Description of Processes for the Immobilization of Selected Transuranic Wastes

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DESCRIPTION OF PROCESSES FOR
THE IMMOBILIZATION OF SELECTED
TRANSURANIC WASTES

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SUMMARY

Processed sludge and incinerator-ash wastes contaminated with transuranic (TRU) elements may require immobilization to prevent the release of these elements to the environment. As part of the TRU Waste Immobilization Program sponsored by the Department of Energy (DOE), the Pacific Northwest Laboratory is developing applicable waste-form and processing technology that may meet this need. This immobilization program is part of the overall TRU Waste Management Program under the direction of the lead DOE Albuquerque Operations Office and is being coordinated by the TRU Waste Systems Office of Rockwell International, Rocky Flats Plant, Colorado. This report defines and describes processes that are capable of immobilizing a selected TRU waste-stream consisting of a blend of three parts process sludge and one part incinerator ash. These selected waste streams are based on the compositions and generation rates of the waste processing and incineration facility at the Rocky Flats Plant.

The specific waste forms that could be produced by the described processes include:
- in-can melted borosilicate-glass monolith
- joule-heated melter borosilicate-glass monolith or marble
- joule-heated melter aluminosilicate-glass monolith or marble
- joule-heated melter basaltic-glass monolith or marble
- joule-heated melter glass-ceramic monolith
- cast-cement monolith
- pressed-cement pellet
- cold-pressed sintered-ceramic pellet.

ACKNOWLEDGMENT

I would like to acknowledge the assistance and input of R. L. Treat of Pacific Northwest Laboratory in developing the processes described here. I would also like to thank G. B. Long for editing and coordinating the publication of this report.

CONTENTS

INTRODUCTION

Wastes contaminated with transuranic (TRU) elements may require treatment to prevent the uncontrolled release of these elements to the environment. A need exists to identify and characterize these wastes, to evaluate the possible immobilization requirements and treatment alternatives, and to develop immobilization process technologies to assure adequate waste confinement. The Pacific Northwest Laboratory has actively been pursuing these needs through the TRU Waste Immobilization Project under the sponsorship of the U.S. Department of Energy. This project is intended to meet all of the above objectives.

This report concentrates on the last of the above objectives--the development of process technologies. Processes are defined and described that are capable of immobilizing a selected TRU waste-stream consisting of a blend of process sludge and incinerator ash. In this study, the process sludge is produced by the decontamination of aqueous wastes resulting from various plutonium recovery and purification processes. The aqueous wastes are decontaminated using a hydrated ferric oxide precipitate which is separated from the supernate by passage through a rotary vacuum filter. A diatomaceous earth-filter precoat enhances removal of the insoluble contaminated solids. These filtered solids and media are the process sludge. The incinerator ash comes from the burning of contaminated combustibles, such as paper, gloves, lab coats, etc. As a model for our study, we assume the ash is produced by one of two methods depending on the level of activity in the material to be incinerated. The high specific-activity ash has been incinerated in a rotary kiln incinerator and then acid-leached to recover plutonium. The low specific-activity waste has been incinerated in a stirred-bed incinerator and the ash directly discharged as waste. Both the process sludge and the incinerator ash are contaminated with small amounts of plutonium and other actinides. The presence of these contaminants may require that the wastes be immobilized prior to final disposal. This report identifies the process bases and assumptions, supplies brief process descriptions, and provides preliminary process

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flowsheets for selected immobilization schemes that can be used to process these TRU wastes. The processes described are:

- in-can glass-melting
- joule-heated glass-melting
- glass marble
- cast cement
- pressed cement
- cold-pressed sintered-ceramic.

OVERALL PROCESS BASES

The conceptual immobilization facility is designed to solidify 285 MT/yr of TRU wastes consisting of a blend of three parts process sludge and one part incinerator ash. The assumed chemical composition of this blend is shown in Table 1. This feedrate is based upon the mass generation rates for sludge and ash at the new plutonium-recovery, volume-reduction and aqueous-waste decontamination facilities at the Rocky Flats Plant in Golden, Colorado. For all but the cement processes, an average operating rate of 26.5 kg/h of the TRU waste blend (19.9 kg/h of sludge and 6.6 kg/h of ash) is assumed for a 24 h/d, 300 d/yr operation. However, all processes are designed to operate at 1.5 times the average rate or 40 kg/h of sludge and ash at the design capacity. The cement process is the lone exception to the above flowrates, for it is based on an 8-h/d, 5-d/wk, 43-wk/yr operating frequency. Hence, the cement process treats an average of 110.5 kg/h of the TRU waste blend, and the design rate is 165.8 kg/h.

The elements of each immobilization process that involve handling radio-active materials will be housed in radiation containment cells and adjoining glove boxes. Glove boxes will be used only where contact maintenance and operations are expected to be high, where remote functions are not feasible, and/or where personnel exposure is expected to be low. Some contact mainte-nance in the cells will likely be required although suitable design will mini-mize this possibility.

In order to proceed with preliminary design of the processes, the final waste package is designed to meet the following criteria:

- canister - maximum dimensions of 61 cm (2 ft) dia x 3.05-m (10-ft) total length

- drum - 58 cm (23 in.) dia x 76 cm (30 in.) in height

- weight - less than 11,300 kg total

- packaging requirements - 47 CFR 173.398 (b) Type A

- design life - 10 yr.

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TABLE 1. Assumed Chemical Compositions for Typical Sludge and Ash

Compound	Composition, wt%		
	Process Sludge	Incinerator Ash[a]	Waste Blend[b]
Al_2O_3	1.48	18.59[c]	5.76
B_2O_3	--	.32	.08
BaO	--	.97	.24
CaO	7.61	4.00	6.71
C	--	9.70	2.43
Co_2O_3	--	.01	--
Cr_2O_3	--	.10	.03
CuO	--	.02	--
Fe_2O_3	21.95	1.43	16.82
K_2O_3	.64	.97	.72
MgO	3.50	5.34	3.96
MnO_2	--	.02	--
MoO_3	--	.02	--
Na_2O	6.20	1.82	5.10
NiO	--	.04	.01
P_2O_5	3.99	4.81	4.19
SiO_2	37.58[c]	25.48[c]	34.55
SrO	--	.02	--
S	--	.36	.09
TiO_2	--	24.26[c]	6.07
ZnO_2	--	1.67	.42
ZrO_2	--	.03	.01
H_2O	10.00	--	7.50
PuO_2	.002	.2	.05
Other	7.05	--	5.29
	100.002	100.18	100.03

(a) Unleached.
(b) Based on a sludge:ash generation-rate ratio of 3.
(c) Highly variable.

The immobilization facility will receive the incinerator ash in reusable criticality-safe containers. The immobilization facility will also receive the sludge from the processing facility in slurry form from the filter feed tank and/or as dried sludge in reusable tapered drums designed to facilitate removal of the waste. Transferring the sludge as a slurry and locating the rotary vacuum filter, sludge drier and cooler in the immobilization facility is the preferred receiving method because of the ease and safety of material transfer and handling.
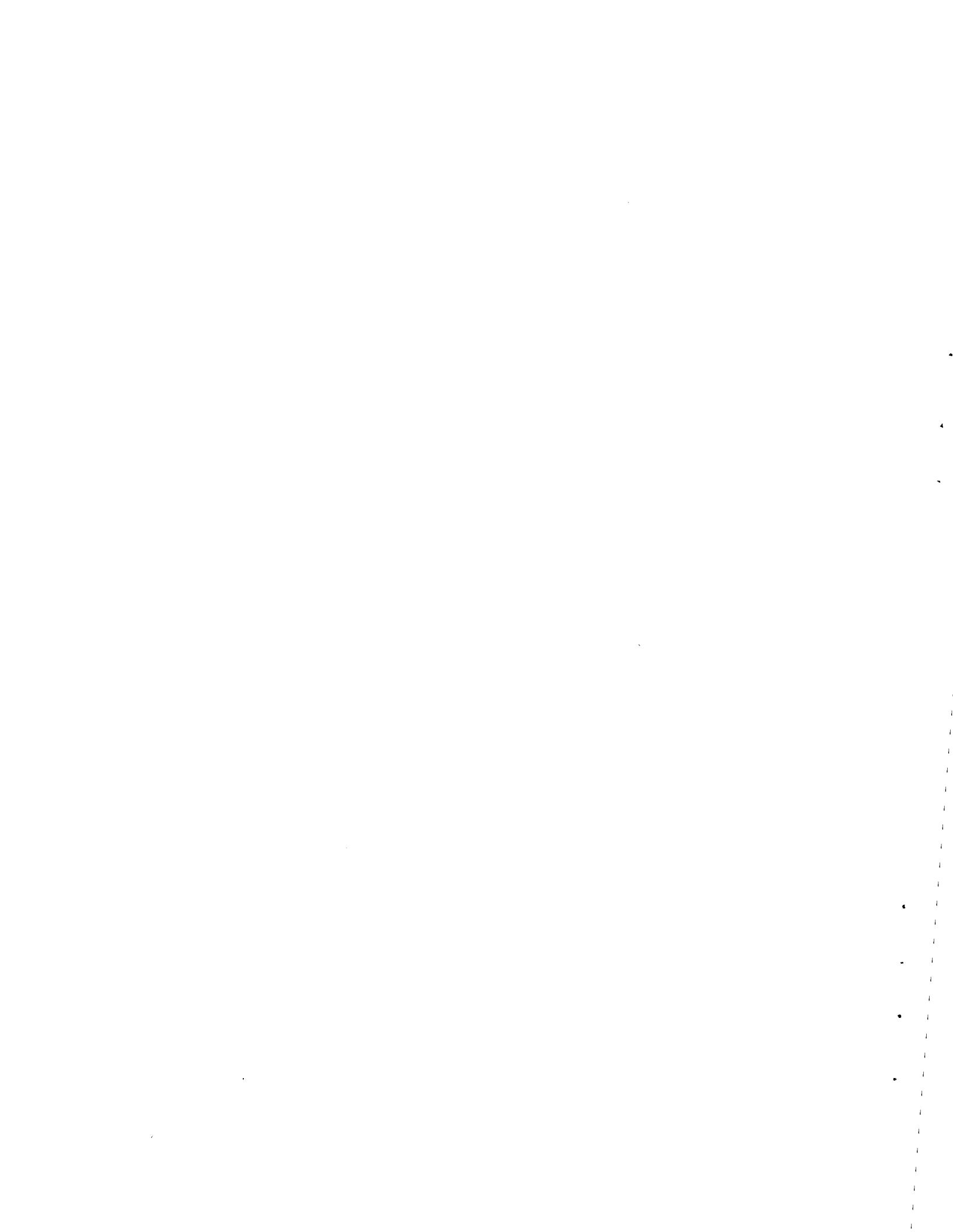
PROCESS DESCRIPTIONS AND FLOWSHEETS

Various immobilization processes and a preliminary design of their flow-sheets are described here. These immobilization processes form three basic waste-product forms via various processing options: glass, cement, and crystalline ceramic.

IN-CAN GLASS-MELTING PROCESS

In the In-Can Glass-Melting (ICGM) process (Blair 1979), large monoliths of a glass/waste mixture are produced. Dried sludge, ash, and borosilicate glass frit are control-fed to a continuous powder blender for homogeneous mixing. Afterwards, the blended mix flows down to a unidirectional diverter valve into a pair of In-Can Melters (ICM's). A schematic of the process flowsheet with the operating flowrates indicated is illustrated in Figure 1. This diagram shows that only one of the two ICM's can be operating and receiving the blended mix at any given time. Figure 2 shows the general arrangement of a pair of ICM's with one canister being filled while the other is being exchanged. The Figure 3 schematic illustrates an enlarged view of the connecting section between the material flow and the canister.

The canisters heated in the ICM constitute a major component of this system. Specific design considerations of the waste canister are size, material of construction, and canister-wall thickness. The size of the canister will be determined by the maximum allowable diameter and height permitted by the repository since TRU wastes require no heat-generation constraints in repository design. Thus, the canister can be as large as the design criteria permit. From the assumptions of this study, the canister will be constructed of 304L stainless steel and will have a 61-cm (2-ft) outside diameter, 58.4-cm (23-in.) inside diameter and a 3.05-m (10-ft) overall height. The stainless steel canister-wall thickness, 1.3 cm (1/2 in.), is determined by consideration of the lifting load at elevated temperatures, internal corrosion, external oxidation, creep, spallation, tensile stress during cooling, ruggedness factors and material of construction.

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DRIED SLUDGE

SLUDGE
FEED
TANK

GLASS
FRIT

ASH

ASH
UNLOADING

SLUDGE
WEIGH
FEEDER

M

26.5 kg/h

6.6 kg/h

19.9 kg/h

CONTINUOUS
POWDER BLENDER

M

53 kg/h

OFF GAS

UNDIRECTIONAL
DIVERTER

ICM
#1

ICM
#2

0.6 CANISTERS/DAY

2049 kg/CANISTER

WELDER

FORCED-AIR
COOLING RACK

LID CLOSURE

DECONTAMINATION

STORAGE
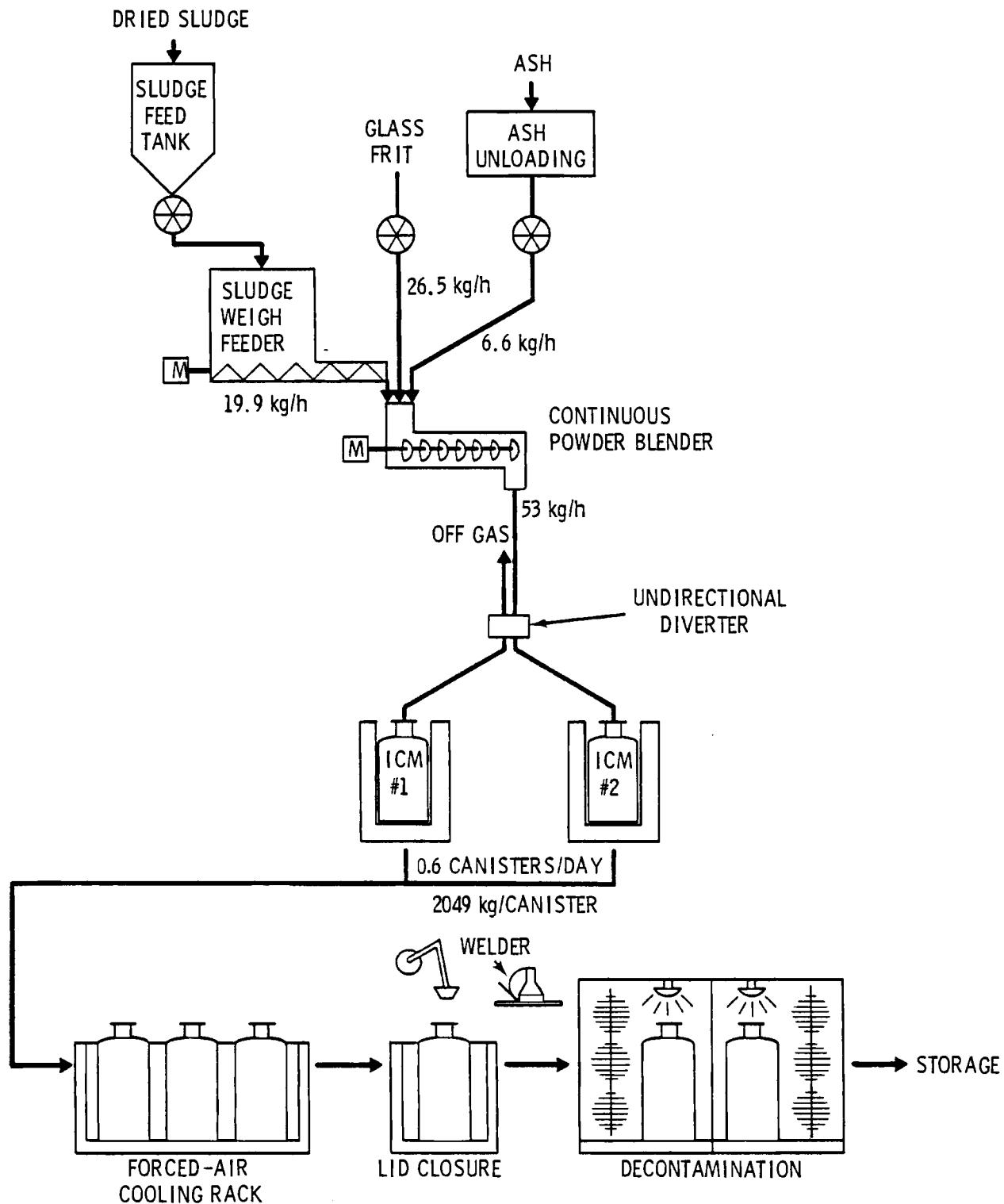
FIGURE 1. In-Can Melting Process
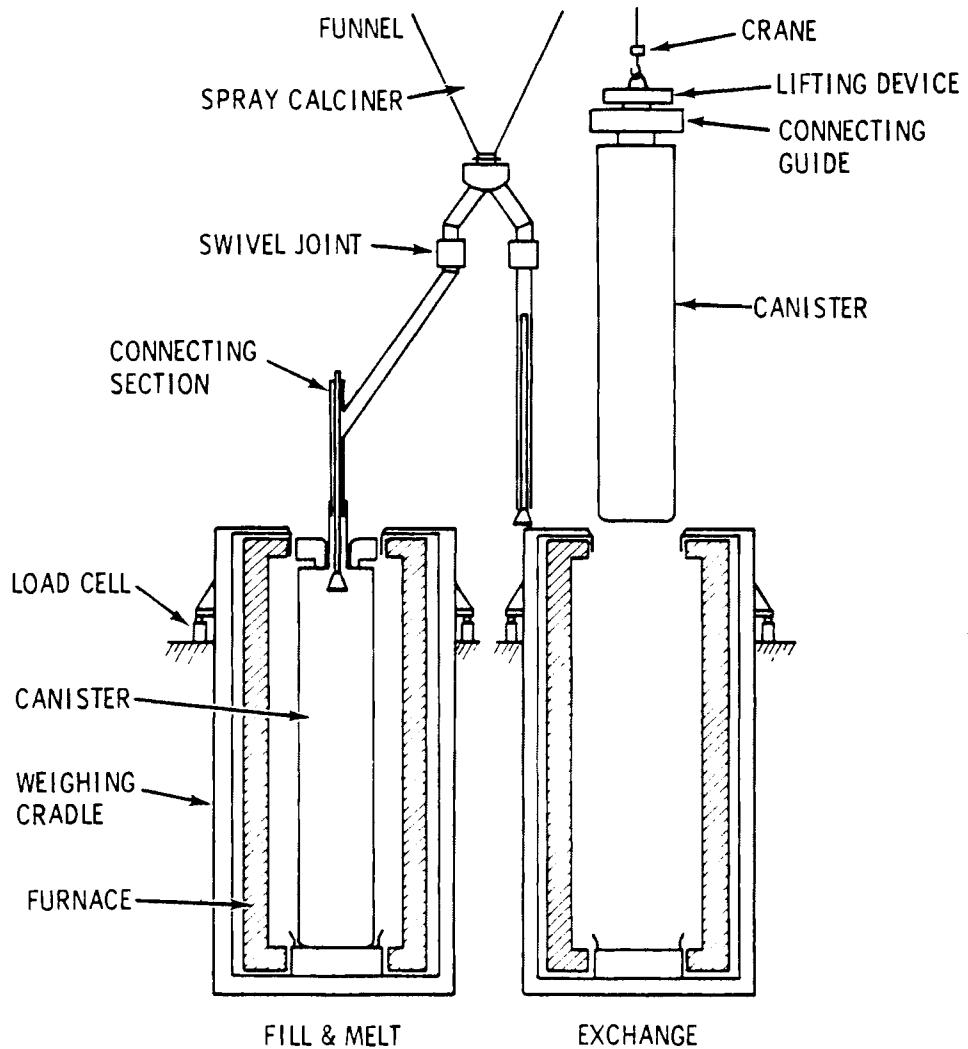
FIGURE 2. General Arrangement of ICM System

A free space of approximately 30 cm (11.8 in.) at the top of the canister is required to accommodate some glass pile-up and potential foaming problems. In addition, 20 cm (7.9 in.) is required for a handling device that is attached to the canister lid. This makes the effective glass height 2.55 m (8.4 ft) and the volume 683 L. Based on a 50-wt% waste loading and a glass/waste density of 3 kg/L, each canister can accommodate 1025 kg of blended TRU waste in a 2049-kg glass/waste melt.

Assuming an average design melting rate of 80 kg/h for a 61-cm-dia canister, a 26-h fill-time for each canister (or 0.9 canister/d) can be anticipated.
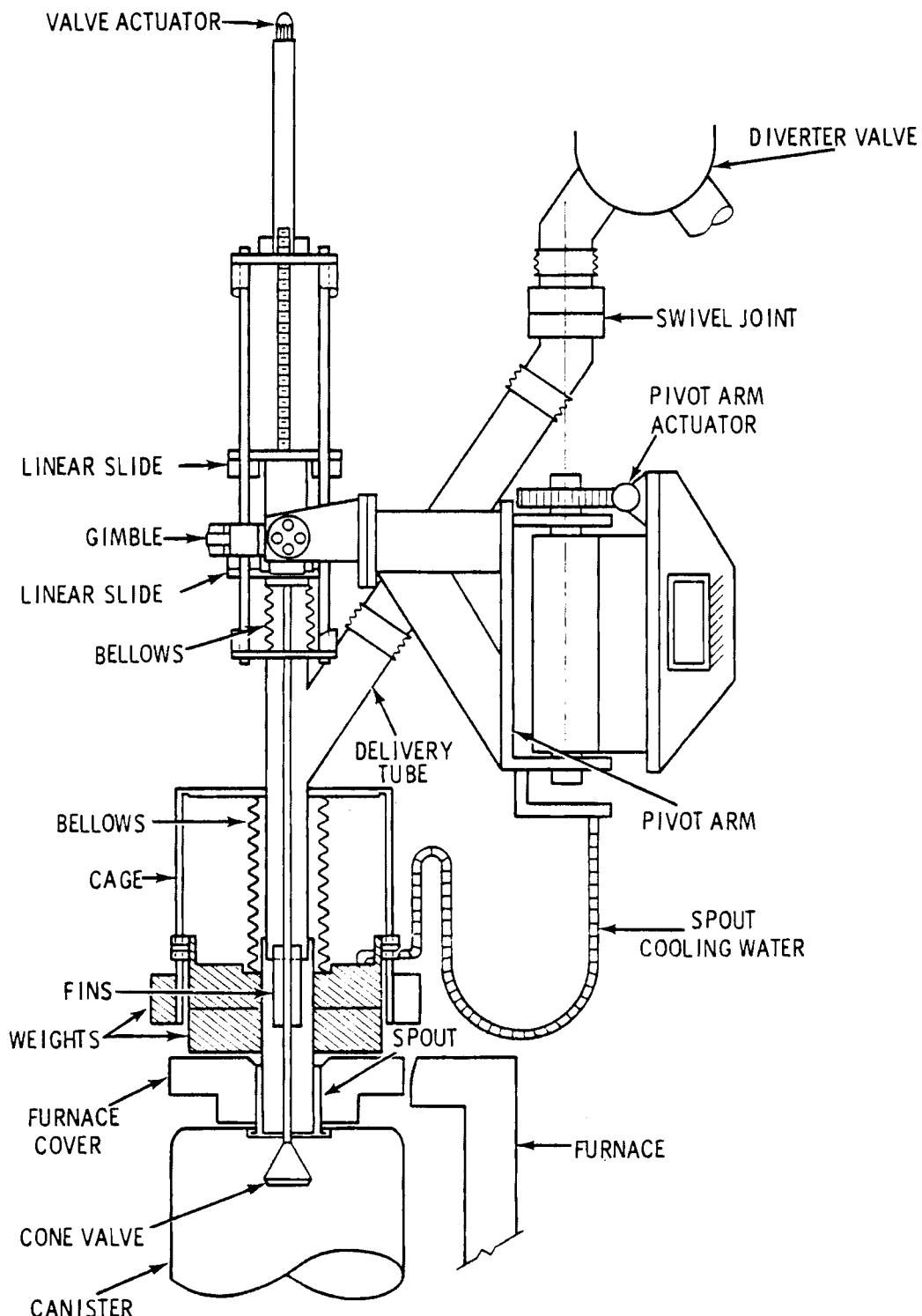
FIGURE 3. Schematic of the ICM Connecting Section

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Considering the operating-time cycle of 40.5 h indicated in Table 2, and since the fill rate matches the production rate, two ICM's will be used to meet production.

When a canister is full, the waste and glass frit continue to melt completely at a temperature of $\sim 1050^\circ C$ over a period of 3.5 h. After complete melting, a cooldown period is initiated. Once the canister has recovered sufficient tensile strength (at $\sim 700^\circ C$), the canister is removed and transferred to a forced-air cooling rack. There, it is cooled further to prevent excessive devitrification of the monolith and to enable subsequent handling. The canister is then transferred to a lid-closure station where the lid is remotely welded to the canister. Finally, the exterior of the canister is decontaminated and the canister is transported to storage.

TABLE 2. Canister Operating-Time Cycle

Operations	Time, h
Place Canister in Melter and Connect	2.0
Heat Empty Canister	3.5
Fill	26.
Top and Allow Bubble Release	3.5
Cool to $700^\circ C$	3.5
Disconnect, Remove Canister from Melter	2.0
TOTAL	40.5

JOULE-HEATED GLASS-MELTING PROCESS

The Joule-Heated Glass-Melting (JHGM) process also produces large glass/waste monoliths. In the JHGM process (Figure 4), dried sludge, ash and borosilicate glass frit are metered into a continuous powder blender for mixing. The blender regulates the flow of the mixture into the joule-heated glass melter where the mixture forms a cold-cap of material on top of a reservoir of molten waste glass. The operation is semi-continuous since the molten-glass level can rise in the melter while drums are being changed. Glass flow can be increased to 150 kg/h (Buelt et al. 1979) to meet design production demands.

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DRIED SLUDGE

SLUDGE
FEED
TANK

GLASS
FRIT

ASH

ASH
UNLOADING

26.5 kg/h

6.6 kg/h

SLUDGE
WEIGH
FEEDER

M

19.9 kg/h

M

OFF GAS

CONTINUOUS
POWDER BLENDER

GLASS

JOULE-HEATED
GLASS MELTER

GLASS
53 kg/h

TEMPERATURE-
CONTROLLED
JACKET

55-GAL DRUM
480 kg/DRUM
80% FILL
2.7 DRUMS/DAY

FORCED-AIR
COOLING RACK

LID CLOSURE

DECONTAMINATION

STORAGE
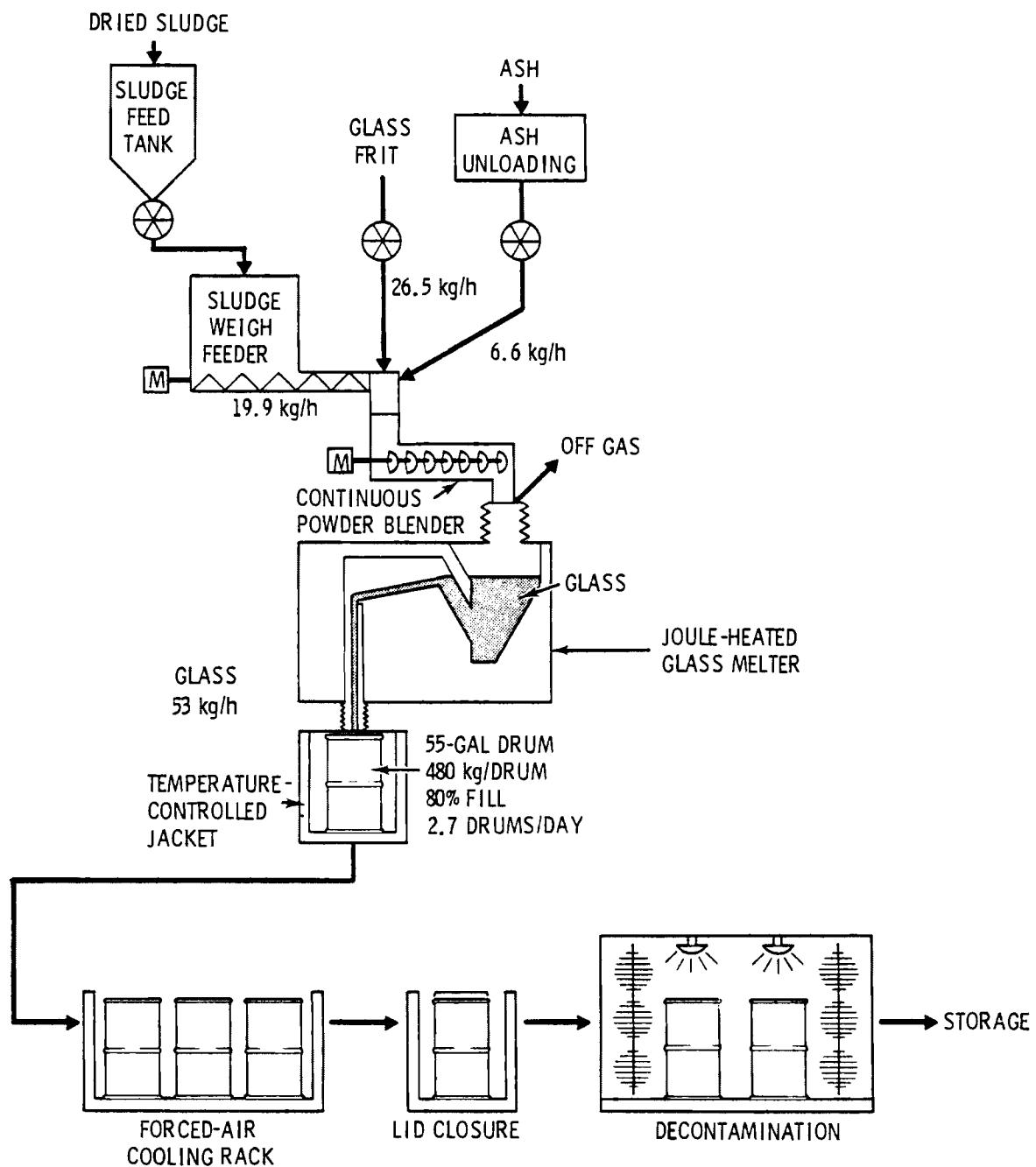
FIGURE 4. Joule-Heated Glass-Melting Process

Melting energy is supplied to the melter by an alternating current that passes through the molten glass between immersed Inconel® 690 electrodes.

The molten glass at $1050^\circ C$ is drawn up via an air-lift system from the bottom of the melter into a heated overflow trough within the melter as illustrated in the schematic cutaway view in Figure 5. The molten glass is then poured into 55-gal drums enclosed in a temperature-controlled jacket for initial drum heatup to prevent thermal shock and for cooldown purposes after the drum is filled. The average operating rate of the melter for this process is 53 kg/h. At this rate, or even at the design rate of 80 kg/h, no problems using a regular 55-gal mild-steel drum are envisioned, especially using the temperature-controlled jacket. Also, because the glass has already been formed in the melter, container-filling can be carried out much more rapidly than in the ICGM process. In addition, because of this rapid filling, the JHGM drums will not be exposed to temperatures as high as those of the canisters in the ICGM process.

Assuming a 50-wt% waste loading and a borosilicate glass/waste density of 3 kg/L, a drum filled 80% will contain 480 kg of waste glass. At operating conditions, 2.7 drums will be filled per day or 1 drum every 9 h.

After a drum is filled, it is transferred to a forced-air cooling rack for faster cooling to prevent devitrification of the glass and to enable subsequent handling of the drum. Then, the drum is moved to a glove-box station for emplacement of a standard ring-type lid closure. Finally, the exterior of the drum is decontaminated and the drum is transferred to storage.

The joule-heated glass melter can also be used to produce a glass ceramic or a high-temperature aluminosilicate or basaltic-type glass. The glass ceramic can be formed by controlled devitrification of the glass in the canister, which forms crystalline phases. This devitrification can be accomplished by a slow-controlled cooldown of the canister or by a rapid cooling down to $650^\circ C$ followed by a controlled heatup to $850^\circ C$ to recrystallize the glass. High-temperature ($1300^\circ C$) glasses are currently being evaluated to determine if they are significantly better than the borosilicate glasses. The

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®Huntington Alloys, International Nickel Co.

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LID HEATER

SLURRY

ELECTRODE CONNECTOR

GLASS

DRAIN SPOUT

OVERFLOW CHANNEL

CANISTER
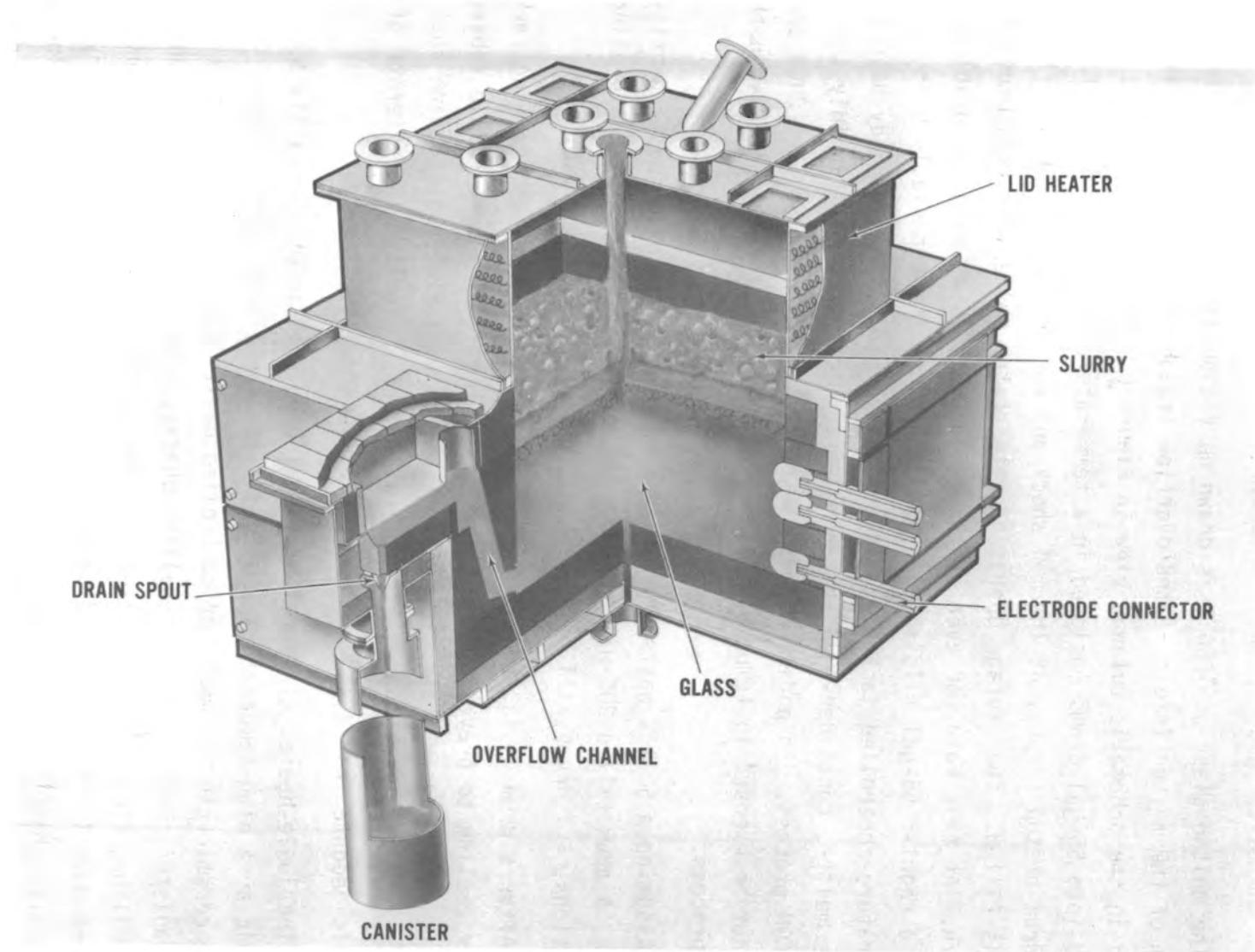
FIGURE 5. Joule-Heated Glass Melter

higher operating temperatures for these glasses require that the melter have tin oxide electrodes rather than Inconel 690 to achieve and withstand these high melting temperatures.

GLASS-MARBLE PROCESS

The glass-marble process produces ∿1-cm-dia marbles of a glass/waste mixture. As described in the JHGM process, the ash, sludge and glass frit are fed into a continuous powder blender for mixing. The blend flows from the blender directly onto the surface of the molten glass in the melter. Again, the melting energy for this melter is supplied by an alternating current that passes through the molten glass between immersed electrodes. The newly added material continuously settles and melts into the molten glass. As new frit and TRU wastes are melted, glass is drawn from the bottom of the melter, raised to an overflow trough, and continuously discharged as a thin molten stream.

The molten glass stream is poured into an enclosure housing the marble machine (Treat et al. 1980) as depicted in Figure 6. The marble machine is the first unit in the process that deviates from the JHGM process. As the glass stream leaves the melter, it pours into moving vibrating molds. As the molds move along a vibrating track, the molten glass forms semimolten spheres, which cool rapidly to form marbles. This glass-pouring and marble-forming operation is shown in Figure 7. When the molds reach the end of the vibrating track, the glass marbles fall from the molds onto a vibrating sorter.

The sloping, vibrating sorter is located in the enclosure under the exit end of the marble machine. Spherical marbles roll off one area of the sorter and are then fed into a pneumatic transfer system. Slag, glass ribbons, and broken or deformed marbles do not roll and, hence, are vibrated off the sorter and fall to the bottom of the marble-machine enclosure, where they are fed into a mill for crushing and recycling.

A glass-flow diverter assembly is another route the glass may take when being poured from the melter. This equipment allows almost instantaneous diversion of the glass flow from the marble machine in case of some process upset and is only in operation long enough for the glass stream from the melter to

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DRIED SLUDGE

ASH

SLUDGE
FEED
TANK

GLASS
FRIT

ASH
UNLOADING

26.5 kg/h

FRIT FILTER

RECYCLE
HOPPER

MARBLE
SURGE
HOPPER

SLUDGE
WEIGH
FEEDER

M

6.6 kg/h

19.9 kg/h

M

CONTINUOUS
POWDER
BLENDER

RECYCLE FEED
3 kg/h

SLIDE
VALVE

TO OFF GAS

VOLUME
HOPPER
160-L CAPACITY

JOULE-HEATED
GLASS
MELTER

WATER

56 kg/h

SORTER

MARBLE
FILL
STATION

MARBLE MAKER

GLASS-FLOW
DIVERTER

SAMPLE

55-GAL DRUM
240 kg/DRUM
80% FILL
50% VOID
5.3 DRUMS/
DAY

MILL

MARBLES

53 kg/h

TO WATER
TREATMENT

FEED
VALVE

SCRAP

PD BLOWER

HEPA FILTER

FORCED-AIR
COOLING RACK

LID CLOSURE

DECONTAMINATION

STORAGE

FIGURE 6. Glass Marble Process

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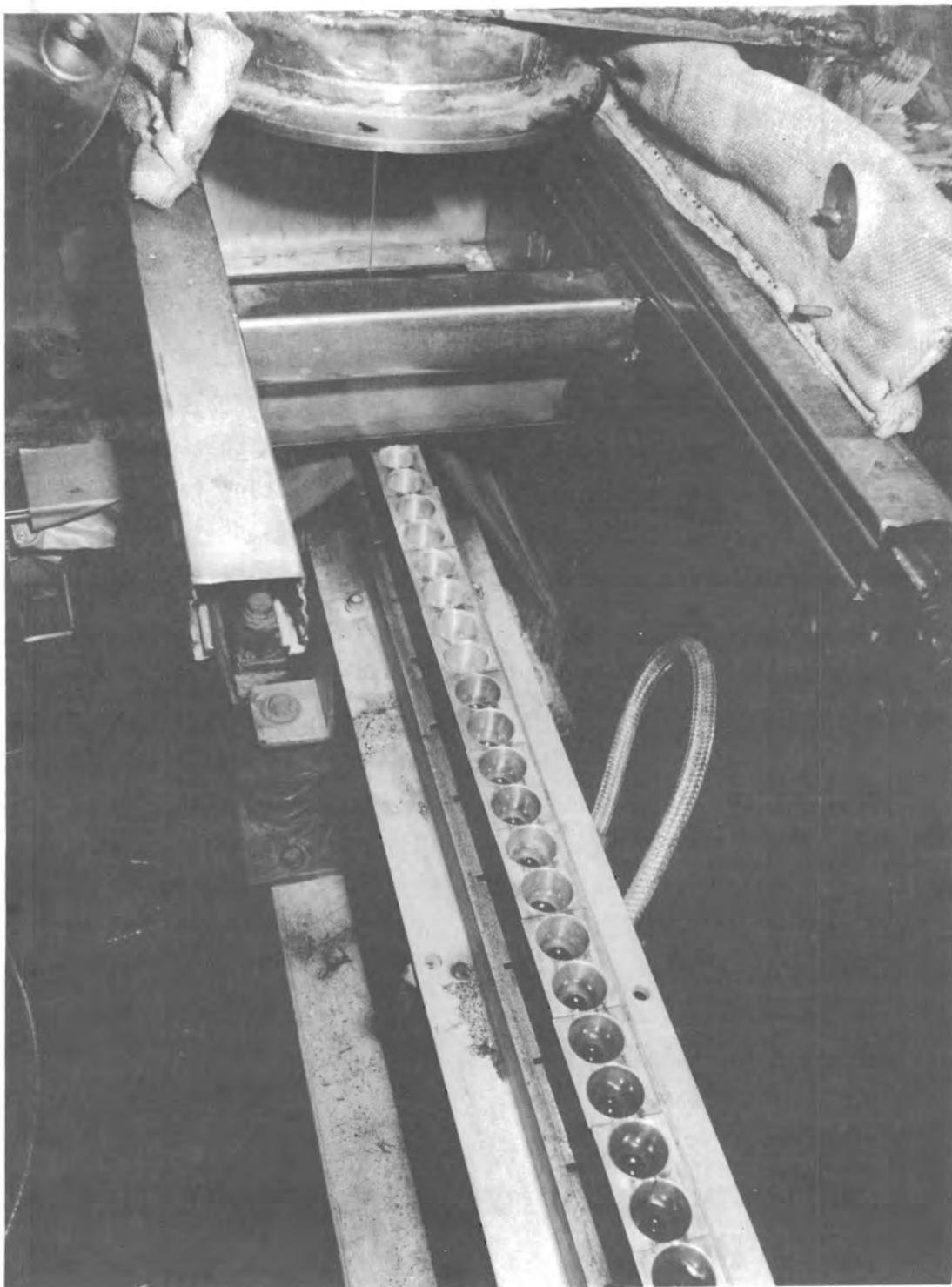
FIGURE 7. Glass Pouring and Marble Formation

be discontinued. The flow diverter consists of a funnel and a chute leading to a storage vessel. When in use, water is continuously flowing in this diverter system, causing the glass to fracture and form glass frit again. This glass frit is augered from the storage vessel into the marble machine enclosure for feeding into the mill along with the scrap from the marble machine operation.

When enough material is accumulated, the mill is operated to reduce the glass material to particle sizes that can be conveyed in a pneumatic system and recycled into the melter. This solid-process scrap material is conveyed to a recycle hopper located at a sufficient elevation above the melter to allow gravity-controlled feeding from the hopper into the melter.

The closed, negative-pressure pneumatic system with two loops is antici-pated 1) to transport acceptable marbles at an operating rate of 53 kg/h to a marble surge hopper, and 2) to convey ground scrap glass to the recycle hopper at rates up to and equal to that of the glass production.

The surge hopper collects the marbles conveyed via the pneumatic system. Glass fines that may have been conveyed with the marbles are separated and carried out the top of the surge hopper via the pneumatic system to the scrap recycle hopper. From the surge hopper, the marbles flow to the volume hopper via gravity for a volumetric measurement. When filled, the volume hopper con-tains approximately 160 L or 80% of the fill of a 55-gal drum. Closing the upper slide valve establishes the batch size to be fed to the drum. A fill mechanism directs and controls the flow of 240 kg of marbles to the drum (assuming a 50% void). At the operating flowrate, 5.3 drums will be filled per day. The benefits anticipated from this additional processing--glass marble manufacture--include ease of sampling for quality control, negligible devitrification, and ease of product recycling.

After the drum is filled, it is transferred for cooling and lid emplace-ment and closure. The drum is then inspected, decontaminated if necessary, and transferred to storage.

The flow numbers associated with Figure 6 are for the nominal operating flowrates. These numbers are based on a 50-wt% waste loading in the borosili-cate glass that has a 3 kg/L density. This allows for an average operating

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melting rate of 56 kg/h assuming a 5% recycle rate. The 80% drum-fill of the volume hopper also considers a 50% void in the total volume.

CEMENT PROCESSES

The operating basis of the cement process differs from the other processes in that it is designed to operate on an 8-h/d, 5-d/wk, 43-wk/yr schedule instead of the 24-h/d, 300-d/yr schedule assumed for the other processes. The ash and sludge are added to this process without a preblending step because the blending operation is performed by a cement/grout mixer. The ash is added to the grout mixer at an average rate of 26.8 kg/h, while the sludge rate is 85.6 kg/h (83.9 kg/h of new sludge plus 1.7 kg/h of process recycle). Cement additives are introduced at 208.7 kg/h to the mixer, forming a 35-wt% waste blend and a 65-wt% cement mixture. The processing water is input according to a water/solids ratio of 0.395 or 126.8 kg/h which has experimentally been found sufficient to produce a flowable mix. Another additive to the mixer is 4.5 kg/h (1% of the total mixer throughput) of off-gas filter media used for dust and moisture entrapment. These flowrates produce a nonaggregate, cast, cement waste-form with an overall waste loading of 25 wt%. The flowsheet for this cast cement process is shown in Figure 8.

The above materials are batched into the grout mixer to provide 160 L of cement mix. This cement batch is then mixed for 3 to 5 min. The wet batch of cement mix is centrifugally discharged to a feed hopper for loading into 55-gal drums. With an assumed wet-cement density of 2 kg/L, 320 kg of cement/waste are expected for the 80% fill of each drum; thus, 11.4 drums/d are produced.

The cement mixer is flushed at least once daily. Flush solutions are pumped to the filter feed tank for processing through the rotary drum filter. Approximately 1.7 kg/h of solids (1% of flushings at 169.3 kg/h) are incorporated into the sludge stream from these flushings.

An optional post-mixing treatment to this process is to uniaxially press the unbound or free water from the the cement. This processing concept is being developed at the Mound Facility (Lewis 1980). Using this pressing operation, small cement pellets measuring 5.1 cm (2 in.) in dia by 5.1 cm (2 in.) in

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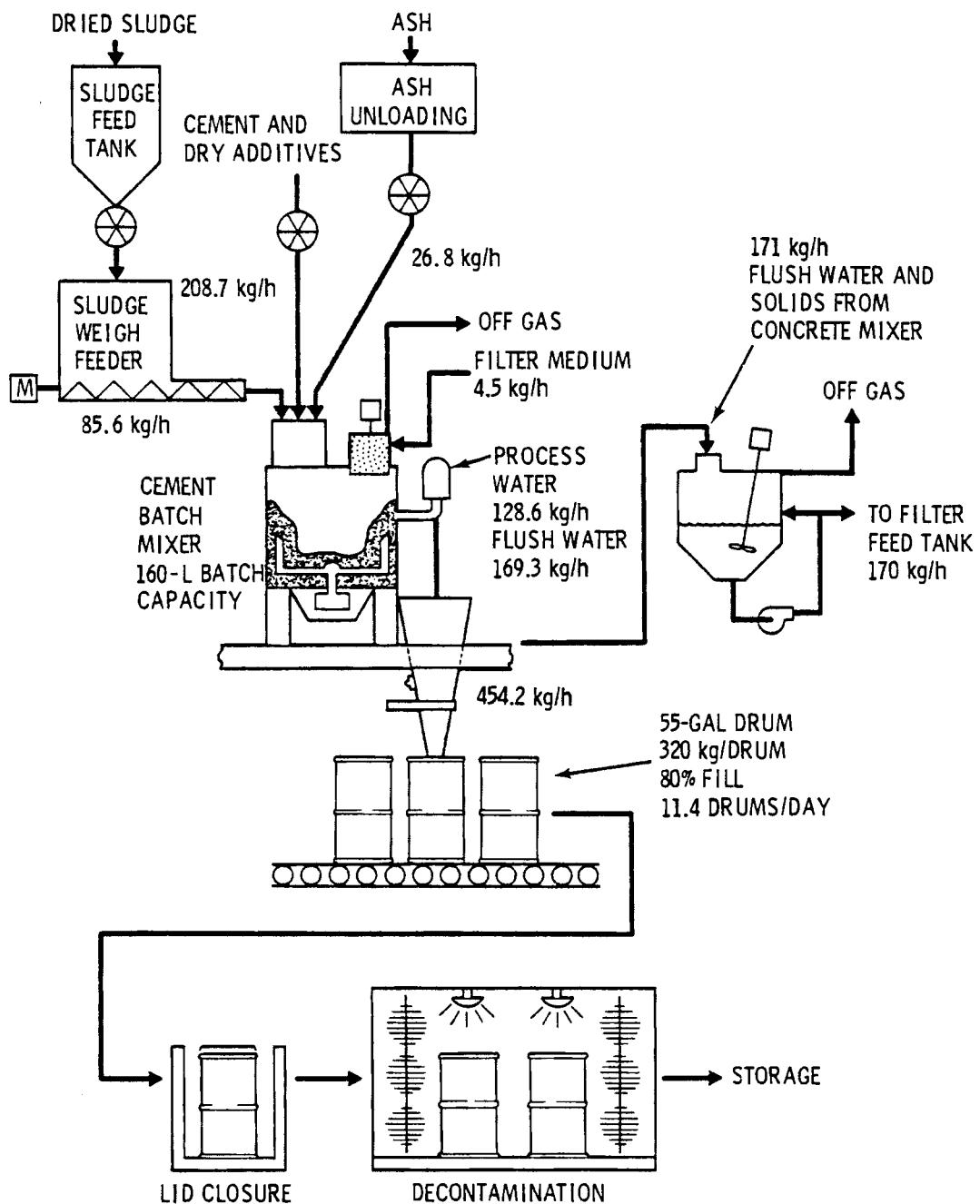
FIGURE 8. Cast Cement Process

length would be produced. This process option has the same combined sludge/ash feedrate of 112.4 kg/h as the previously described cement process. This pressing option allows a 40-wt% waste and 60-wt% cement mixture to be fed to the mixer. Again, as in the prior cement process, a filter media for dust and moisture is slowly added to the mixer at 1% of the throughput rate, or 4.2 kg/h. Process water at the rate of 142.6 kg/h is added to supply a water/solids ratio of 0.5 for flowability consideration.

As shown in Figure 9, the moist cement mixture flows from the mixer to three 36.3-MT (40-ton) hydraulic presses. These presses are required to meet the design pellet-production rate of approximately 40 pellets/min. In the pressing step, pellets 5.1 cm (2 in.) in dia with a length-to-diameter ratio of 1.0 are manufactured. Approximately 172 MPa (25,000 psi) is required to produce pellets with a density of 1.92 kg/L. The water in the mixture is used as the die lubricant. During the pressing operation, about 80% of the water (117.4 kg/h) in the mixture is forced from the die, leaving a water/solids ratio of 0.1 in the final pressed pellet. The water is collected in an interim storage tank and recycled to the filter feed tank for incorporation back into the sludge processing.

After ejection from the die, the pellets are stored for 1 d for dry-curing before being loaded into a storage or shipping container. Of the 320.3 kg/h of pellets produced, it is estimated that upon visual inspection approximately 2% of the pellets will be broken, cracked, or damaged in some manner. These 6.4 kg/h of damaged pellets will be crushed and recycled back to the mixer for reprocessing. The 319.9 kg/h (or 1588 pellets/h) of cured pellets are loaded into a 55-gal drum to an 80% fill. The bulk pellets are estimated to have a 50% void volume. Thus, 153.6 kg of pellets with an overall pellet waste-loading of 35 wt% are loaded into each drum. Sixteen and three-tenths drums are assumed to be loaded per day. As in the glass marbles process, the benefits of an interim processing step--pressing of pellets--include the ease of performing quality assurance and recycling, in addition to achieving potential higher waste-loading and a lower gas generation rate caused by the radiolysis of water.

DRIED SLUDGE

ASH

SLUDGE
FEED
TANK

CEMENT AND
DRY ADDITIVES

ASH
UNLOADING

26.8 kg/h

288.4-kg/h
FLUSH AND PRESS
WATER PLUS SOLIDS

168.6 kg/h

SLUDGE
WEIGH
FEEDER

OFF GAS

FILTER MEDIUM
4.4 kg/h

OFF GAS

M

85.6 kg/h

CEMENT
BATCH
MIXER
160-L BATCH
CAPACITY

PROCESS
WATER
145.9 kg/h
FLUSH WATER
169.3 kg/h

TO FILTER
FEED TANK
287 kg/h

437.7 kg/h

MILL

RECYCLED
PELLETS
6.4 kg/h

36.3 MT
UNIAXIAL
PRESSES

PRESSED
WATER
117.4 kg/h

313.9 kg/h
1588 2-in. x 2-in.
PELLETS/h

SAMPLE

55 GAL DRUM
153.6 kg/DRUM
80% FILL
50% VOID
16.3 DRUMS/DAY

STORAGE

LID CLOSURE

DECONTAMINATION

FIGURE 9. Pressed Cement Process

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From the drum-loading station, the drums from either cement process are transferred for lid closure, inspection, decontamination as necessary, and storage.

COLD-PRESSED SINTERED-CERAMIC PROCESS

The head-end processing of the Cold-Pressed Sintered-Ceramic (CPSC) process through the powder blender is similar to that of the glass processes, except that a clay mineral, such as bentonite or another sintering additive, is introduced to the sludge/ash blend instead of glass frit. The input rates to the powder blender, as shown in Figure 10, for a 24-h/d, 300-d/yr facility are sludge, 19.9 kg/h; ash, 6.6 kg/h; and bentonite, 53 kg/h. The bentonite additive assumes a 33-wt% waste loading.

From the powder blender, the material is batched into a vibratory grinding mill for size reduction to increase the reactive surface area to better promote the formation of desirable ceramic phases. The milled material is air-classified to 400 mesh or below, with the coarser material recycled back to the vibratory grinding mill for further size reduction. The appropriate size material is then pneumatically transferred to the press surge hopper for storage prior to the cold-pressing operation. The pneumatic air and any carry-over fines leaving the press surge hopper are transported to the recycle hopper for incorporation back into the vibratory grinding mill.

The milled blend is gravity-fed from the press surge hopper to a 9.1-MT (10-ton) uniaxial cold press of hydraulic design. The material is pressed into 5.1-cm (2-in.)-dia by 5.1-cm (2-in.)-long pellets at a pressure of 14 MPa (2,000 psi). The design flowrate requires production of 12 pellets/min, which can be accomplished by one pressing unit. Once the pellets have been formed, they are passed on to a sintering furnace where they are sintered at 1000°C for 2 h under atmospheric conditions. The green density of the pellets is approximately 1.7 kg/L, while the sintered density increases to approximately 2.5 kg/L.

FIGURE 10. Cold-Pressed Sintered Ceramic Process

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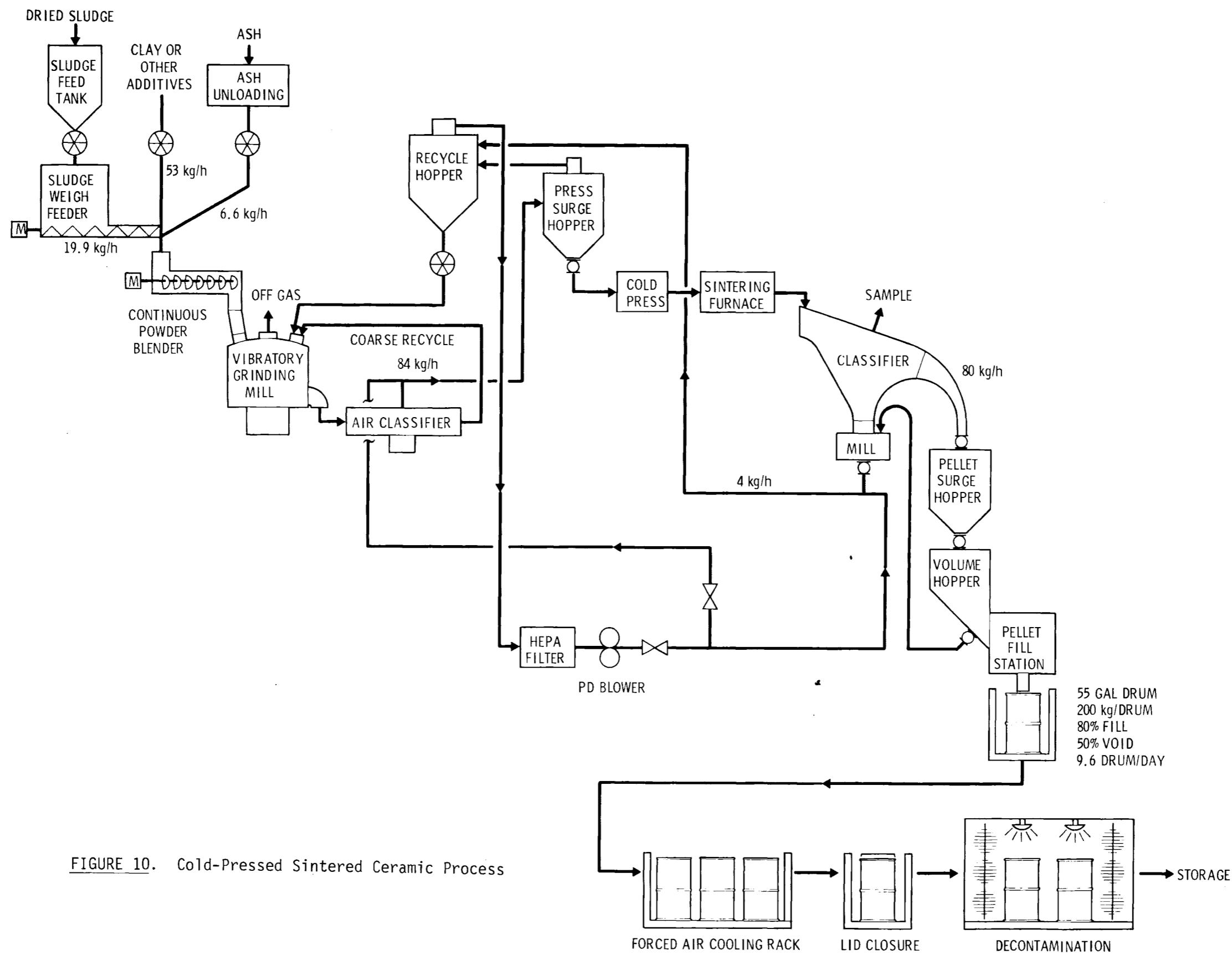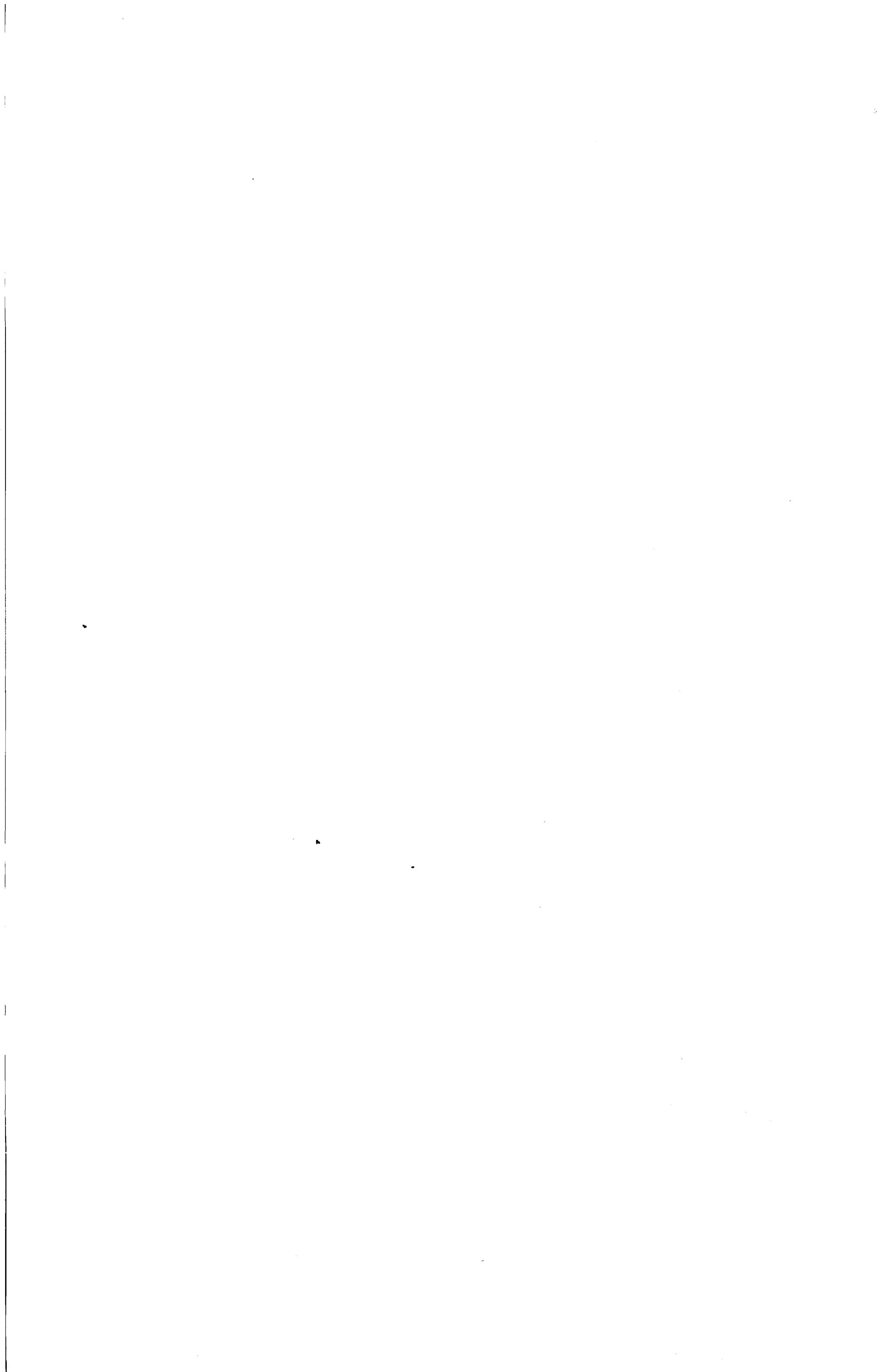
After sintering, the pellets are transferred to a screen classifier for dust, and broken pellet or chip removal. Good pellets (chipped pellets are assumed acceptable) continue on to the pellet surge hopper for eventual load-out. The dust and pellet chips are vibrated to the bottom of the classifier where they fall into a mill for crushing into particles that can be conveyed via a pneumatic system and delivered to the recycle hopper. This solid-process scrap material is gravity-fed to the vibratory grinding mill from the recycle hopper for incorporation back into the process.

The closed, negative-pressure pneumatic system has two functions: 1) to transport finely milled material to the press surge hopper at an operating rate of 84 kg/h and 2) to convey ground scrap pellet material to the recycle hopper at an average rate of 4 kg/h (assumed 5% recycle) but with a design rate equal to that of sintered pellet production.

The pellet surge hopper allows pellets to flow via gravity to a volume hopper for volumetric loading to a 55-gal drum. A full-volume hopper contains approximately 160 L or an 80% fill of a 55-gal drum. The pellet fill station attached to the volume hopper controls and directs the pellet flow into the drum. Each drum will hold 200 kg of pellets assuming a 50% void volume in the drum at an 80% fill. At this loading, 9.6 drums/d will be required to meet the operating flowrate.

After the drum is filled, it is transferred for cooling, lid closure, inspection, decontamination and storage.

CONCLUSIONS

All the processes described are viable options for producing a stable, immobilized waste-form for the selected transuranic wastes. The benefits of the various waste-form products have previously been studied (Palmer et al. 1980). This report has identified the unit operations, equipment, process materials, and immobilized waste volumes for each system. Because of the high generation rate of TRU wastes, waste volumes need to be considered in choosing a TRU waste-form and process to minimize handling, transportation, and repository volumes and costs. A summary of daily operating volumes of containerized waste and the waste loading for each process is provided in Table 3. This table represents the nominal container volume generated daily; the number of containers required per day; and the total overall waste loading on a weight percent basis. The waste loading column in Table 3 includes the weight of the waste, the immobilizing media, the air in the void spaces, and the container. This column provides an indication of the waste loading when the container weight is taken into account. For reference, the weight-percent waste loading in the waste form is also shown. These numbers will be helpful in choosing an economical and practical waste form and process as this study continues. This information, along with the concepts, descriptions and flowrates presented in this report, will be used to further evaluate the costs and feasibilities of producing a stable TRU waste-form.

TABLE 3. TRU Waste Volume and Loading Considerations

Process	Volume of Containerized Waste		Total Waste Loading	
	L/d	Containers/d[a]	Container, wt%	Waste form, wt%
In-can melting	460	0.6	38.3	50
Joule-heated melting	530	2.7	48.0	50
Glass marble	1060	5.3	46.2	50
Cast cement	2280	11.4	23.6	25
Pressed cement	3260	16.3	31.8	35
Cold-pressed sintered ceramic	1920	9.6	30.4	33

(a) All processes use a 55-gal drum container except the in-can melting process that uses a 0.6-m-dia x 3-m-tall canister.

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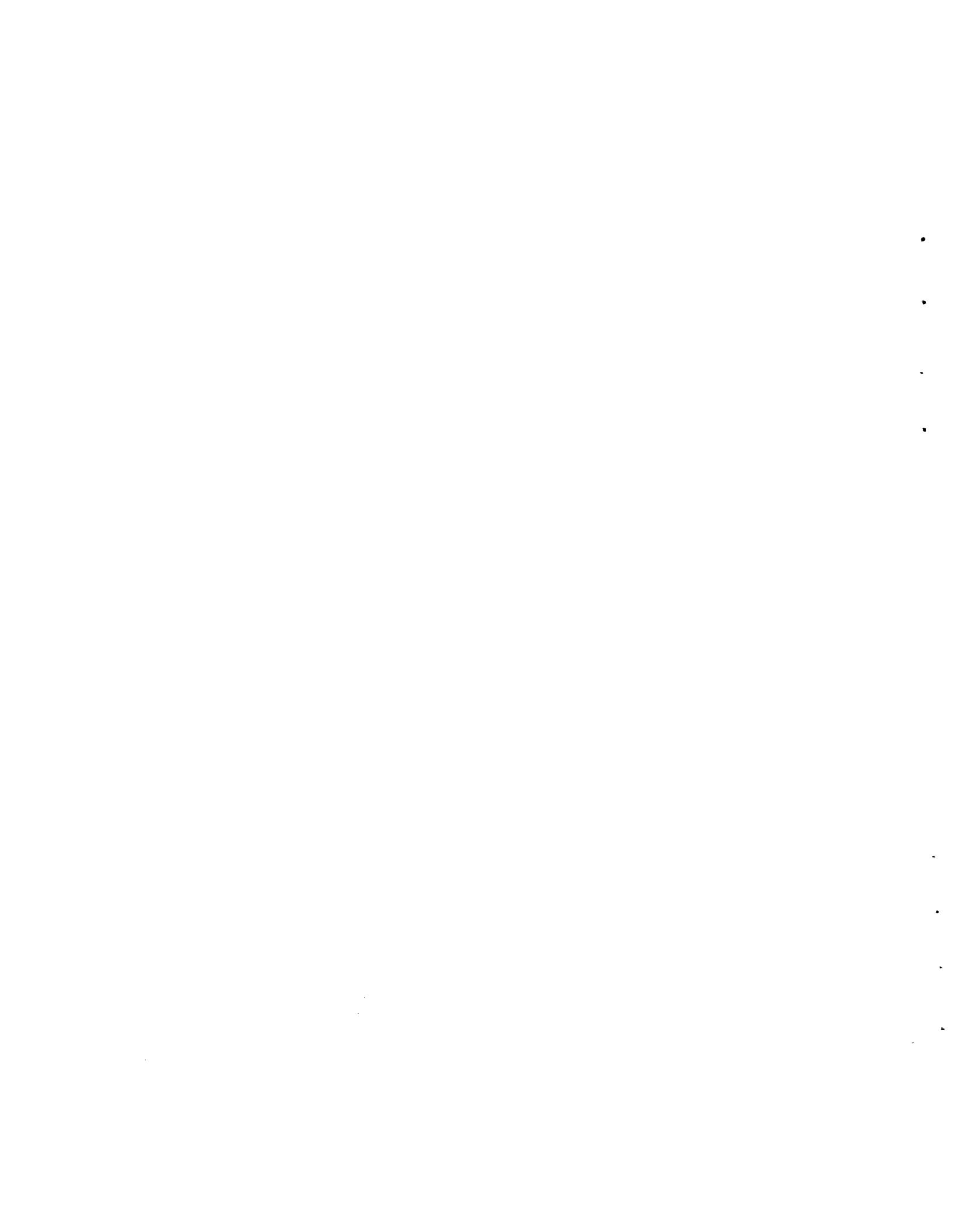
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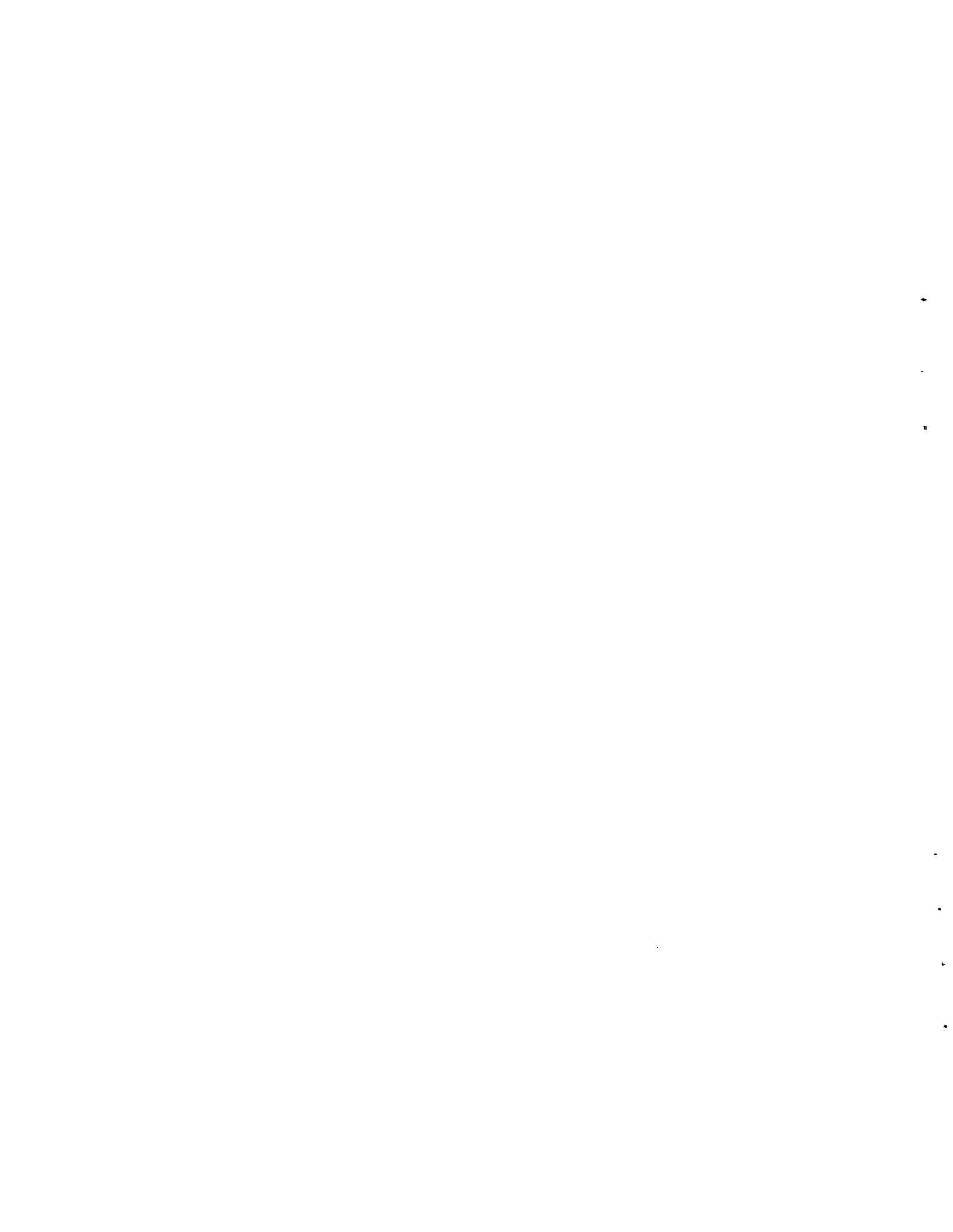
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