powders in enclosures which can cause equipment malfunction and would create a radiological safety hazard.

Prototypic testing was performed using alumina powder with a much higher angle of repose than normally processed uranium and plutonium powders. The higher angle of repose corresponds to a greater tendency to bridge and hold up so test results were conservative. These tests showed a minimum three-inch diameter pipe with low frequency, high amplitude vibrators would assure successful transfers. Pneumatic vibrators provided the best combination of size, frequency, and amplitude for these operations. High frequency electric vibrators tended to pack powder, amplifying bridging problems.

A variety of valves were tested with pneumatically actuated slide valves proving to be the most dependable. Tests included life cycle tests (4500 cycles) duplicating operating conditions with alumina powder. The valves were also closed on solid columns of alumina powder. Valves will not normally have to close on powder columns, but this is a possibility during upset conditions.

Dust-free transfers are accomplished from fissile and fertile material receiving through batching by having no breaks in transfer pipes and feeders. This includes weigh hoppers which must float free of rigid piping. In this situation, piping interfaces are connected by flexible joints made with thin rubber bellows.

The Vee-shell blender interfaces with piping from batching and, on the discharge side, a belt feeder with double gate valve arrangements. The entire blender is raised or lowered to these interfacing positions. The valves seal

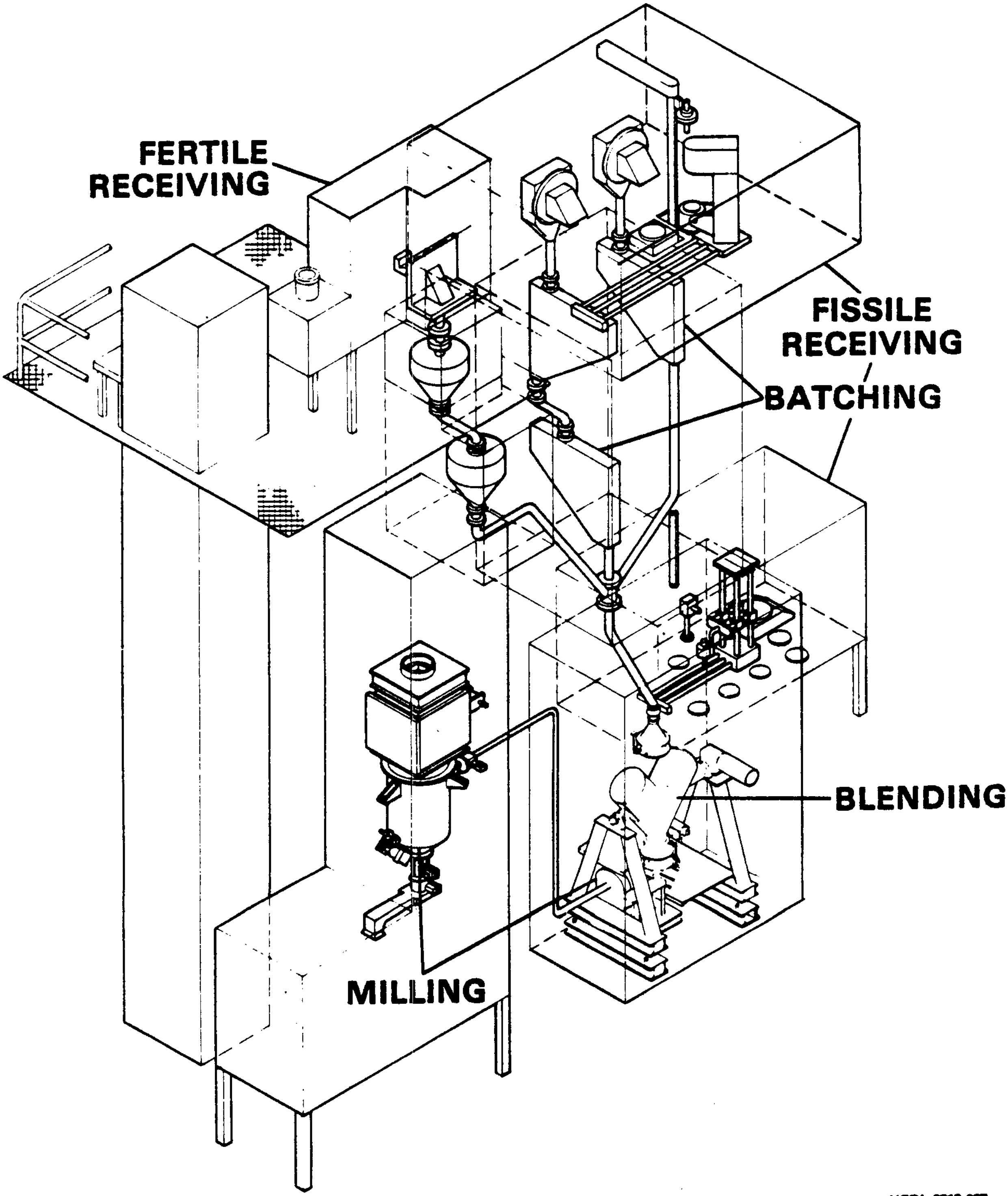

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Figure 3: Powder Receiving and Preparation

and then open for the powder transfer. To prevent dusting, the interface between valves is purged and vacuum cleaned prior to breaking it. The entire blender is weighed for accountability of SNM.

In compaction and granulation operations that are gravity fed, powder and granule movement is primarily by enclosed piping, hoppers, and screen decks. This arrangement is shown in Figure 4. Powder flowability is maintained through the hopper with assistance of aeration through a porous bottom to fluidize the powder if necessary. The powder flows to a rotary airlock feeder where scavenge nitrogen gas is used to keep rotor pockets empty. A close-coupled hopper which swivels at the airlock feeds the press. Coarse, fine, and properly sized granules feed into three canisters on weigh scales. The canisters are moved by a robot when full. The granules pass through vacuum hoods to remove fine dust and prevent the dust from billowing from these canisters.

Canister

Four liter, stainless steel canisters are utilized in PuO_2 and UO_2 receiving, binder addition, compaction and granulation, and lubricant addition operations. A canister handling robot, canister opener and canister dumper were designed by WHC to perform canister handling operations.

The canister handling robot is uniquely designed to operate in the confines of a glovebox and accurately maneuver up to 50 lb loads. It is controlled by a dedicated computer, with collision avoidance and automatic path definition programmed in the software. Thousands of prototypic test cycles proved its accuracy, repeatability, and durability. Four of these robots are utilized in powder processing operations.

The opener was designed to remove canister lids and also maneuver canisters to fill and dump stations. Controlled by a process computer, it receives canisters from the handling robot, grips the canister lids using a pneumatic bladder, removes the threaded lids, and moves opened canisters to the empty or

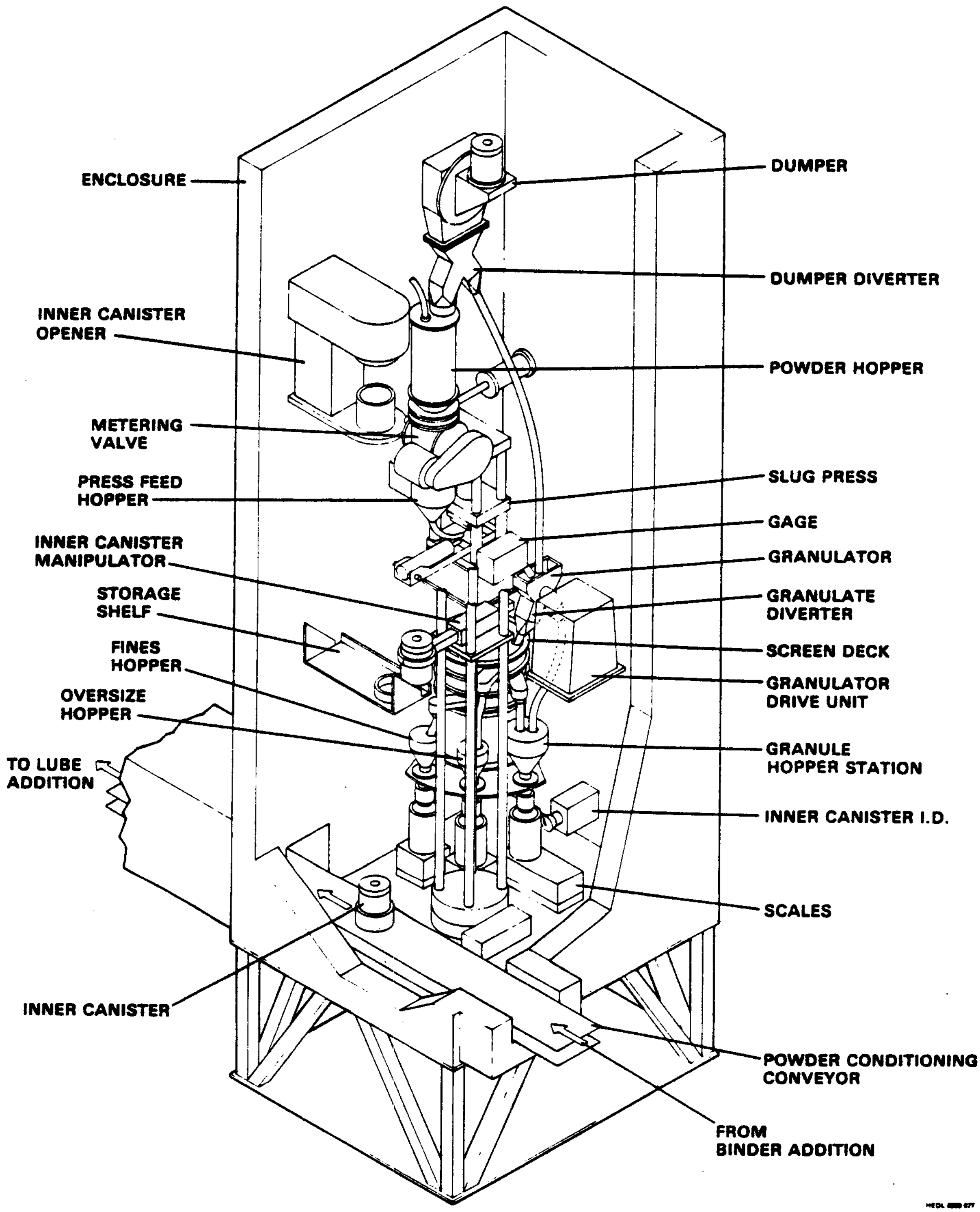

Figure 4: Compaction and Granulation

fill stations. Life cycle testing was used to prove its reliability and durability. Four openers are used throughout the powder processing portion of the line.

Assuring dust-free powder and granule transfers from and into canisters were also a major concern. A dustless gravity dumping device which grips the open canister and rotates to dump the powder was devised. Its operation was successfully tested with surrogate alumina powder. The four dumpers are controlled by process computers.

Belt Feeders

Belt feeders are used to feed the jet mill and download the jet mill collection hopper into canisters. The feeders are enclosed in porous metal covers to prevent dusting and accommodate pressure fluctuations in the milling operation. Belt feeder testing demonstrated it provided uniform feed rates for the jet mill. Canisters could also be loaded to $\pm$ 50 grams of a target weight in the hopper discharge operation.

Pneumatic Transfer

Powder is pneumatically transferred from the jet mill to its collection hopper through approximately 25 feet of two-inch diameter, 300 series stainless steel pipe. Nitrogen gas flow of 100 SCFM is exhausted through an electrostatically augmented cartridge filter system. The filter system is periodically blown back to clean it during the milling operation.

POWDER STORAGE

Powder and granule storage involves several types of hoppers and vessels.

Powder and granule storage design had three major considerations:

1. Configuration for criticality safety

2. Complete discharge of powder or granules
3. Elevated temperatures from design case 20% ^{240}Pu

Criticality

All storage vessels containing PuO_2 or MOX have critically safe geometries. Over batching, high material density, and full moderation were assumed as part of conservative criticality design criteria. Slab geometries are used for hoppers in batching and compaction and granulation operations. The jet mill receiving hopper has an annular configuration. This shape is critically safe and accommodates the large volume required to contain low density milled powder. Canisters have a critically safe diameter. The Vee-shell blender shape could not be modified without seriously impairing its blending function effectiveness. Administrative and computer interlock controls will be used to prevent over batching and full moderation.

Discharge

Discharge from all hoppers is gravity feed. All vessel discharge is aided by low frequency, high amplitude vibration produced by pneumatic vibrators. Two vessels also use pulsed aeration to aid discharge.

The jet mill receiving hopper is lined with porous metal aeration pads. The internal cone that creates the annular configuration is also composed of porous metal for aeration. These pads are pneumatically pulsed each second to prevent powder from packing, aid vessel discharge, and cool the powder. The Vee-shell blender is also lined with aeration pads for the same purpose.

Thermal

Another consideration in storage vessel design was elevated temperatures due to heat generated by the design basis 20% ^{240}Pu isotope content in recycled plutonium. High temperatures would degrade polymer seals on equipment and melt binder and lubricant additions. Thermal conductivity tests were performed on samples of depleted UO_2 powder. Four conditions of powder were tested: jet milled, compacted jet milled, unmilled, and granulated. Results were used to calculate temperature distributions in each vessel. Calculations indicated temperatures in excess of 500°F in the jet mill receiving hopper, and 1000°F in the V-shell blender. Canisters and slab hopper temperatures containing granules (which at a higher density generate the most heat) were approximately 300°F and powder above 250°F.

Gas cooling is used to reduce temperatures in the V-shell blender and jet mill receiving hopper. The previously described aeration systems will be used when these vessels are loaded, cooling them to less than 250°F.

Slab hopper and canister temperatures were of considerable concern since they were above the melting temperature of reference binder and lubricant materials. A test program was run to select high melting temperature binders and/or lubricants. Over 30 test fuel lots were fabricated and fully characterized. Two high melting temperature waxes (above 400°F) and methylcellulose were selected for use with processing recycled plutonium.

CONCLUSION

Installation of the SAF fuel fabrication facility has been completed. To provide remote, automated operation of this fuel fabrication line considerable innovation and testing in powder processing was required. A variety of powder transfer and storage techniques will make a significant contribution toward the successful operation of this line.