OU4 TRADE STUDY

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VITRIFICATION WASTE FORM STUDY

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VITRIFICATION WASTE FORM STUDY

ENGINEERING STUDY

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1.0 INTRODUCTION

1.1 Background

The July 22, 1997 "Agreement Resolving Dispute Concerning Denial of Request for Extension of Time for Certain Operable Unit 4 Milestones" specified that the Feasibility Study/Proposed Plan (FS/PP), and ROD for Silos 1 and 2 Remedial Action should be revised and resubmitted. While vitrification technology will again be evaluated as part of a Revised Feasibility Study to support a selected remedy, a basis is required for the selection of a vitrified glass form product. This study will provide a basis for the selection of a vitrified waste form product in support of the Revised Feasibility Study for Silos 1 and 2 (Document No. 40730-RP-001). The engineering study, 40730-ES-0002, "Disposal Container Size Optimization Study for Chemical Stabilization-Cement," provides a similar basis for the Revised Feasibility Study for Silos 1 and 2 for the chemical-based alternatives.

1.2 General Scope of Work

The Silos Project Engineering department will develop pre-conceptual designs for the following glass waste form alternatives: gems, cullet, monolith, and plate glass. The purpose of this work activity is to determine the most technically sound and cost effective alternative(s) for meeting defined program objectives (e.g., Remedial Action Objectives [RAOs] for Silo 1 and 2 material). The following elements are integrated into each alternative to support this activity:

- Technical basis for design;
- Safety/Environmental basis; and
- Cost estimates.

1.3 Objectives

The objective of this trade study is to evaluate alternative glass waste forms and determine the most cost effective and technically feasible technology in support of the FS/PP evaluation. The following elements are developed to support this study:

- Technical Basis

  A basis for the design will be provided for the production of each waste form alternative. This basis will integrate functional and programmatic requirements required for waste form production. The design will be developed to provide an engineering description of each glass form alternative and will include process descriptions and operating concepts;

- Safety and Environmental Basis

  The engineering design process for this work effort will integrate programmatic safety and environmental/regulatory requirements into the pre-conceptual design development. Each alternative technology will similarly reflect these requirements in its overall protection of human health and the environment; and

- Cost Estimates

  Differences in capital cost estimates will be developed for the waste form alternatives. These estimates will use a reference joule-heated vitrification facility (e.g., common melter, feed-prep, and off-gas systems) and will only detail glass handling and packaging systems (the common systems will not serve to discriminate between the alternatives). Operating costs for the waste forms will be estimated for waste packaging, transportation, and waste disposal at NTS for all alternatives (other operating costs elements such as utilities and equipment replacement are assumed to be similar for each alternative).

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1.4 Basis and Assumptions

The following quantities of material contained in the Transfer Tank Area (TTA) will be vitrified (ref. CERCLA/RCRA Units Waste Information Manual, Oct. 1995):

TABLE 1-1
QUANTITIES OF MATERIALS

Material	Volume (ft^3)	Dry Density (lbs/ft^3)	Dry Weight (tons)
Residues	216,324	90.00	9,735
BentoGrout™	23,706	18.50	220
Total	**240,030**	**NA**	**9,955**

The following will be used as basis and assumptions throughout this work effort:

TABLE 1-2
BASIS AND ASSUMPTIONS

Item	Description
1.4.1	An acceptable waste product has two program requirements for the NTS WAC: TCLP and the Performance Assessment (PA). Since the TCLP requires the waste product to pass through a 9 mm mesh size prior to testing, this implies that an acceptable waste product is independent of the waste form (e.g., gem, cullet). Also, since PA requirements remain to be defined for the K-65 material at NTS, there exists no basis to differentiate between vitrified waste forms in order to support the PA.
1.4.2	The vitrification process will produce a glass product with a waste loading of 75 weight percent (wt%) solids and density of approximately 168.8 lb/ft^3. Approximately 13,275 tons of glass will be produced by the plant, which equates to a total operating efficiency (TOE) of 70 percent over a three-year operational campaign.
1.4.3	The operating duration of the vitrification plant is three years. The rated capacity of the plant is approximately 18 tons per day (TPD). A single Joule heated melter is the assumed melter configuration (the design basis for the FS later used approximately 90 wt% waste oxide loading and a 15 TPD melter).
1.4.4	A cooling tower is assumed to be available for waste form heat removal.
1.4.5	The glass sampling frequency and quantity is similar for all glass form alternatives and does not serve to discriminate between them. Glass failure, determined within 24 hours (assumed duration for TCLP test), is assumed to represent 1 percent of the total glass produced. All failed glass is assumed to be recycled during normal plant operations. Ingrowth of radioactive decay products will be at equilibrium values during product recycle.

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TABLE 1-2 (continued)

Item	Description
1.4.6	K-65 material is classified as LSA-II solid material under Department of Transportation (DOT) regulations and as such, must be packaged in a container that meets the design performance criteria of an IP-2 container (49 CFR Part 173.410-412). A reference shipping container used in this evaluation is the SEG Endurorok ER-61.3-7A (a DOT Specification 7A Type A container). The variations of vitrified product mass inside the reference containers is assumend not to affect DOT requirements for shipment (e.g., surface exposure limits). The gross load limit of a shipping container is not to exceed 21,000 lbs based on 2 containers per shipment and a 42,000 lbs load capacity of the transfer truck. The assumed tare weight of a reference shipping container is 12,000 lbs.
1.4.7	If the reference shipping container is not efficiently utilized by packaging a waste form, then it is modified (in height only) to meet the gross load limit of 21,000 lbs. A modified shipping container will be used to appropriately reflect the disposal cost for that waste form.
1.4.8	Shipping containers containing glass product that failed TCLP will be inspected for reuse. There is no significant secondary waste generated from the reuse of shipping containers.
1.4.9	The vitrification process volatilizes constituents found in the K-65 residue (e.g., sulfates, sulfites, nitrates, nitrites). This evaluation does not consider the mass loss of these constituents and in doing so, does not take the benefit in volume reduction for disposal costs. Since this is common to all alternatives, it does not serve to discriminate between them.
1.4.10	All facilities designed to provide product cooling will be once through systems. The radon emanation rate from vitrified glass is considered minimal. However, to ensure potentially radioactive effluent discharges are minimized, HEPA filtration is used for particluates. The discharge from ventilation systems will be directed away from potential sources of contamination to prevent resuspension. All exhaust air (HVAC, pneumatic transfer) will be filtered with best available technology (BAT) prior to release into the environment.

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TABLE 1-2 (continued)

Item	Description
1.4.11	All systems will be designed and operated according to ALARA principles. The design objective will be to control radon emissions to maintain worker and public radiation exposures ALARA. The design will use total confinement of radon to avoid radon releases. In addition, penetrating radiation must be controlled to levels that maintain worker and public radiation exposures ALARA.

During vitrification of the K-65 residue, essentially all the radon is liberated from the molten glass into the melter off-gas system. The radon daughter products, which contribute approximately 90 percent of the gamma radiation dose, decay off quickly, leaving the new glass with a low radiation dose. However, the activity of radium, the parent radionuclide in the vitrified material, remains constant. As the vitrified material cools, radon daughter products begin to accumulate as the parent radionuclide decays. Eventually (approximately 40 to 60 days), a maximum activity is reached in the vitrified material that is almost the same as before the K-65 residue was vitrified. This phenomena is called ingrowth.

Additional assumptions required for the waste form alternatives are identified in the appropriate sections of this study.

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2.0 CONCLUSION AND SUMMARY

This evaluation normalized many features of design common to the alternatives considered in this study. Only those elements of design unique to a waste form (e.g., waste form handling and packaging) are detailed in this evaluation. For example, melter capacity, facility layout, shipping container handling, and waste loading remain as constant as practical, and therefore, do not discriminate between the alternatives. All elements of design remain to be optimized in the future.

2.1 Conclusion

The plate glass waste form was eliminated from consideration since it does not appear to be appropriate for low capacity glass production. Based on the results of this evaluation, the preferred order of waste form alternatives is monolith, cullet, and gems, respectively. This conclusion is based on the cumulative score of the waste form rankings of the evaluation criteria. Waste forms were ranked highest (score of 3) to lowest (score of 1) per criteria. In considering the results reported in **Table 2-1** it is important to note the following points:

- The evaluation was based, in part, on qualitative assessment methods;
- The design basis for each alternative required many assumptions for this evaluation. As the assumptions are investigated, the results of this study is subject to change;
- No weighing factors were assigned to the evaluation criteria. Weighing factors may be used to represent stakeholder values, and therefore, can vary these results as a function of stakeholder importance;
- Cost was not allowed to discriminate between the alternatives since the uncertainty of the cost estimate (assumed to be 40 percent) is greater than the differences between the alternatives.

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TABLE 2-1
CRITERIA SCORING

Criteria	Monolith	Cullet	Gems
Process Flow Sheet	2	3	1
Facility Impact	3	1	2
Operability, Complexity, Maintainability	2	3	1
Maturity of Technology	3	2	1
Schedule Impact	2	3	1
Regulatory Impact	3	3	3
Safety	3	2	1
Total Technical Scores	**18**	**17**	**10**

2.2 Summary of Evaluation Criteria

The sections below summarize the evaluation criteria considered in this study for the remaining alternatives.

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Process Flowsheet

Given a general lack of understanding in how the physical properties of the preferred K-65 glass formulation will affect glass form production, there is uncertainty in the process control features required to control the waste form process (it is assumed that the process control features required for cullet production are much simpler to produce an acceptable waste product since the waste form is produced from quenching). Additionally, there is uncertainty about the necessary process control features required to produce a vitrified waste form (the alternative, a devitrified waste form, may not be an acceptable waste product).

Based upon the information presented in **Section 4.1** the preferred order of the waste form alternatives for this criteria is cullet, monolith, and gems.

Facility Design Impacts

The largest impact on the size of a facility for a specific waste form is providing the appropriate space allocation for waste form cooling. Cullet equipment (to include the rework area) requires the largest allocation of facility space to contain its equipment. Cullet requires approximately 2,900 ft^2 of facility space. Gem cooling is performed in a 200 ft long enclosed cooling conveyor. The gem conveyor (and associated equipment) is serpentined in a room approximately 2,300 ft^2 in size. Monolith cooling and rework equipment require approximately 2,000 ft^2 of facility space.

Based upon the information presented in **Section 4.1** the preferred order of the waste form alternatives for this criteria is monolith, gems, and cullet.

Operability, Complexity, and Maintainability

All the waste forms permit continuous melter feeding, with only the monolith requiring intermittent interruptions in discharge operations to permit changing a MTC. This requires additional design features to the melter system resulting in operability and maintainability issues unique to the monolith alternative. Gems and cullet depend upon mechanical

systems to produce a waste form. Producing a gem product is inherently more complex than cullet due to the required mechanical design features, proximity of the gem making equipment to the melter, and the variances in physical properties of the molten glass. Cullet handling is automated and heat removal is considered efficient due to water cooling of the waste form. Immediate quenching/cooling of the cullet creates less operability and maintainability challenges in the facility and facilitates handling of the waste form. Monolith handling requires reusable, thermal-resistant molds to maintain the close tolerances needed to allow the MTCs to fit in the concrete shipping containers. For monolith handling, three remote pick and place operations per MTC are required (two each in the cooling room, and one each for either the loading cell or rework area). Gems and cullet utilize automated material handling systems that are inherently less complicated to operate.

All waste forms provide ALARA design features that facilitate maintenance activities. The limited amount of waste inventory present during gem and cullet production permits contact maintenance on much of these material handling systems. The larger amount of waste inventory present in the monolith option requires special maintenance design features for this alternative and limited maintenance durations (e.g., crane maintenance area, cooling room).

Based upon the information presented in **Section 4.2**, the preferred order of the waste form alternatives for this criteria is cullet, monolith, and gems.

Maturity of Technology

With the exception of M-Area at the Savannah River Site and two demonstration projects at Fernald (MAWS and VITPP), all radioactive waste vitrification facilities world-wide have produced a monolith waste form. Cullet (as well as gem) production is used routinely in the commercial glass industry, so there is a maturity of technology that must be modified to support the unique requirements of radioactive waste processing.

Based upon the information presented in **Section 4.3**, the preferred order of the waste form alternatives for this criteria is monolith, cullet, and gems.

Schedule Impacts

A qualitative assessment of the probability for each waste form to impact the overall schedule was performed in this evaluation. Two distinct phases of the project were considered: Design, where technical difficulties in the selection and erection of waste form equipment could delay completion, and operations, where equipment breakdowns could delay production. The following information is summarized from **Section 4.4**;

- Design

  The design of the cullet quench flume and tank and the dryer should be straight forward with little risk since all equipment is commercially available. Design of the monolith production systems will be difficult compared to cullet considering the handling systems for receiving and filling the MTCs, reuse of the molds, and loading the MTCs into shielded disposal boxes. The design of the cooling rack will also require some detailed heat transfer analysis to ensure proper air flow around the MTCs for controlled cooling. Design of the gem making machine and the gem cooling conveyor is expected to present the most risk of the alternatives. Many problems were encountered during operation of the gem machine in the VITPP. Some of these problems have been solved by Duratek (vendor at the VITPP and M-Area) at the M-Area melter, but differences in waste characteristics (and physical properties of the molten glass) can create problems unique to the K-65 material.

- Operations

  Operational problems are expected to be minimal for the cullet equipment (conventional equipment), with issues limited to operations and maintenance in a radioactive environment. Remote handling operations of monoliths could present problems if MTCs become out of spec due to warping under significant heat loads. Operational problems experienced with the gem alternative were plentiful with the VITPP gem machine.

Since glass characteristics are expected to vary during the treatment of K-65 residues, it is expected that operational problems would abound with the gem alternative.

Based upon the information presented in **Section 4.4**, the preferred order of the waste form alternatives for this criteria is cullet, monolith, and gems.

Regulatory Impacts

The regulatory compliance strategy for the waste forms is the same for each waste form alternative (e.g., application of best available technology is the same). As such, there are no significant discriminators between the gem, cullet, or monolith waste forms noted for this criteria.

Safety

Waste form handling and packaging is similar for gems and cullet, with a major difference that cullet provides an additional ALARA design feature (a water cooling medium). Monolith production is characterized as the alternative with the highest inventory of daughter radionuclides (bismuth-214, lead-214) per waste form, and includes a cooling room with the capacity to store 48 monoliths. Cullet and gem production utilize automated production methods; monolith utilizes a combination of automated and remote methods to control production. Gems and cullet are produced in small, discrete waste forms, where the accumulation of glass fines in production equipment (locations to be determined during plant operations) may result in the ingrowth of radon daughter products as the parent radionuclides decay (resulting in the increase of personnel exposure). Since remote operations are ALARA design features that effectively reduce personnel exposure, and considering that production of the monolith waste form is in a self-contained container, the preferred order of the waste form alternatives for this criteria is monolith, cullet, and gems.

Costs

This summary presents a cost comparison of gem, cullet, and monolith waste form production processes and their associated facility requirements. The cost figures represent

only the capital (for the waste form handling and packaging systems) and operating cost elements (packaging, transportation, and disposal) as defined in **Section 4.7** of this study. **Table 2-2** shows the cost difference in glass waste form production processes. **Section 4.7** presents the basis for these estimates.

TABLE 2-2
COST SUMMARY

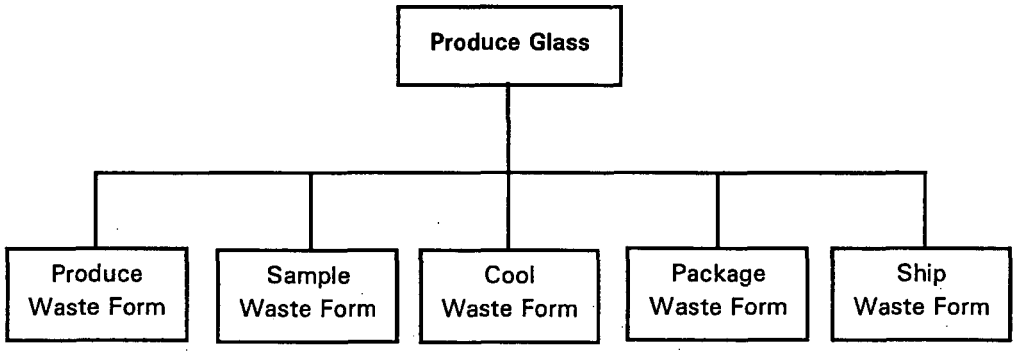
Alternative	Cost ($MM)	Uncertainty ($MM)	Δ Monolith
Gem	29.66	±11.86	6.64
Cullet	34.93	±13.97	1.37
Monolith	36.30	±14.52	0.00

Since the uncertainty of the cost estimate is assumed to be 40 percent, cost did not discriminate because the differences in the cost estimates between the alternatives are less than the uncertainties in the estimates.

3.0 GLASS WASTE FORM ALTERNATIVES

The functional requirements for the waste form process considered for this study are illustrated in **Figure 3-1**. These functions are common to all waste forms considered in this study and are detailed in the following sections.

FIGURE 3-1
WASTE FORM FUNCTIONAL REQUIREMENTS



Four waste form alternatives are considered in this study and include gems, cullet, monolith, and plate glass. A discussion detailing glass form production, cooling, sampling, packaging, recycling, and facility for each alternative is presented below.

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3.1 Gem Production

Figure A-1 illustrates a Mechanical Flow Diagram (MFD) of the gem making process and handling system. The gem production method selected for this study represents one of the available gem production methods and includes discharging molten glass from the melter onto a water-cooled, fluted and rotating cylinder to create gobs of molten glass. As the cylinder rotates, gobs of molten glass fall onto a cooling conveyor for heat removal. This method has been demonstrated at the Fernald Vitrification Pilot Plant (VITPP) and proven to be effective at the Savannah River Site's M-Area on a 5 TPD melter.

In addition to the assumptions of **Section 1.4** and **Section 3.0**, the following are applicable to this alternative:

- The void volume for packaging gems is 30 percent. The void volume is defined as the volume inside a shipping container that is not occupied by the waste form (i.e., unused space);
- All gem calculations are based upon a 1.2 inch diameter with a mass of 0.03 lbs (13.6 grams);
- Heat removal (2,200 to 150 °F) of a gem waste form is assumed to occur in less than 10 minutes based on calculations/observations (VITPP operations) at ambient conditions;
- Gem waste forms do not require annealing.

Glass Forming

Eight molten glass streams are poured from the melter onto four gem making machines (two streams per gem machine) for a total of 8 gem streams at plant capacity. Approximately 14 gems per second are required to be produced at plant capacity (105 gems/min per stream).

Melter confinement is ensured by negative pressure maintained by the melter off-gas system. A gem machine is composed of two water-cooled, counter-rotating cylinders. The

gob cutter (made of stainless steel) features machined flutes that fill with molten glass poured from the melter as it rotates. The crest of each flute rotates against the gob roller, a smooth cylinder made of graphite, and creates a "pinch point" that cuts the stream of molten glass and produces a discrete waste form called a gob. As the gob cutter rotates, molten gobs fall from the cutter onto a conveyor and flatten. Due to the surface tension of the viscous glass, however, the gob quickly "pulls" itself together to form a gem. Gem size is not a critical parameter and may vary during production.

All gem production equipment is assumed to be in close proximity of the melter and all components require constant monitoring and operator access. All gem forming components are enclosed to contain radon and minimize air in leakage into the melter system. Scheduled maintenance activities include (but are not limited to) melter discharge orifice cleaning, gob cutter/roller cleaning, alignment and replacement, seal/gasket replacement, cooling plate/ conveyor cleaning. Also included in the scheduled maintenance activities are those activities to maintain the gem forming support systems (e.g., cooling water system, closed loop ventilation system). The melter generally runs on a continuous basis during production operations and can be idled for both scheduled and unscheduled maintenance activities.

Gem Cooling

As the molten glass exits the melter discharge chamber, radiant heat transfer quickly reduces the skin temperature of the glass several hundred degree prior to landing on the plate-cooled conveyor. The primary mode of heat transfer is radiation, however, gems also cool from convection (HVAC) and conduction (metallic belt/cooling plate). Experience (M-Area, Savannah River Site) suggests a gem will cool from 2,200 to 750 °F within 2 minutes of exiting the melter under normal ambient conditions. Gems falling onto the plate-cooled conveyor are kept separate until their surface temperature have cooled sufficiently so as not to stick to adjacent gems (approximately 750 °F). Cooling plates located underneath the gems are rated to remove approximately 122,000 Btu/hr. After approximately 40 ft of travel, cooled gems are transferred to a perforated cooling conveyor where approximately 900 cfm of forced air convectively cools them. Gems must be cooled an additional 7.5

minutes for their centerline temperature to reach 150 °F. Given a conveyor speed of approximately 0.35 ft/sec (based on 1.2 inch diameter gems spaced on 2.4 inch centers), the total conveyor length is 200 ft long (includes plate-cooled conveyor). Conveyor speed and the gem cooling air can both be independently controlled to provide operational flexibility.

The gem cooling/ventilation system must be designed so that all gems see inlet temperature air as they travel along the entire length of the conveyor (this feature has significant impact on the ventilation distribution and control systems). Gem cooling requires an enclosure to direct airflow, minimize air in leakage to the melter system, and to minimize worker exposure (**Section 1.4**). The cooling system is a once-through system that utilizes outside air and rejects heat to ambient (via HEPA filtration). At production capacity, the gem cooling system is sized to remove approximately 900,000 Btu/hr.

During normally scheduled maintenance activities, the melter is idled and all gems are removed from the conveyor system and collected in a hopper system. All motor drives , controllers, and dampers are mounted external to the conveyor enclosure allowing easy access for operational/ maintenance activities. In addition, operators have access to critical conveyor/gem cooling components with little-to-no material holdup in the gem cooling areas. However, during postulated non-scheduled maintenance activities (e.g., failure of critical conveyor/gem cooling component such as a cooling plate circulating pump), approximately 240 lbs of gems (based on production of 14 gems per second and a 9.5 minute cooling time) may be holdup in the conveyor system. The hopper system consists of two hopper bins in series. The fill hopper is sized to batch load a shipping container (see discussion below). An accumulation hopper, physically located above the fill hopper, is conservatively sized for overflow conditions and can easily hold gems in the conveyor system after the melter is idled. Due to the uncertainty in predicting unscheduled failure mechanisms, redundant critical components are required to ensure operational availability, mitigate material holdup issues, and to facilitate maintenance activities.

Product/Glass Sampling

Waste sampling for this alternative is simplified due to the discrete nature of the gem waste form. As gems are conveyed/cooled, representative waste samples can easily be taken at various points within the glass form production process. Since the residence time to produce a cooled gem is on the order of 10 minutes, and considering there is no accumulation of materials during gem production, worker safety/exposure issues are minimized during the gem sampling process (conveyor enclosure is steel construction and reduces radiation to worker). **Figure A-1** illustrates a sample point for gem production prior to transferring gems from the perforated to the vertical conveyor. A simple diverter is used to redirect gems from the perforated conveyor into a sample collection jar. This sample collection process is performed manually and requires little to no instrumentation. Shipping Container Loading

Cooled gems are transferred from the perforated cooling conveyor into an elevated fill hopper using a vertical conveyor. The fill hopper accumulates cooled gems and is appropriately sized to gravity batch load a modified gem shipping container (approximately 70 ft^3 in capacity). The fill hopper is volume controlled and interlocked to an accumulation hopper. During unloading of the fill hopper, the accumulation hopper, mounted to the top of the fill hopper, accumulates gems to permit continuous plant production. The accumulation hopper is volume controlled and interlocked to gem production (e.g., melter discharge, conveyor system).

To fill a modified gem shipping container, a forklift places a container on a transfer conveyor located in an airlock. The conveyor transfers the shipping container through an inspection/decon vestibule and into a loading cell. A specially designed lid removal unit remotely removes the lid bolts and grappling fixtures permit the device to lift the lid from the container. The conveyor then positions the container in the appropriate filling position where a hydraulic lifting device (built into the conveyor) raises the container and seals it to a filling station. The filling station is a specially designed HEPA vented hood arrangement that routes gems discharged from the fill hopper into the shipping container. Once the container is in place, the fill hopper is actuated and the shipping container is gravity filled

with gems. Once full (and after a predetermined venting time to remove/settle suspended particulates), the hydraulic lift lowers the shipping container onto the conveyor and it is transferred to the lidding station for lid installation. The lidded container is transferred into the inspection/decon vestibule for survey and decon (as necessary) by an operator. Once satisfying the inspection criteria, the container is transferred from the vestibule to the airlock where a forklift removes it from the production facility. **Figure A-2** illustrates shipping container handling for this alternative.

Shipping containers are staged outside the facility until product sampling (TCLP) confirms waste product performance meets waste acceptance criteria (WAC) for the disposal site. Once sampling verifies product quality, shipping containers are moved to an interim storage facility for staging and product turnover (for ultimate disposal by FDF). If the product fails sampling, the container is transferred to the facility for reprocessing. To optimize a shipping container for the gem waste form, the total gross weight limit 21,000 lbs per shipping container is used (assumption 1.4.11). **Table 3-1** provides details for the modified gem shipping container.

TABLE 3-1
MODIFIED GEM SHIPPING CONTAINER

Dimension, Exterior WxLxH (in)	Dimension, Interior WxLxH (in)	Tare Weight[1] (lbs)	Glass Weight[2] (lbs)	Container Volume (cft)	Total # of Containers[3]
54x72x63.7	42x60x47.7	12,826	8,174	143.3	3,248

Notes:
[1] Weight of empty modified container;
[2] Weight of gems packaged inside container;
[3] Number of shipping containers required to package all Silo 1 and 2 waste as gems.

All calculations are documented in Calc file: 40730-CA-004.

It takes approximately 5.5 hours to load the fill hopper for batch filling a modified gem shipping container when the plant is operating at capacity. Gem shipping containers are

filled at a rate of 4.4 per day at plant capacity. Approximately 3,248 modified gem containers are required over the life of the plant.

Gem Recycle

Recycle of out-of-spec (TCLP) gems functionally consists of removal of gems from container and gem transfer to a product recycle bin located in the vicinity of the melter. The gem waste form is well suited for product recycle since it is produced in a small, discrete form, and can easily be removed from a shipping container for recycle. **Figure A-3** provides an illustration of gem recycle.

Packaged shipping containers passing radiological inspection are removed from the facility and staged outside (shielded staging enclosure) until product sampling (TCLP) confirms waste product acceptance. The staging enclosure is sized for one day of production throughput (5 shipping containers). Shipping containers containing gems that fail TCLP are brought back into the production facility in a similar manner as empty shipping containers. Failed glass containers are placed on the conveyor in the airlock and are transferred into the inspection/decon vestibule where the lid removal unit remotely removes the lid bolts and grappling fixtures lift the lid from the container. The conveyor is transferred into a rework room where a bridge crane is used to vacuum transfer the contents of the container. A gulper tool (concentric vacuum pipes used to fluidize the gems) is used to remove gems from the shipping container. The gems are pneumatically transferred to a filter/receiver located above the melter where they are control fed (a rotary airlock is used to control-gravity feed gems) directly into the melter. Exhaust air from the gem recycle transfer is HEPA filtered prior to release from the plant stack.

The empty shipping container is inspected and verified as acceptable for reuse (CCTV and/or operator are used to inspect). When the next batch of gems is ready for packaging, the shipping container is conveyed into the filling position in the load area where the hydraulic lifting device raises the container and seals it to the filling station (refer to shipping container loading discussion above). After filling and venting, the shipping container is transferred into inspection/decon vestibule where it is remotely lidded and

inspected for contamination. Gem recycle is integrated and coordinated with operations such that there is little-to-no impact to plant operations/capacity.

Gem Facility

The gem facility layout is illustrated in **Figures A-4** through **A-6**. The configuration of the conveyor is arranged to permit a conventional facility design. An approximate area of 2,300 ft^2 is required for the waste form production areas.

3.2 Cullet Production

Figure A-7 shows a MFD of the water quenched cullet formation and handling system. The cullet production method selected for this study represents one of the commercially available cullet production methods. Other methods of cullet production include air cooling and/or mechanical systems to produce the desired cullet form. However, due to radiological/contamination control issues, the water quenched method was selected for this study.

In addition to the assumptions of **Section 1.4**, the following are applicable to this alternative:

- Interstitial void volume for packaging cullet is 45 percent based on FDF measurement;
- Cullet will reject its heat to the quench water system and cool from 2,200 to 125 °F in approximately 5 minutes;
- Quench water is assumed to reduce worker exposure (due to the ingrowth of radon daughter products) associated with the accumulation of cullet fines in the quench tank. This, along with engineering/administrative controls, is assumed to provide ALARA design features for producing the cullet waste form.

Glass Forming

Molten glass is fed from the melter to a downward sloping quench flume. The quench flume is a V-shaped metal trough supplied with quench water and is enclosed to capture off-gases/steam vapor and to minimize melter in leakage. The quench flume off-gas is tied

to the cullet off-gas system and is maintained at a negative pressure with respect to the facility. Quench water flow rate and temperature are parameters that may be used to control cullet production (varying either of these will affect cullet size). Cullet size is not a critical parameter and may vary during actual production.

Cullet production requires molten glass to be poured from the melter at approximately 0.42 lbs per second based upon melter capacity. Quenching equipment (primarily a passive system) is assumed not to be in close proximity of the melter, with all quench parameters requiring monitoring (e.g., quench water temperature, flow, off gas pressure). The quench flume, enclosed to contain the off gases/steam vapors generated during the quench process, minimizes air in leakage to the melter system by maintaining a more negative pressure than the melter off gas system. Scheduled maintenance is required on support systems (e.g., quench water and off-gas systems), however, maintenance is considered minimal for the quench flume itself since there are only a few serviceable components on this system (e.g., circulating water pump). The melter generally runs on a continuous basis during production operations and can be idled for both scheduled and unscheduled maintenance activities.

Glass fines generated throughout the cullet forming, cooling, and handling process require collection, transfer, and handling. A hydrocyclone unit is used in the quench water circulation system to physically separate the fines from the quench water, where the fines are transferred to the melter feed preparation system for reprocessing. In addition, in-line filtering (not shown on MFD) may be used to further reduce/control fine generation/accumulation in the quench water system. If fines accumulate at the bottom of the quench tank, the melter can be idled, the quench system drained, and the fines can be flushed, collected, and transferred to the melter feed preparation system (i.e., upstream of the thickener tank).

Glass Cooling

As molten glass comes into direct contact with quench water it generates steam vapor and rapidly loses heat, solidifies, and fragments into jagged pieces of glass called cullet. Cullet

and water exit the quench flume and enter a quench tank where further cooling and hardening of the glass occurs. A belt conveyor (metallic mesh) is used to transport cullet through the quench tank. The cullet has a residence time of approximately 5 minutes in the quench tank where it cools from 2,200 to 125 °F and rejects its heat to the quench water system. The quench water system is sized to remove 1,027,000 Btu/hr. The process plant's cooling tower is used for ultimate heat removal.

Cullet exiting the quench tank is dewatered in the cullet dryer by preheated air circulated by the quench off-gas system. Air temperature in the cullet dryer is raised to approximately 150 °F from a preheater (rated at 42,900 Btu/hr) and evaporates approximately 2 percent moisture (based on FDF measurement of wetting cullet). The cullet dryer system collects off-gas from the quench flume, quench tank, and cullet dryer, condenses moisture (0.27 gpm) and removes heat (176,200 Btu/hr) from the circulated air (675 scfm). In addition, a slip stream can be directed to the HVAC system for exhausting. The plant cooling tower system is used for ultimate heat rejection.

Operator access to the quench flume/tank is not a critical feature as there are minimal maintainable components. Maintainable items (e.g., motor drives, pumps) are located external to the quench flume/tank and are located within the facility to facilitate operator access. The quench flume/tank is an enclosed system and confines off gas/contamination, reduces worker exposure (steel construction), maintains negative pressure (quench off gas system) with respect to the facility and minimizes air in leakage to the melter system. Scheduled maintenance activities for this system are minimal and are not expected to impact cullet production. During normally scheduled maintenance activities, the melter can be idled and cullet collected in a hopper system. However, during non-scheduled maintenance activities (e.g., failure of critical quench tank component due to erosion), approximately 125 lbs of cullet are holdup in the conveyor system (does not include fine accumulation in system). The hopper system consists of two hopper bins in series. The fill hopper is sized to batch load a shipping container (see discussion below). An accumulation hopper, physically located above the fill hopper, is conservatively sized for overflow conditions and can easily hold the cullet in the quench tank system after the melter is idled.

Due to easy operator access on critical quench tank components and the ability to locate equipment away from radiation sources, no additional design features (i.e., redundancy) are required.

Product/Glass Sampling

Waste sampling for this alternative is simplified due to the discrete nature of the cullet waste form. As cullet is conveyed/cooled, representative waste samples can easily be taken at various points within the glass form production process. Since the residence time to produce cullet is on the order of minutes, and considering there is no accumulation of materials during cullet production, worker safety/exposure issues are minimized during the sampling process (all equipment is steel construction and reduces radiation to worker). **Figure A-7** illustrates a sample point for cullet production prior to cullet transferring from the perforated to the vertical conveyor. A simple diverter is used to redirect cullet from the cullet dryer into a sample collection jar. This sample collection process is performed manually and requires little to no instrumentation.

Shipping Container Loading

Cullet is fed from the cullet dryer into a fill hopper using a vertical conveyor. The fill hopper accumulates cullet from the melter and is appropriately sized to gravity batch load a modified cullet shipping container (approximately 80 ft^3 in capacity). The fill hopper is volume controlled and interlocked to an accumulation hopper. During unloading, the accumulation hopper, mounted to the top of the fill hopper, accumulates cullet and permits continuous cullet production and melter operation. The accumulation hopper is volume controlled and interlocked to cullet and melter production.

To fill a modified cullet shipping container, a forklift places a container on a transfer conveyor located in an airlock. The conveyor transfers the shipping container through an inspection/decon vestibule and into a loading cell. A specially designed lid removal unit remotely removes the lid bolts and grappling fixtures permit the device to lift the lid from the container. The conveyor then positions the container in the appropriate filling position

where a hydraulic lifting device (built into the conveyor) raises the container and seals it to a filling station. The filling station is a specially designed HEPA vented hood arrangement that routes cullet discharged from the fill hopper into the shipping container. Once the container is in place, the fill hopper is actuated and the shipping container is gravity filled with cullet. Once full (and after a predetermined venting time to remove/settle suspended particulates), the hydraulic lift lowers the shipping container onto the conveyor and it is transferred to the lid removal unit for lid installation. The lidded container is transferred into the inspection/decon vestibule for survey and decon (as necessary) by an operator. Once satisfying the inspection criteria, the container is transferred from the vestibule to the airlock where a forklift removes it from the production facility. **Figure A-2** illustrates shipping container handling for this alternative.

Shipping containers are staged outside the facility until product sampling (TCLP) confirms waste product performance meets waste acceptance criteria (WAC) for the disposal site. Once sampling verifies product quality, shipping containers are moved to an interim storage facility for staging and product turnover (for ultimate disposal by FDF). If the product fails sampling, the container is transferred to the facility for reprocessing.

To optimize a shipping container for the cullet waste form, the total gross weight limit 21,000 lbs per shipping container is used (assumption 1.4.11). **Table 3-2** provides details for the modified cullet shipping container.

TABLE 3-2
MODIFIED CULLET SHIPPING CONTAINER

Dimension, Exterior WxLxH (in)	Dimension, Interior WxLxH (in)	Tare Weight[1] (lbs)	Glass Weight[2] (lbs)	Container Volume (cft)	Total # of Containers[3]
54x72x70.1	42x60x54.1	13,666	7,325	157.7	3,625

Notes:
[1] Weight of empty modified container;
[2] Weight of cullet packaged inside container;

[3] Number of shipping containers required to package all Silo 1 and 2 waste as cullet.

All calculations are documented in Calc file: 40730-CA-004.

It takes approximately 5.2 hours to load the fill hopper for batch filling a modified cullet shipping container when the plant is operating at capacity. Cullet shipping containers are filled at a rate of 4.67 per day at plant capacity. Approximately 3,625 modified cullet containers are required over the life of the plant.

Cullet Recycle

Recycle of out-of-spec (TCLP) cullet functionally consists of removal of cullet from container and cullet transfer to a product recycle bin located in the vicinity of the melter. The cullet waste form is well suited for product recycle since it is produced in a small, discrete form, and can easily be removed from a shipping container for recycle. **Figure A-3** provides an illustration of cullet recycle.

Packaged shipping containers passing radiological inspection are removed from the facility and staged outside (shielded staging enclosure) until product sampling (TCLP) confirms waste product acceptance. The pad is sized to stage one day production throughput (5 shipping containers). Shipping containers containing cullet that failed TCLP are brought back into the production facility in a similar manner as empty shipping containers. Failed glass containers are placed on the conveyor in the airlock and are transferred into the inspection/decon vestibule where the lidding station remotely removes the lid bolts and grappling fixtures lift the lid from the container. The conveyor is transferred into a rework room where a bridge crane is used to vacuum transfer the contents of the container. A gulper tool (concentric vacuum pipes used to fluidize the cullet) is used to remove cullet from the shipping container. The cullet is pneumatically transferred to a filter/receiver located above the melter where it is control fed (a rotary airlock is used to control-gravity feed cullet) directly into the melter. Exhaust air from cullet recycle transfer is HEPA filtered prior to release from the plant stack.

The empty shipping container is inspected and verified as acceptable reuse (CCTV and/or operator are used to inspect). When the next batch of cullet is ready for packaging, the shipping container is conveyed into the filling position in the load area where the hydraulic lifting device raises the container and seals it to the filling station (refer to shipping container loading discussion above). After filling and venting, the shipping container is transferred into inspection/decon vestibule where it is remotely lidded and inspected for contamination. Cullet recycle is integrated and coordinated with operations such that there is little-to-no impact to plant operations/capacity.

Cullet Facility

The cullet facility layout is illustrated in **Figures A-8** through **A-10**. The layout appears to utilize allotted space efficiently for operations, maintenance, and product recycle. An approximate area of 2,900 ft^2 is required for the waste form production areas.

3.3 Monolithic Glass Production

Figure A-11 shows a MFD of the monolith making process and handling system. In addition to the assumptions of **Section 1.4**, the following are applicable to this alternative:

- A monolith transfer container (MTC) is steel constructed of 1/4 inch thick carbon plate, is rectangular in shape (approximately 20" x 40" x 40", WxLxH), and can be managed by overhead lifting devices when it is at room temperature. A reusable, breakaway metal basket (i.e., mold) is used to provide structural stability for the MTC during glass pouring operations. The basket is designed to be lifted and to facilitate monolith cooling. 3 MTCs/monoliths are packaged into a shipping container;
- The void volume for monolith packaging in a modified shipping container is 24 percent based on glass volume calculations;
- Cooling time of monolith from 2,200 to 150 °F is assumed to be 70 hours (based upon West Valley monoliths and preliminary calculations);

- Molten glass is poured into a MTC and is expected to efficiently fill the volume of the MTC (based on monolithic pours into large containers at the VITPP). MTCs are assumed to be filled at 90 percent volume capacity with glass;
- Devitrification of the glass waste form is assumed to be controlled during the pouring/cooling of the monolith (remains to be demonstrated during system/ plant startup testing);
- Conditioned air required for cooling monoliths is provided by cascading air from the melter room (required from maintaining environmental conditions) into the monolith cooling room. This feature results from HVAC design optimization developed for the joule-heated vitrification alternative documented in the *Basis for Design* in support of the Silos 1 and 2 Feasibility Study, Document No. 40430-PR-0001.

Glass Forming

Molten glass is fed from the melter through a melter pour spout. Melter confinement is maintained using a vented bellows configuration that seals to the MTC. MTCs (fit into a metal basket) are delivered to the melter by the MTC conveyor. A hydraulic lift station, located in-line with the conveyor and under the melter feed spout, raises the MTC to the bellows such that the melter pour spout is inserted into the opening provided on the MTC. A negative pressure is maintained within the MTC/bellows by the melter off-gas system. During glass pouring, the elevated temperature of the steel may cause deformation of the MTC. However, the metal basket provides additional structural support for the MTC and permits it to retain its original geometry.

Monolithic glass is formed by pouring molten glass directly into a MTC. This allows the melter to be operated (e.g., feeding the melter) in a continuous mode but requires melter designers to provide control for melter pouring capability. Based upon experience at the Fernald VITPP, the molten glass is expected to efficiently occupy the MTC volume. The mass of a monolith is 3,016 lbs (this includes the mass of a MTC). Based upon melter capacity, it is assumed a MTC is filled every 1.7 hours.

All monolith production equipment is assumed to be in close proximity of the melter and require constant monitoring and operator access. Since monolith production is a closed system (e.g., the bellow seal), air in leakage to the melter is readily minimized. Scheduled maintenance activities include (but are not limited) component cleaning, alignment, seal/gasket replacement (heat degradation), as well as those activities to maintain the support systems. The melter generally runs on a continuous basis during production operations and can be idled for both scheduled and unscheduled maintenance activities.

Glass Cooling

During glass pouring, heat is lost from the molten glass to the local environment by radiant and convective heat transfer. Once a MTC is filled, it is removed from the melter by the MTC transfer conveyor, capped, and transferred to an adjacent cooling room through an airlock. Inside the cooling room, a 3-ton bridge crane receives a basket/MTC from the conveyor and appropriately positions it in a 4x12 storage rack array designed for controlled cooling. The storage rack is constructed of steel and allows a monolith to be stored approximately 3 ft above the floor.

Personnel access into the cooling room requires passage through a vestibule. The cooling room design includes a shield door for maintenance access, heat shielding, CCTV for remote operations, HVAC ductwork, a crane maintenance area, and a storage rack system sized for 48 cooling positions. The heat shield protects the interior concrete walls from excessive temperatures (from radiant heat transfer of the monoliths) and is designed to cool passively by natural convection. The heat shielding is constructed of steel plate, insulation, and mounted on steel channel (affixed to the concrete wall) to increase its overall heat capacitance and facilitate natural convection cooling.

Monolith cooling requires a significant volume of air (16,000 cfm) to be circulated through the cooling room and is designed with a heat removal capacity of approximately 900,000 Btu/hr. The cooling air is provided by a zoned HVAC system (air handler unit) that cascades conditioned air from the melter room into the monolith cooling room. Inside the monolith cooling room, cool air is directed over the monoliths using a zoned flow control concept

(zone flow/temperature monitoring). The melter room/monolith cooling room HVAC system is a zoned-once-through system that enters into the melter room and exits the monolith cooling room. The heated air is passed through a HEPA filtration system prior to exhaust through the facility HVAC stack. This type of zoned-once-through system is selected since it is less expensive than a recirculated system, and it is expected that this system can use ambient air without cooling it during the winter months.

In general, normally scheduled maintenance activities for monolith cooling equipment is not expected to impact melter production. Operators have easy access to HVAC equipment located in the HVAC room. Non-scheduled maintenance activities of critical components (e.g., failure of bridge crane) can be mitigated by design features (crane retrieval system) and are expected to be minimum for this waste form alternative. A crane maintenance area located above the monolith cooling room is included in the design. The MTC transfer conveyor (melter to cooling room) is motor driven/speed controlled with all critical equipment located in accessible locations. The cooling room is shielded and enclosed according to ALARA principles. Access to the crane maintenance area is provided by stairs located on a clean side of the process building. An airlock permits controlled entry to this area. The airlock includes an equipment door for failed equipment items.

Product/Glass Sampling

Waste sampling for monolith production is complicated since the final product (cooled monolith) does not facilitate simplistic sampling methods as discussed for the previous alternatives. In order to simplify sampling glass for this waste form, a sample must be collected at a point where the glass is mobile, or molten. Therefore, sampling is performed remotely under the melter discharge chamber. The monolith sample must be representative of the monolith waste form (e.g., cooling profile) in order to demonstrate waste product acceptance.

Shipping Container Loading

To fill a modified monolith shipping container, a forklift places a container on a transfer conveyor located in an airlock. The conveyor transfers the shipping container through an inspection/decon vestibule and into a loading cell. A specially designed lid removal unit remotely removes the lid bolts and grappling fixtures permit the device to lift the lid from the container. The conveyor then positions the container in the appropriate filling position. As a monolith is cooled (and has passed TCLP), the 3-ton bridge crane lifts and places the basket/monolith on a motorized conveyor in the cooling room for transfer into the loading cell. An airlock with motorized doors provides controlled entry of the monolith into the loading cell. Once the monolith passes the airlock, the breakaway metal basket is removed from the monolith and the 3-ton hoist lifts, transfers, and loads the monolith into the shipping container (the baskets are inspected and reused in the waste forming process). Once the shipping container is full (3 monoliths), it is conveyed to the lid removal unit for lid installation. The lidded container is transferred into the inspection/ decon vestibule for survey and decon (as necessary) by an operator. Once satisfying the inspection criteria, the container is transferred from the vestibule to the airlock where a forklift removes it from the production facility. **Figure A-11** illustrates the shipping container handling for this alternative.

To optimize a shipping container for the monolith waste alternative, the total gross weight limit 21,000 lbs per shipping container is used. A modified shipping container can package 3 monoliths. **Table 3-3** provides details for the modified monolith shipping container.

TABLE 3-3
MODIFIED MONOLITH SHIPPING CONTAINER

Dimension, Exterior WxLxH (in)	Dimension, Interior WxLxH (in)	Tare Weight[1] (lbs)	Glass Weight[2] (lbs)	Container Volume (cft)	Total # of Containers[3]
54x72x54.5	42x60x41.2	11,890	7,728	122.6	3,436

Notes,

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[1] Weight of empty modified container;
[2] Weight of monolithic glass packaged inside container (does not include weight of MTC);
[3] Number of shipping containers required to package all Silo 1 and 2 waste as monolith.

All calculations are documented in Calc file: 40730-CA-004.

Since it takes approximately 1.7 hours to fill a MTC, approximately 4.7 modified monolith shipping containers per day are filled (at design capacity) per day. In order to package all vitrified waste product, approximately 3,436 modified monolith shipping containers are required over the life of the plant.

Monolith Recycle

Recycle of out-of-spec (TCLP) glass (monolith) functionally consists of removal of monolith glass from container, size reduction, and product (frit) transfer. The monolith waste form complicates product recycle since the waste form is a large and solid piece of vitrified glass and cannot easily be removed from a MTC. Additionally, out-of-spec monolith must be size reduced in stages in order to generate frit required for recycle. **Figure A-12** provides an overview of the monolith recycle facilities.

If a monolith has been determined to fail TCLP, it is permitted to cool in the cooling room. At the end of its cooling period, the cooling room bridge crane lifts the failed monolith, removes its breakaway metal basket, and places it on a gravity rework conveyor that transfers it into a rework area. Monolith recycle is performed remotely in dedicated facilities due to the ingrowth of the radon daughter products and its associated equilibrium activity (**Section 1.4**). A rework bridge crane picks up the failed monolith from the rework conveyor and places it in a grated impact container. A commercially available robot is used to remove the MTC (steel casing) from the monolith, and to downsize the monolith into smaller pieces of glass. Once the glass is downsized, the robot deploys a vacuum attachment to transfer glass to a filter-receiver. From there, the broken glass is gravity transferred into a hammermill where a frit (small particle glass) is produced and then pneumatically transferred to a frit bin (located above the melter) for product recycle. Scrap metal removed by the robot is transferred into a metal container and disposed of as secondary waste.

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Monolith Facility

The monolith facility layout is illustrated in **Figures A-13** through **A-15**. The layout appears to utilize allotted space efficiently for operations, maintenance, and product recycle. An approximate area of 2,000 ft^2 is required for the waste form production areas.

3.4 Plate Glass Production

Figure A-16 shows a MFD of plate glass making process and handling system. Three types of flat glass processes are available from the commercial glass industry: rolled glass, flat drawn sheet, and the float process. Each process has thorough demonstration in glass making; the float process being the most common to the commercial industry. For the purposes of this evaluation, the rolled glass concept is applied for the plate glass alternative for the following reasons:

- The rolled glass process of drawing molten glass from the melter is less complex than the flat drawn sheet process (e.g., relies upon gravity and simplistic mechanical systems rather than complex mechanical systems);
- The rolled glass method provides adequate melter confinement features by maintaining the molten glass level above the rollers;
- The float process is desirable where an optically flat, smooth finish glass plate is required. This process requires a confined, non-oxidizing environment for the molten tin bath (in addition to the plate glass forming equipment), where the molten tin bath will create additional challenges for the glass product off gas system.

In addition to the assumptions of **Section 1.4** and **Section 3.0**, the following are applicable to this alternative:

- Interstitial void volume for packaging plate glass is 10 percent;
- Plate glass thickness is nominally 10 mm to ensure appropriate glass handling quality (empirical data from commercial glass industry).

Glass Forming

Molten glass is fed from a melter through a set of water cooled glass rollers in a process referred to as continuous horizontal rolling (produces glass ribbon). Melter confinement is maintained by maintaining a height of the molten glass above a refractory tweel (gate) within the melter discharge chamber. Controlling the height of the refractory twill regulates glass flow from the melter and creates a bolster (small accumulation of molten glass) behind the water cooled glass rollers. The rollers draw the molten glass from the melter and control the glass ribbon thickness and width. A common ribbon thickness that ensures plate glass handling quality is 0.39 inch (10 mm). Glass production can be varied by adjusting the roller distance.

Plate glass production requires molten glass to be drawn into glass ribbon at a design capacity of approximately 0.42 lbs per second (based upon 18 TPD melter capacity). Assuming a ribbon thickness of 10 mm, plate glass is produced at a rate of 0.08 ft^2/s. Table 3-4 provides critical plate glass production parameters as a function of melter capacity and 10 mm ribbon thickness. Among the information presented in this table is the time it takes any point within the glass ribbon to travel through a 100 ft annealing lehr (furnace).

TABLE 3-4
PLATE GLASS PRODUCTION DATA (18 TPD)

Ribbon Width (inch)	Conveyor Speed (ft/sec) $x10^{-2}$	Time through lehr (hour)
24	3.76	0.74
36	2.51	1.11
44[1]	2.05	1.35
48	1.88	1.48

Where;

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[1] assumed ideal plate glass width (prior to trimming) for packaging into modified plate glass shipping container.

From the information presented above, it is clear to note that plate glass production is not ideally suited for low capacity production (commercially, plate glass production is on the order of hundreds of TPD melter capacity). As an example, the conveyor speed for a 44 inch wide ribbon is 0.0205 ft/sec (0.24 inch/sec), which is not easily achieved (high torque, precision low speed conveyor application). Based on these parameters, plate glass production is not considered a viable waste form alternative for this evaluation (a facility layout is not provided for this waste form). However, this alternative is detailed and selectively evaluated (**Section 4**) for the possibility of future waste form investigation.

All rolling equipment (e.g., water cooled horizontal rollers) are assumed to be in close proximity of the melter and all components require constant monitoring and operator access. All equipment (e.g., conveyors and glass production equipment) is enclosed to contain radon, to minimize air in leakage to the melter system, and for worker safety. Scheduled maintenance activities include (but are not limited) roller cleaning, roller replacement, roller alignment, and seal/gasket replacement (heat degradation). Scheduled and unscheduled maintenance activities will result in idling the melter.

Glass Cooling

Once formed, glass ribbon is conveyed down a system of tray rolls and enters a roller lehr (annealing lehr) for annealing and controlled cooling. Strain developed in the glass from the rapid cooling during the rolling process must be relieved prior to safe handling. The lehr removes this stress by elevating the glass temperature above its stress relief temperature and then gradually cooling it through its characteristic annealing regions. The lehr is designed to provide the appropriate time and temperature requirements according to the glass annealing regions. The cooling process in the lehr is carefully controlled for all sides of the glass ribbon to ensure glass quality. For 10 mm thick glass plate, roller lehrs are approximately 100 ft (30 m) in length and approximately 4 to 6.5 ft in width, depending on production throughput (empirical data from commercial glass industry). The annealing lehr is an enclosed system (tunnel shaped) with insulated heated and controlled cooling

sections, and transfers glass ribbon with speed controlled rollers and a metallic fabric conveyor belt. Glass exits the lehr typically at ambient temperature and moves on a conveyor system for further form processing.

Product/Glass Sampling

Waste sampling for plate glass production is complicated since the final product does not facilitate simplistic sampling methods as discussed for the previous alternatives. In order to simplify sampling glass for this waste form, a sample must be collected at a point where the glass is mobile, or molten as it discharges from the melter. Alternatively, sampling may be performed downstream of the scoring/trimming function that produces the plate form.

Waste sampling at the scoring/trimming location is simplified due to the discrete nature of the "trimmed sections" of plate. As the trim is separated from the plate, representative glass samples can easily be collected downstream of the separation point. Since the residence time to produce plate glass is relatively short, and considering there is little-to-no accumulation of materials during production, worker safety/exposure issues are minimized during the sampling process (all equipment is steel construction and reduces radiation to worker). **Figure A-16** illustrates a sample point for plate glass sampling. A simple diverter is used to redirect "trimmings" from the conveyor into a sample collection jar. This sample collection process is performed manually and requires little to no instrumentation.

Shipping Container Loading

The conveyor system transporting ribbon glass from the lehr is a speed controlled rubber collared steel roller system approximately 82 ft in length. The continuous ribbon glass is scored (longitudinal and cross scored), trimmed (edges), and broken into large sections by series of glass handling devices. The large sections of glass are transferred perpendicular to the flow of the ribbon glass by transfer tables that deliver them to one of two redundant processing lines, both approximately 39 ft in length. Two process lines are required to ensure that equipment malfunctions/failures of these mechanical handling systems do not impact glass roller operations. The large glass sections move to a longitudinal scored

breaker device and are broken into smaller plate glass sections prior to staging and packaging.

Scoring the glass ribbon requires an etching tool to "score" the glass for a controlled break. A longitudinal scorer simply scores the glass from a fixed point as the glass moves past it. Typically, the cutting wheel is constructed of carbide and maintained in a cutter housing. A cross scorer scores the ribbon glass in the plane perpendicular to its flow, requiring mechanical assistance. Both types of score machines are simple in concept and perform their function as the glass is moving on the conveyor system.

Glass recycle must be incorporated into the plate glass production systems at all points where breakage is feasible. At points where the ribbon glass is scored and broken, the stresses introduced to the glass could result in uncontrolled breakage of the glass form. The recycle systems must therefore be designed to identify, collect, process, inspect and recover from breakage events in the process handling systems.

The plate glass sheets are transferred by an automated handling device into a shipping container. Once full, a monorail hoist is used to replace the shipping containers lid. The conveyor transfers the container into the vestibule where its lid is secured/bolted, it is surveyed and deconned (as necessary) by an operator. Once satisfying the inspection criteria, the shipping container is transferred from the vestibule to the loading area where a forklift removes it from the process facility.

Shipping containers are staged outside the facility until product sampling (TCLP) confirms waste product performance meets waste acceptance criteria (WAC) for the disposal site. Once sampling verifies product quality, shipping containers are moved to an interim storage facility for staging and product turnover (for ultimate disposal by FDF). If the product fails sampling, the container is transferred to the facility for reprocessing.

To optimize a shipping container for the plate glass, the total gross weight limit 21,000 lbs per shipping container is used (assumption 1.4.11). **Table 3-5** provides details for the modified plate glass shipping container.

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TABLE 3-5
MODIFIED PLATE GLASS SHIPPING CONTAINER

Dimension, Exterior WxLxH (in)	Dimension, Interior WxLxH (in)	Tare Weight[1] (lbs)	Glass Weight[2] (lbs)	Container Volume (cft)	Total # of Containers[3]
54x72x57.5	42x60x41.2	11,890	9,128	129.4	2,909

Notes,
[1] Weight of empty modified container;
[2] Weight of plate glass packaged inside container;
[3] Number of shipping containers required to package all Silo 1 and 2 waste as plate glass.

All calculations are documented in Calc file: 40730-CA-004.

It takes approximately 6.8 hours to fill a modified shipping container when the plant is operating at capacity (18 TPD). Each shipping container can contain 102 plates of glass. Approximately 3.5 modified plate glass shipping containers per day are filled. In order to package all vitrified waste product, approximately 2,909 modified plate glass containers are required over the life of the plant.

Plate Glass Recycle

Recycle of out-of-spec (TCLP) plate glass functionally consists of removal of the glass from container, size reduction, and product (frit) transfer. Plate glass recycle is performed remotely in dedicated facilities due to the ingrowth of the radon daughter products and its associated equilibrium activity (**Section 1.4**). The plate glass waste form is well suited for product recycle since it can be easily removed from a shipping container using remote plate glass handling equipment and introduced (via conveyor) into the hammermill used to size reduce plate glass for product recycle. Once reduced, frit is staged in a hopper prior to pneumatic transfer to the feed preparation tank.

4.0 EVALUATION OF ALTERNATIVES

In order to assess the alternatives considered in this study, criteria are selected as a basis for evaluation that will serve to discriminate against the alternatives. The alternatives are compared against the criteria in this section, and the results are used in **Section 2.1** as a basis for a conclusion of the alternatives. The evaluation criteria includes: process flowsheet/facility design impact; operability, complexity and maintainability; maturity of technology; schedule impact; regulatory impact; safety; and cost. A qualitative/ quantitative assessment (as appropriate) is presented in the following sections for each of the vitrified waste form alternatives.

4.1 Process Flowsheet/Facility Design Impact

TABLE 4-1
PROCESS FLOWSHEET/FACILITY DESIGN ADVANTAGES

Waste Form	Issue	Advantage
Gems	1.	Convective air flow (in conjunction with the cooling plates) permits expedient cooling of gems during production. This method of heat removal allows the use of a ambient air for waste heat removal;
Cullet	1.	Water quenching of molten glass in the production of cullet allows for efficient removal of heat and can easily be adjusted to provide the appropriate cooling. This method of heat removal permits the use of a cooling tower for ultimate heat rejection;
	2.	All equipment requiring maintenance can be located within the facility to facilitate maintenance and apply ALARA principles;
	3.	Since an acceptable quenched waste product is a function of glass formulation, quench water temperature, and time, the process control requirements to produce acceptable cullet appear to be the most simple of the alternatives.
Monolith	1.	No glass forming systems are required (gravity pour from the melter);
	2.	Process requirements/process control parameters to pour monolith are simple;
	3.	Requires the least amount of facility space;
Plate Glass	1.	None determined.

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TABLE 4-2
PROCESS FLOWSHEET/FACILITY DESIGN DISADVANTAGES

Waste Form	Issue	Disadvantage
Gems	1.	The gem cooling system is complex and requires significant cooling capacity. This system must provide convective air flow perpendicular to the plane of travel of the gem for the entire length of the conveyor;
	2.	The optimal gem size must be determined to reduce maintenance requirements and facility space;
	3.	Since an acceptable waste product is a function of glass formulation, gem production, and gem cooling, the process control requirements to produce an acceptable gem product appear to be the most complex of the alternatives (e.g., the temperature and viscosity of molten glass during gob/gem production are critical parameters and must be closely controlled and monitored);
	4.	The gem conveyor system is large (length) and inefficiently utilizes facility space;
Cullet	1.	Cullet, by virtue of its rapid cooling, has significant stress fractures and will generate fine particles during handling and transfer. The cullet production system must be designed to manage glass fines for ultimate disposal;
	2.	The particle size distribution of fines generated during cullet production will be a probabilistic function. Although process equipment can be dedicated to address equipment erosion problems associated with abrasive nature of fines (e.g., hydrocyclone, in-line filters), equipment erosion will continue to be an issue.
	3.	There exists no basis for estimating the cullet fines generated during waste form production (this study assumes 5 percent). Since waste form production decreases as fine generation increases, there is uncertainty with respect to sizing this waste form alternative's plant capacity;

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TABLE 4-2 (continued)

Waste Form	Issue	Disadvantage
	4.	The cullet off gas system must have the capability to condense steam vapor, remove particles, dry cullet, and maintain melter confinement. Controlling melter in-leakage requires maintaining a negative pressure differential across the melter discharge orifice and is complex;
	5.	The cullet system design must be an enclosed system to provide primary confinement;
	6.	Requires the most amount of facility space;
Monolith	1.	Monolith sampling methods must be representative of the monolith waste form product (e.g., samples must cool similarly to demonstrate product meets waste acceptance criteria);
	2.	Monolith production requires the melter to be operated in a discontinuous discharge mode. Melter confinement is maintained during monolith pouring. However, as MTCs are removed from the melter, confinement must be maintained by mechanical systems;
	3.	HVAC equipment details to provide appropriate airflow conditions for monolith cooling have not been developed. This development may impact the layout of the cooling room (e.g., change its size);
	4.	The monolith cooling duration requires verification to appropriately size HVAC equipment and cooling room configuration (e.g., storage rack design);
Plate Glass	1.	Low capacity glass production (18 TPD) is not compatible with plate glass production;
	2.	Plate glass manufacturing requires controlled annealing and cooling of the product glass. These facilities require long annealing lehrs (and conveyor systems) that occupy large areas within the vitrification facility;
	3.	An off-gas system is required to vent industrial and residual heat sources in the plate glass processing systems (e.g., lehr furnace);

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TABLE 4-2 (continued)

Waste Form	Issue	Disadvantage
	4.	Melter confinement is difficult due to the complexity of the plate glass production process and must rely on the primary enclosure (i.e., the off-gas system);
	5.	To ensure continuous plate glass production, redundancy must be built into the plate glass processing systems (i.e., production lines);
	6.	The annealing process is very important for plate glass stabilization. This process must be properly controlled to produce an acceptable waste form that is not brittle;
	7.	The temperature and viscosity at the feed channel where the molten glass stream passes through the roll mill are critical in order to avoid sticking of the waste form. Systems must ensure proper temperature control to the water cooled rollers;
	8.	Clean up of broken glass will be more difficult than any of the other waste forms. Broken glass must not only be recovered for recycle, but equipment components must be cleaned of the fragmented glass and inspected prior to resuming process operations (to ensure glass surface quality). These activities must be performed without impacting roller operations;
	9.	Melter confinement is complex since it depends upon maintaining the molten glass level;

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4.2 Operability, Complexity, and Maintainability

TABLE 4-3
OPERABILITY, COMPLEXITY, AND MAINTAINABILITY ADVANTAGES

Waste Form	Issue	Advantage
Gems	1.	Packaging efficiency for gems is higher than cullet;
	2.	Gem production utilizes automated bulk material handling methods and readily facilitates product cooling and sampling;
	3.	The gem conveyor system is mechanically complex. However, operator access/maintenance is easily facilitated by locating critical components in accessible locations;
	4.	Shipping container loading minimizes mechanical handling systems and utilizes gravity;
	5.	Gem size can be controlled by adjusting melter throughput and/or gem maker and conveyor speed;
	6.	Gem production permits the melter to be operated in a continuous feed/discharge mode;
	7.	Failed product recycle permits gems to be transferred directly to the melter without size reduction;

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TABLE 4-3 (continued)

Waste Form	Issue	Advantage
Cullet	1.	Cullet production utilizes automated bulk material handling methods and readily facilitates product cooling and sampling;
	2.	The cullet conveyor system is mechanically complex. However, operator access/maintenance is easily facilitated by locating critical components in accessible locations;
	3.	Cullet production equipment (i.e., quench flume, quench tank) are simplistic mechanical components with expected high availability;
	4.	Shipping container loading minimizes mechanical handling systems and utilizes gravity;
	5.	Cullet is generated from the molten glass-water interaction and does not require complex mechanical systems for waste form production;
	6.	Cullet size can be empirically adjusted by controlling quench water temperature and flow rate;
	7.	Cullet production requires a single quench tank and cullet dryer. Due to their simplicity in design, availability is expected to be high;
	8.	Cullet production permits the melter to be operated in a continuous feed/discharge mode;
	9.	Failed product recycle permits cullet to be transferred directly to the melter without size reduction;

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TABLE 4-3 (continued)

Waste Form	Issue	Advantage
Monolith	1.	Packaging efficiency for monolith is higher than gems and cullet;
	2.	Monoliths minimize mechanical systems and utilize gravity to produce the waste form;
	3.	The MTC provides simple engineered barrier for contamination control;
Plate Glass	1.	Packaging efficiency for plate glass is higher than monolith, gems and cullet;
	2.	Plate glass production permits the melter to be operated in a continuous feed/pour mode and readily facilitates product sampling;

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TABLE 4-4
OPERABILITY, COMPLEXITY, AND MAINTAINABILITY DISADVANTAGES

Waste Form	Issue	Disadvantage
Gems	1.	The gem production equipment (8 melter discharge orifices and 4 gem machines) are located in close proximity to the melter and require a high degree of operator access/maintenance. Availability of this equipment can be significantly compromised due to orifice blockage and/or the uncertainty in the physical properties of the molten glass and the failure to produce a gem form;
	2.	The gem handling/cooling system is mechanically complex. In addition, the system must be enclosed (for primary confinement) and may require a high degree of operator access/maintenance;
	3.	The automated bulk material handling systems require operators to monitor operations;
	4.	Glass gems are brittle because of the stresses produced during the cooling process and will tend to fracture during rapid cooling and handling/packaging;
	5.	Water cooling and lubricating are required for the gem machine and cooling belt conveyor. These functions remain to be demonstrated and may present significant difficulties;
	6.	Melter confinement, a function of the molten glass interface with the melter discharge orifices and pressure differential between the cullet and melter off gas systems, is expected to be a complex operating feature;

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TABLE 4-4 (continued)

Waste Form	Issue	Disadvantage
Cullet	1.	Packaging efficiency is the worst of all waste form alternatives;
	2.	Cullet is abrasive and may cause excessive wear on mechanical handling equipment (e.g., hydrocyclone, conveyors, mechanical seals);
	3.	The automated bulk material handling systems require operators to monitor operations;
	4.	Cullet fines must be collected and recycled into the melter feed system. The plant's total operating efficiency (TOE) may be compromised if excessive cullet breakage can not be managed effectively;
Monolith	1.	The melter pour spout equipment located in close proximity to the melter requires a high degree of operator access/maintenance;
	2.	The metal basket (or mold) considered in this alternative permit a MTC to maintain its original geometry during glass fill. Details of design/handling/reuse of metal basket are not evaluated or provided;
	3.	The monolith cooling concept relies upon a simple HVAC system postulated to remove a calculated heat. The ability to effectively cool the required number of monoliths is a complex function of thermodynamics and is beyond the scope of this report;
	4.	Monolith handling requires use of remote systems that are inherently more complex to operate than automated systems;
	5.	Filled monolith forms must be handled individually for packaging into shipping containers;
	6.	Product sampling is more complex due to the slow cooling curve of the monolith (devitrification);

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TABLE 4-4 (continued)

Waste Form	Issue	Disadvantage
	7.	Monolith production does not permit continuous melter discharge operations;
	8.	Failed product recycle is significantly more complex than the discrete waste forms (gems, cullet);
Plate Glass	1.	The plate glass production systems are complex in design, require enclosure and a high degree of operator access (i.e., maintenance);
	2.	Plate glass production requires a tightly controlled glass composition in order to balance the operating conditions;
	3.	The temperature/viscosity relationship is critical in plate glass production (stress/strain required to produce the glass form). This relationship must be well understood prior to designing and operating a plate glass production facility;
	4.	Plate glass production is expected to generate fines within the production equipment. This presents significant contamination control issues with respect to operability and maintainability of this alternative;
	5.	In order to draw glass from the melter, the height of molten glass on the melter side of the water cooled rollers must be tightly controlled. Failure to control this parameter could result in flooding the rollers (high level) or shearing of the glass ribbon (low level);
	6.	If glass ribbon production stops for a short period of time (less than a minute), freezing of the viscous glass at the roll mill will occur;
	7.	Replacement of rubber rollers on the conveyor system may cause stress fractures and breakage of glass ribbon during scoring and breaking operations since the new rollers are expected to have a different diameter than older worn rollers;
	8.	Plate glass production (roll process) requires many operators to monitor, control, and maintain the process and is not conducive to automation;

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4.3 Maturity of Technology

Maturity of technology is defined as the relevant application of a glass form production process for remedial objectives. At a first glance, the commercial glass industry provides all glass form alternatives with a broad range of demonstrated experience. Materials of construction, glass melt temperatures, heat of reaction, volatilization of constituents, and corrosivity are all well understood within the commercial glass industry. As a result, the commercial glass industry is a demonstrated technology that can produce high quality glass forms efficiently and economically. However, since there exists significant differences in glass composition between a K-65 based and a typical commercial glass formulation, the process of glass melting, glass handling, and selection of construction materials differs significantly from what is commonly understood by the commercial industry. In short, since glass chemistry and physics of the commercial industry are not applicable to the K-65 residue, no preferential credit for maturity of technology is given to any of the waste forms considered in this evaluation.

The adaptation of commercial glass technology for remediation objectives must consider the physical characteristics/attributes of the K-65 glass formulation. Issues such as glass forming, worker exposure, contamination control, and environmental ALARA must be integrated into the design basis. These issues, although unique to each glass formulation, have been addressed in previous vitrification projects and are summarized in **Table 4-5** (the information presented in this table has been collected from miscellaneous sources and remains to be verified). From this information, vitrification projects that have, in general, selected to produced monolith waste forms.

The cullet waste form significantly differs from the gem waste form since no mechanical systems are required to produce the discrete waste object. Although mechanical systems are required to transport and cool cullet, the glass-water interaction that produces cullet is a non-mechanical process that minimizes the ability to produce a waste form as a function of the physical characteristics/attributes of the K-65 glass formulation. Therefore, this attribute appears to favor cullet over gems.

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TABLE 4-5
SUCCESSFUL REMEDIATION PROJECTS (VITRIFICATION)

MELTER LOCATION	STATUS	OPER TEMP (°C)	SIZE (MT/d)	FEED TYPE	FEED COMPOSITION	HOMOGENEITY & CHARACTERIZATION	COMMENTS
PLANTS THAT HAVE COMPLETED THEIR MISSION							
Fernald	Pilot Plant; Mission Complet	1350	3 TPD of gems	Surrogate and 50-60% water	Surrogate simulating radium bearing residues and metal oxides wastes.	Surrogate is fairly well characterized.	Three chamber, Joule heated melter. Melter failed, gem production undemonstrated.
Germany PAMELA	Mission Completed	1120 to 1180	1@0.72 of Monolith	Liquid fed plus dry frit	High-level liquid waste containing TRU and fission products.	Very homogeneous liquid source. Well characterized.	265 m^3 of waste processed in 6 years, beginning in 1985. 8 to 10% waste oxide loading. Joule heated melter.
France - Marcoule	In operation	1100 to 1300	1@0.36 of Monolith	Dry calcine feed	High-level liquid waste containing TRU and fission products.	Each batch is assumed to be very homo-geneous and well characterized.	Began operation in 1978. Low frequency induction heated melter with rotary calciner.

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TABLE 4-5 (continued)

MELTER LOCATION	STATUS	OPER TEMP (°C)	SIZE (MT/d)	FEED TYPE	FEED COMPOSITION	HOMOGENEITY & CHARACTERIZATION	COMMENTS
PLANTS THAT HAVE COMPLETED THEIR MISSION (continued)							
France La Hague	2 units in operation, 2 being upgraded	1100 to 1300	4 @ 0.6 each of Monolith	Dry calcine feed	High-level liquid waste containing TRU and fission products.	Each batch is assumed to be very homo-geneous and well characterized.	Began operation in 1989. Low frequency induction heated melter with rotary calciner.
England Sellafield	2 units in Operation, 1 under const.	1050	3 @ 0.6 each of monolith	Dry calcine feed	High-level liquid waste containing TRU and fission products.	Very homogenous and well characterized.	Licensed French low frequency induction heated melter technology with rotary calciner. 2 units operating since 1990.
Japan Tokai	In operation for 1 year	1150	x @ 0.72 each of monolith		Assumed to be high-level waste containing TRU and fission products.		Using new German cold crucible, high-freq. Induction heated melter technology.
Russia	1st unit failed. 2nd unit in operation	1200	2 @ 3 each of monolith	Liquid fed with liquid phosphoric acid glass formers	Assumed to be high-level waste containing TRU and fission products.	Assumed to be homogenous and well characterized	28 sets of bottom entry molly electrodes. Produced phosphate glass. Joule heated melter.

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TABLE 4-5 (continued)

TABLE 4-5 (continued)

MELTER LOCATION	STATUS	OPER TEMP (°C)	SIZE (MT/d)	FEED TYPE	FEED COMPOSITION	HOMOGENEITY & CHARACTERIZATION	COMMENTS
PLANTS THAT HAVE COMPLETED THEIR MISSION (continued)							
Savannah River; M Area	Mission Completed	1150	1 @ 7.5 of gems	Slurry of waste and glass formers	670,000 gal of liquid mixed waste.	Liquid contained in 2 tanks. Very homogenous and well characterized.	Duramelt 5000 melter, with plate electrodes providing joule heating. Gem production demonstrated at 5TPD.
Savannah River; M Area	Mission Completed	1150	1 @ 7.5 of gems	Slurry of waste and glass formers	670,000 gal of liquid mixed waste.	Liquid contained in 2 tanks. Very homogenous and well characterized.	Duramelt 5000 melter, with plate electrodes providing joule heating. Gem production demonstrated at 5TPD.
PLANTS IN OPERATIONAL PHASE							
Savannah River DWPF	Operational	1150	1 @ 2.4 of Monolith	Slurry of waste and frit	High-level waste from reprocessing operations. Contains TRU, fission products, and mercury.	Multiple tanks with different constituents in each. Waste is not well characterized.	Control of noble metals a problem with shorting out electrodes. Joule heated melter.
West Valley	Operational	1150	1@0.72 of Monolith	Slurry of waste and glass formers	High-level waste from reprocessing operations. Contains TRU and fission products.	Single tank of liquid/slurry waste. Fairly homogeneous and well characterized.	Operational campaign near completion.

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4.4 Schedule Impact

A schedule is defined as a comprehensive list of logical activities required to accomplish a given project. Schedule activities considered in this criteria are design and operation. For this evaluation, the risk associated with the design and operation activities is not quantified (i.e., risk/consequence analysis is beyond the scope of this study), however, a qualitative assessment can be made based on findings presented in **Section 4.0** of this study. The following schedule impact(s) are based on a qualitative assessment of the significant findings of the evaluation criteria.

4.4.1 Design Impact

The design of the cullet system should be straight forward with little risk. This is attributed to the rapid nature of cooling of cullet, the ability to scale up the technology, and the commercial availability of cullet production equipment. Design of the monolith alternative will be difficult compared to cullet considering the remote handling systems required to be developed for this waste form. In addition, the monolith alternative minimally requires the development and verification of the assumptions identified in **Section 1.4** of this evaluation (this contributes to the risk of schedule slippage). Similarly, the gem and plate glass alternatives present schedule risk during design development. Since it has been discussed earlier that the ability to efficiently utilize gem/plate glass production equipment is based upon empirical data (i.e., operating parameters must be adjusted to accommodate changes in the glass physical properties), there is risk associated in the development of operating correlations required to design and operate gem/plate glass production equipment as a function of glass property (K-65 residue is not homogenous). Like the monolith alternative, the assumptions defined in **Sections 3.1** and **3.4** for the gems and plate glass minimally require development and verification (this contributes to the risk of schedule slippage for these alternatives).

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4.4.2 Operations

Operational problems are expected to be minimal for the cullet equipment (conventional equipment), with issues limited to operations and maintenance in a radioactive environment. Remote handling operations of monoliths could present problems if MTCs become out of spec due to warping under significant heat loads. Operational problems experiences with the gem alternative were plentiful with the VITPP gem machine. Since glass characteristics are expected to vary during the treatment of K-65 residues, it is expected that operational problems would abound with the gem alternative.

Since plate glass and gem waste form processes rely upon complex process controls (to determine operating parameters) and mechanical systems to produce glass product, it is assessed that the operations schedule risk for these alternatives is higher than the cullet and monolith. Likewise, since the monolith alternative requires remote handling equipment, controlled cooling, and depends upon predetermined tolerances (i.e., MTC warping), it is assessed that the operations schedule risk for monolith is higher than cullet. Since cullet is quenched in an apparent infinite heat sink to produce a waste form (lots of room for variances in the glass physical properties), and considering the off-the-shelf technology employed for this alternative, the operations schedule risk for cullet is assumed to be low.

4.5 Regulatory Impact

Each waste form considered in this evaluation utilizes the same vitrification technology and balance of plant. Therefore, the design and operation of this facility is assumed to be constant for this criteria and does not serve to discriminate between the waste forms (secondary waste volumes are expected to be different, however, the management and disposition of all secondary waste is considered the same for all alternatives). Also, since it is assumed that each waste form alternative utilizes an approved DOT Specification 7A Type A container, this criteria again does not serve to discriminate.

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4.6 Safety

ALARA design features for the waste form alternatives include steel enclosures, water medium, concrete shield walls, automation, and remote operations (list not inclusive). The application of the ALARA design features for this evaluation are based upon preliminary calculations, technology selection, engineering practice, and industrial safety.

Gem and cullet production are automated processes based on continuous material throughput and use mechanical conveyance systems to transport product. Both cool the waste form rapidly causing stress fractures within the glass product and both generate fines (cullet expected to be the largest generator). There exists uncertainty with respect to the generation and accumulation of fines within each system, and likewise, with the ingrowth from the decay of parent radionuclides within the fines. Both methods utilize steel enclosures. Gems utilize air for cooling, cullet uses water for heat removal. Gem and cullet utilize more mechanical systems than the monolith option and will require more operator interface during operations and maintenance (higher personnel exposure expected than the remote monolith systems).

Monolith filling/pouring is an automated process based on semi-continuous melter throughput. Placement of a monolith for waste form cooling is a remote operation. All the alternatives use remote methods to fill shipping containers. The monolith alternative minimizes contamination concerns during shipping container loading by using a MTC as primary confinement.

4.7 Cost

Cost estimates are used to identify alternatives which are significantly more expensive than competing alternatives. These estimates are required to be order-of-magnitude level accuracy, as defined by the American Association of Cost Engineers. The cost estimates contained herein are based on a variety of cost-estimating data such as cost curves, generic unit costs, vendor information, conventional cost-estimating guides, commercial remedial costs, and previous similar estimates as modified by site-specific information. The

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categories of costs considered are: (1) capital costs of glass handling and packaging equipment; (2) operating costs of waste packaging, transportation, and disposal costs.

A reference joule-heated vitrification facility is assumed for all three alternatives. Cost data (capital and life cycle) is not presented for this reference facility for the following reasons:

- Cost data for the reference joule-heated vitrification facility is included in the Revised Feasibility Study Report for Silos 1 and 2, Preliminary Draft, Document No. 40730-RP-001, February 1999, and is considered business sensitive data by FDF. Therefore, it can not be published in this trade study;
- Cost data (capital and life cycle) for the reference joule-heated vitrification facility is the same for each alternative and therefore, does not serve to discriminate between them.

The cost estimates presented are order-of-magnitude estimates with an intended accuracy range of ± 40 percent. Estimates are considered to be order-of-magnitude because of the uncertainties in the information used to develop the alternatives. Final costs will depend on the actual detailed design used, actual labor and material costs, actual site conditions, productivity, competitive market conditions, final scope, final schedule, final engineering design, and other variables.

4.7.1 Capital Costs

Capital costs are expenditures required to construct a vitrification facility to produce a specific type of glass waste product (e.g., gem, cullet, monolith). Since a reference vitrification plant is assumed to exist for each alternative, capital cost estimates are not prepared for similar systems (e.g., melter, feed preparation, off-gas systems). Instead, capital costs estimates have been prepared for the differences in the capital costs components for each alternative (e.g., facility differences, glass handling and packaging equipment). Capital costs consist of direct and indirect costs. Direct costs are those expenditures necessary for the actual installation of the remedial action. These include equipment, labor, and materials. Indirect costs include expenditures for engineering,

financial, supervision, and other services necessary to carry out a remedial action. The capital cost elements for the waste form alternatives are summarized in Table 4-7.

4.7.2 Indirect Costs

Indirect costs, reported in Table 4-7, are those costs required to support the design, construction, and management of the treatment facilities (associated with a waste form). Costs incurred to support the construction activities include those required for the purchase of small tools and consumable items (welding machines, welding rods, grinding wheels, etc.); the use of temporary facilities and utilities during the construction phase only; initial safety training and ongoing safety meetings; health physics support during construction; the general contractor's markup, overhead, and profit; and the payroll burden and benefits of the construction force. The payroll burden and benefits include health insurance, unemployment benefits, Social Security, and worker's compensation insurance. Additional indirect costs incurred for the engineering, design, and construction management of the glass handling and packaging systems are estimated for each alternative.

Sales tax is added as a percentage of the overall costs of the remedial action alternative. A sales tax of 5.5 percent has been applied to all capital equipment purchases and services. Although sales tax is not typically applicable to CERCLA remediation activities, the State of Ohio requires that sales tax be charged on all equipment purchased.

4.7.3 Packaging

Packaging is a cost component of all waste form alternatives. Packaging costs, reported in TABLE 4-7, include the cost of purchasing the containers and the labor associated with handling, filling, and documentation. Estimated costs are based on the following:

- Monolith Transfer Containers (MTCs) are constructed from quarter inch steel plate and weigh approximately 440 lbs each. Exterior dimensions of a MTC are approximated by 20 in x 40 in x 40 in (WxLxH). 3 MTCs are packaged for disposal in a monolith shipping container. A cost of $660 per unit (MTC) is assumed;

- Shipping container packages are U.S. Department of Transportation (DOT) Specification 7A-Type A containers. A reference container with exterior dimensions of approximately 4.5 ft wide by 6 ft long by 4.8 ft depth (131 ft^3 exterior volume) and interior dimensions of approximately 3.5 ft width by 5 ft length by 3.5 ft depth is used. Container depth was allowed to vary from the reference container in order to optimize the packaging of waste forms (Calculation No. 40730-CA-0004);
- The number of packages was based on a maximum container payload weight of approximately 9,000 lbs, and a maximum payload volume of approximately 61 ft^3, assuming a material density of approximately 168.8 lb/ft^3 and interstitial void values for each waste form;
- Disposal volumes were estimated by multiplying the number of containers presented in **Table 4-6** by the external volume of the container used for the shipment of the material;
- Total packaging cost was estimated assuming the number of containers indicated **Table 4-6**; and
- A unit cost of $5,275 was determined for the reference shipping container based on a material cost of $5,000 per unit and a 5.5 percent sales tax applied to the purchase of each container. The cost per shipping container for each waste form alternative was determined based on the ratio of volumes to the 0.6 power of the modified and reference containers.

TABLE 4-6
VOLUMES AND DISPOSAL QUANTITY ESTIMATES

Waste Form Alternative	Volume of Container (ft^3)	Packaging Void Fraction	Cost per Container ($)	Number of Containers	Total Volume of Waste (ft^3)
Gems	143.3	0.30	5470	3,248	465,520
Cullet	157.7	0.45	5790	3,625	571,663
Monolith	122.6	0.24	6980[1]	3,426	420,113

notes:

1. The cost of a monolith shipping container includes the unit cost of modified shipping container ($4980), the cost of 3 MTCs per shipping container ($1980), plus the normalized cost of MTCs required for one percent monolith recycle (approximately $20 per shipping container).

4.7.4 Transportation

Transportation is a cost component of all the waste form alternatives. This cost item, reported in **Table 4-7**, includes transportation of the packaged material reported in **Table 4-6** and is based on the following assumptions:

- For all alternatives, packages will be transported by truck (2 packages per truckload); and
- Costs are estimated using a unit rate of $3,584 per truck shipment to the NTS based on current average shipping costs.

4.7.5 Disposal

Disposal costs for all alternatives are estimated for NTS. Costs are estimated based on the following:

- Disposal costs for packaged material disposed of at NTS is estimated at $10.00/ft^3 based on projected disposal costs for fiscal 1998.

Disposal costs for each waste form alternative is summarized in **Table 4-7**.

TABLE 4-7
DISPOSAL COSTS OF WASTE ALTERNATIVES

WASTE FORM	CAPITAL COSTS ($M)			OPERATING COSTS ($M)				TOTAL COST ($M)
	DIRECT	INDIRECT	SUBTTOTAL	PACKAGING	TRANS	DISPOSAL	SUBTOTAL	
Gem	1.05	0.37	1.42	17.77	5.82	4.66	28.24	29.66
Cullet	1.31	0.42	1.73	20.99	6.50	5.72	33.2	34.93
Monolith	1.48	0.57	2.05	23.91	6.14	4.20	34.25	36.30

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ATTACHMENT A

FIGURES FOR WASTE FORM ALTERNATIVE STUDY

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LIST OF FIGURES

Figure A-1 Gem Waste Form MFD

Figure A-2 Gem/Cullet Waste Form Container Handling

Figure A-3 Gem/Cullet Product Recyle

Figure A-4 Gem Waste Form General Arrangement Drawing, Sheet 1

Figure A-5 Gem Waste Form General Arrangement Drawing, Sheet 2

Figure A-6 Gem Waste Form General Arrangement Drawing, Sheet 3

Figure A-7 Cullet Waste Form MFD

Figure A-8 Cullet Waste Form General Arrangement Drawing, Sheet 1

Figure A-9 Cullet Waste Form General Arrangement Drawing, Sheet 2

Figure A-10 Cullet Waste Form General Arrangement Drawing, Sheet 3

Figure A-11 Monolith Waste Form MFD

Figure A-12 Monolith Product Recycle

Figure A-13 Monolith Waste Form General Arrangement Drawing, Sheet 1

Figure A-14 Monolith Waste Form General Arrangement Drawing, Sheet 2

Figure A-15 Monolith Waste Form General Arrangement Drawing, Sheet 3

Figure A-16 Plate Glass Waste Form MFD

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ATTACHMENT B

EQUIPMENT LISTING FOR GEM, CULLET, AND MONOLITH WASTE FORM ALTERNATIVES

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ATTACHMENT A

FIGURES FOR WASTE FORM ALTERNATIVE STUDY

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LIST OF FIGURES

Figure A-1 Gem Waste Form MFD

Figure A-2 Gem/Cullet Waste Form Container Handling

Figure A-3 Gem/Cullet Product Recyle

Figure A-4 Gem Waste Form General Arrangement Drawing, Sheet 1

Figure A-5 Gem Waste Form General Arrangement Drawing, Sheet 2

Figure A-6 Gem Waste Form General Arrangement Drawing, Sheet 3

Figure A-7 Cullet Waste Form MFD

Figure A-8 Cullet Waste Form General Arrangement Drawing, Sheet 1

Figure A-9 Cullet Waste Form General Arrangement Drawing, Sheet 2

Figure A-10 Cullet Waste Form General Arrangement Drawing, Sheet 3

Figure A-11 Monolith Waste Form MFD

Figure A-12 Monolith Product Recycle

Figure A-13 Monolith Waste Form General Arrangement Drawing, Sheet 1

Figure A-14 Monolith Waste Form General Arrangement Drawing, Sheet 2

Figure A-15 Monolith Waste Form General Arrangement Drawing, Sheet 3

Figure A-16 Plate Glass Waste Form MFD

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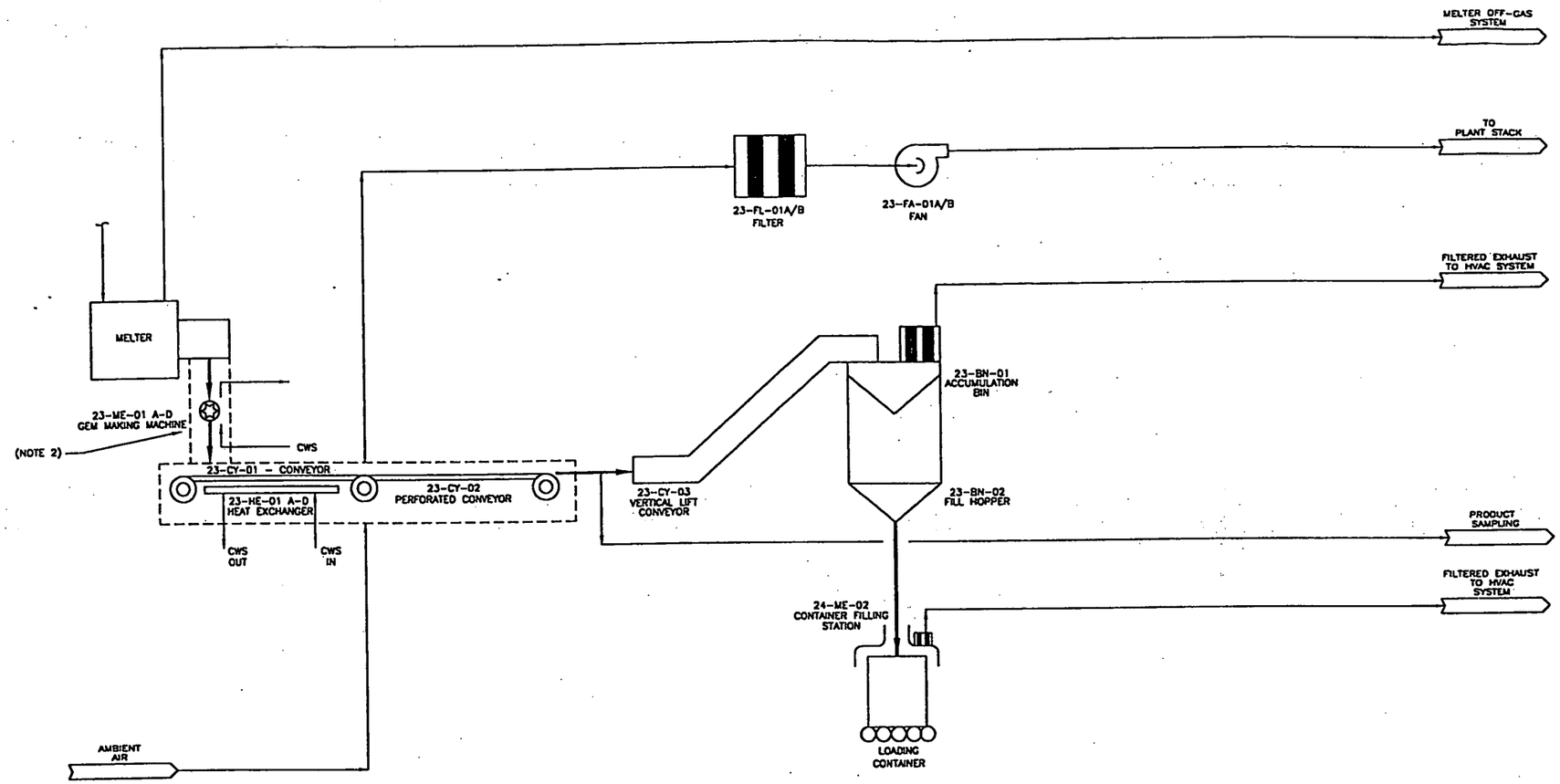


NOTE:
1. FORKLIFT TO LOAD/UNLOAD SHIPPING CONTAINER ONTO CONVEYOR.
2. ENCLOSURE

PRELIMINARY DRAWING.

Figure A-1 Gem Waste Form MFD

000071

DWG/LE SK-6020		CHECKER ACAD	
UNITED STATES DEPARTMENT OF ENERGY FERNALD ENVIRONMENTAL MANAGEMENT PROJECT			
THIS DRAWING PREPARED BY FLUOR DANIEL FERNALD SILOS PROJECT CINCINNATI, OHIO			
DRAWING TITLE MECHANICAL FLOW DIAGRAM GEM PRODUCTION VITRIFICATION - JOULE HEATED WASTE FORM STUDY			
DRAWN BY S. M. YANKEY	DATE 08/28/98	ORIGINAL DRAWN BY R. LOWERY	DATE
CHECKED BY S. YANKEY	DATE 7/2/99	PLANT/BLDG. NO. OU4	PLANT
SCALE NONE	CLASS	SUBMITTED FOR APPROVAL DATE	APPROVAL RECOMMENDED DATE
APPROVAL CONTRACTOR DATE		FMC PROJECT NO. 40730	SPCL CONTR. PROJ. NO. WBS2.1.3.G.P
DRAWING NO. 94X-5500-F-SK-6020	SHEET NO. 1	REV. NO. C	
DISTRIBUTION CODE: XXX	ACAD	INITIALS: SKY DATED: 5/3/99	

- 8066

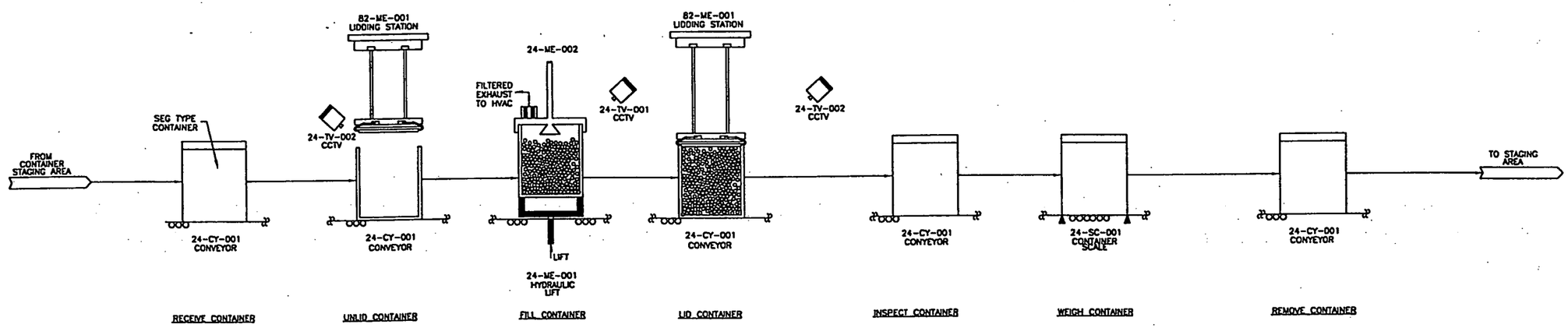


Figure A-2 Gem/Cullet Waste Form Container Handling

000072

DWG SK-6018 CHECKED ACAD

UNITED STATES
DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY

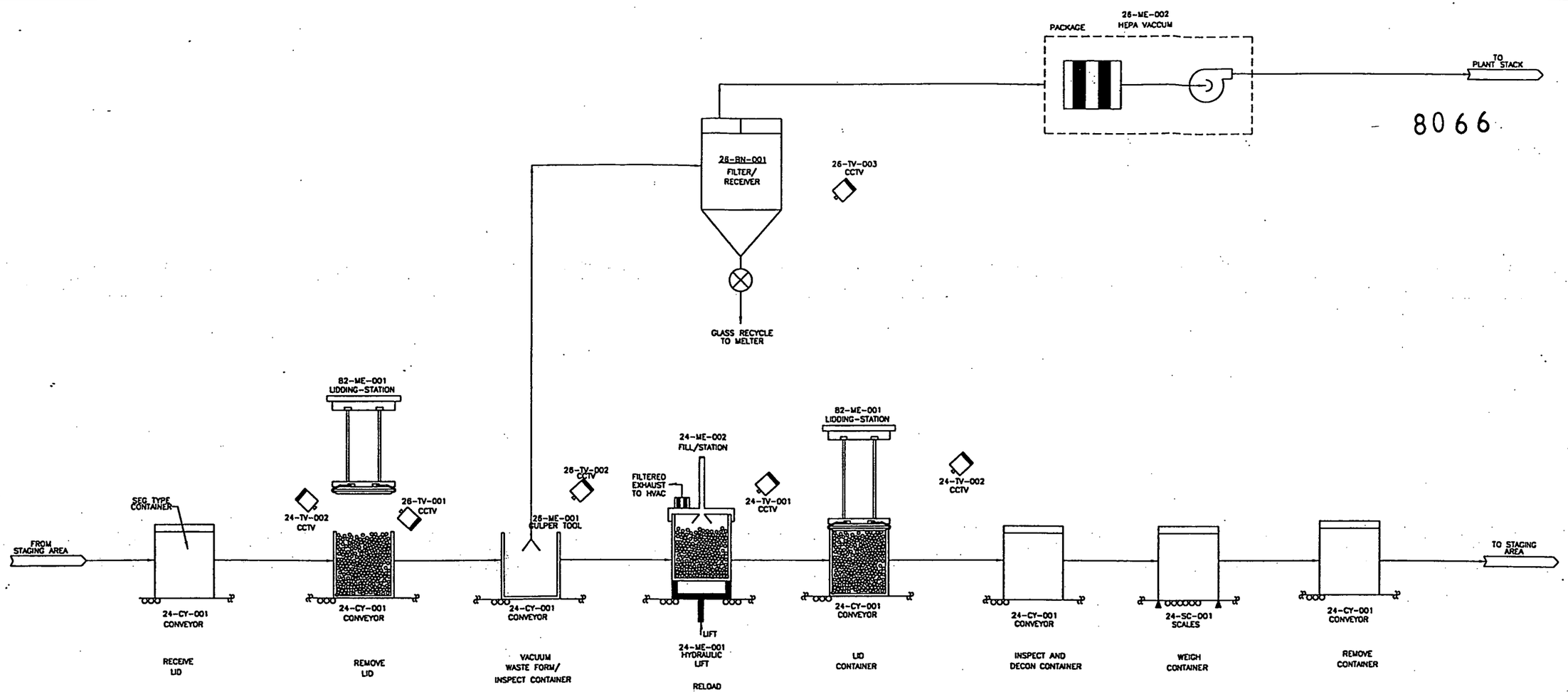
FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE

MECHANICAL FLOW DIAGRAM
GEMS AND CULLET WASTEFORM
SHIPPING CONTAINER FILLING
WASTE FORM STUDY

DRAWN BY S. M. YANKEY	DATE 08/06/98	DESIGNED, CALCULATED BY R. LOWERY	DATE	CHECKED BY S. YANKEY	DATE 3/3/99
PLANT/BLDG. NO. DU4		CLASS		SCALE NONE	FOLDER
SUBMITTED FOR APPROVAL		APPROVAL RECOMMENDED			
DATE	DATE	CHECKING CONTRACTOR	DATE		
SITE PROJECT NO. 40730	SYSTEM, GROUP, PROJECT NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-F-SK-6018		SHEET NO. 1	REV. NO. C

DISTRIBUTION CODE: XXX ACAD INITIALS: SMY DATE: 3/3/99



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000073

PRELIMINARY DRAWING

DWG SK-6014 CHECKED ACAD

UNITED STATES
DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY

FLUOR DANIEL FERNALD

SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE

MECHANICAL FLOW DIAGRAM
GEMS AND CULLET WASTFORM
PRODUCT RECYCLE
WASTE FORM STUDY

DRAWN BY	DATE	DESIGNED, CHECKED BY	DATE	CHECKED BY	DATE
D. LANDER	1/5/98	R. LOWERY		S.YANCEY	3/2/99
PLANT/BLDG. NO. OU4		PLANT		SCALE NONE	CLASS

SUBMITTED FOR APPROVAL A-E DATE

APPROVAL RECOMMENDED

APPROVAL CONSTRUCTION DATE

DOE PROJECT NO.	SYS. CONTR. PROJ. NO.	DRAWING NO.	SHEET NO.	REV. NO.
40730	WBS2.1.3.G.P	94X-5500-F-SK-6014	1	C

DISTRIBUTION CODE: XXX

ACAD

INITIALS: SHY
DATE: 3/3/99

Figure A-3 Gem/Cullet Product Recyle

8066

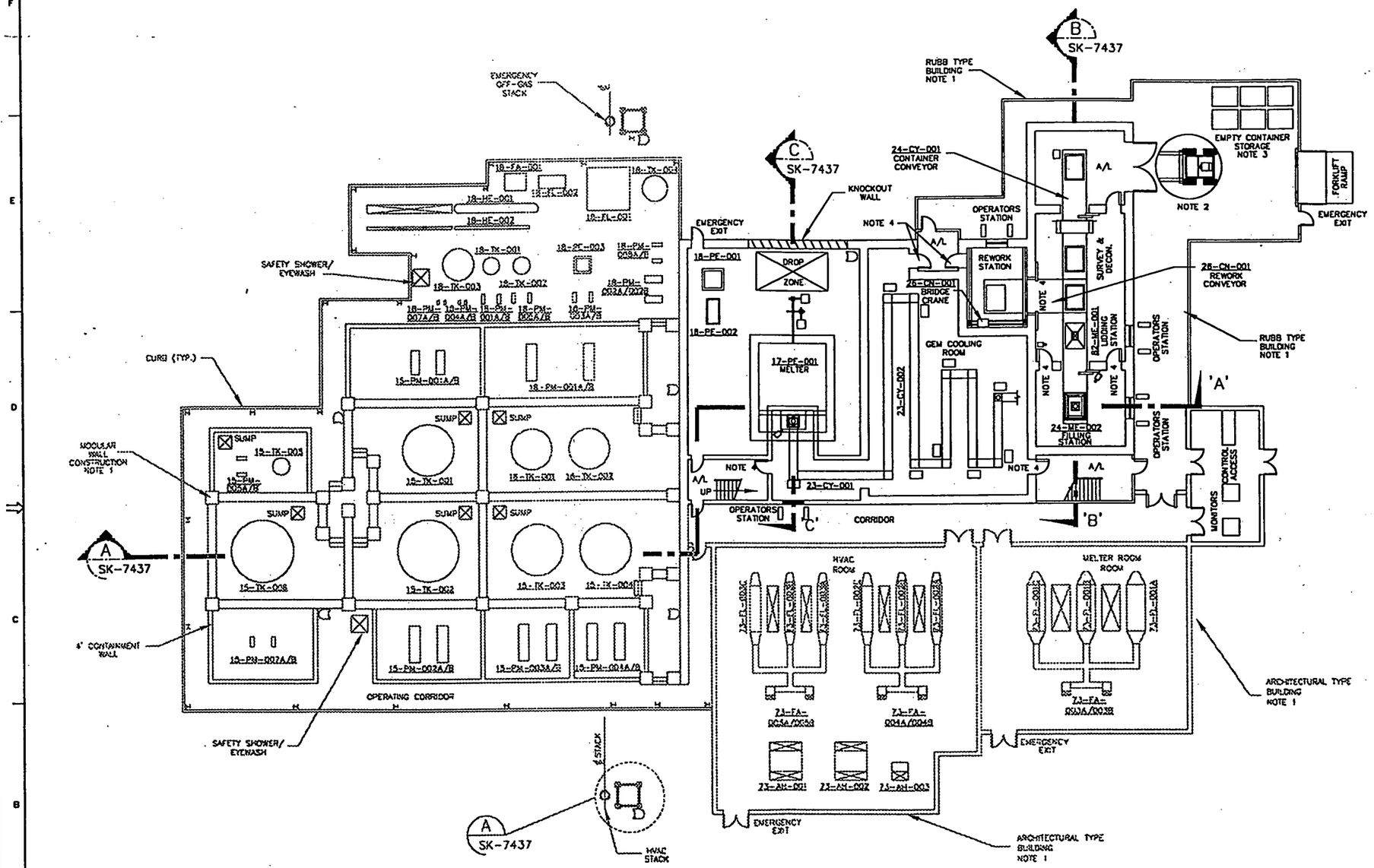

Figure A-4 Gem Waste Form General Arrangement Drawing, Sheet 1

NOTES:

1. BUILDING CONSTRUCTION
   - CONCRETE FLOOR SLAB AND FOUNDATIONS.
   - ARCHITECTURAL TYPE WALLS CONSIST OF STEEL FRAME STRUCTURE, INSULATED METAL SIDING, MEMBRANE ROOFING SUPPORTED BY STEEL DECKING AND INSULATION BOARD.
   - MODULAR WALL CONSTRUCTION CONSISTS OF INTERLOCKING PREFABRICATED SHEILDING WALLS AND COLUMNS.
   - ALL OTHER SHEILDING WALLS ARE 2'-0" THICK CONCRETE.
   - RUBB TYPE BUILDING CONSISTS OF INSULATED MEMBRANE COVERING STEEL FRAMING.
2. SHIELDED FORKLIFT DEDICATED TO VITRIFICATION FACILITY.
3. EMPTY CONTAINER STORAGE IS SINGLE STACK.
4. SHIELD DOOR.

REFERENCE DRAWINGS

94X-5500-P-SK-7436
94X-5500-P-SK-7437

LEGEND:

---------- = REMAINS CONSTANT FOR ALL WASTE LOADING OPTIONS.

PRELIMINARY DRAWING

SK-7407 | ACAD R13

UNITED STATES DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

FACILITY LAYOUT
VITRIFICATION FACILITY – GEMS
PLAN @ 0'-0" EL.
WASTEFORM STUDY

S. M. YANKEY	1/5/99	R. LOWERY	E. MOORE 1/28/99
DU4			3/64" = 1'-0"
40730	WBS2.1.3.G.P	94X-5500-P-SK-7407	1 C

DISTRIBUTION CODE: XXX ACAD INITIALS: SMY DATE: 5/3/99

)00074

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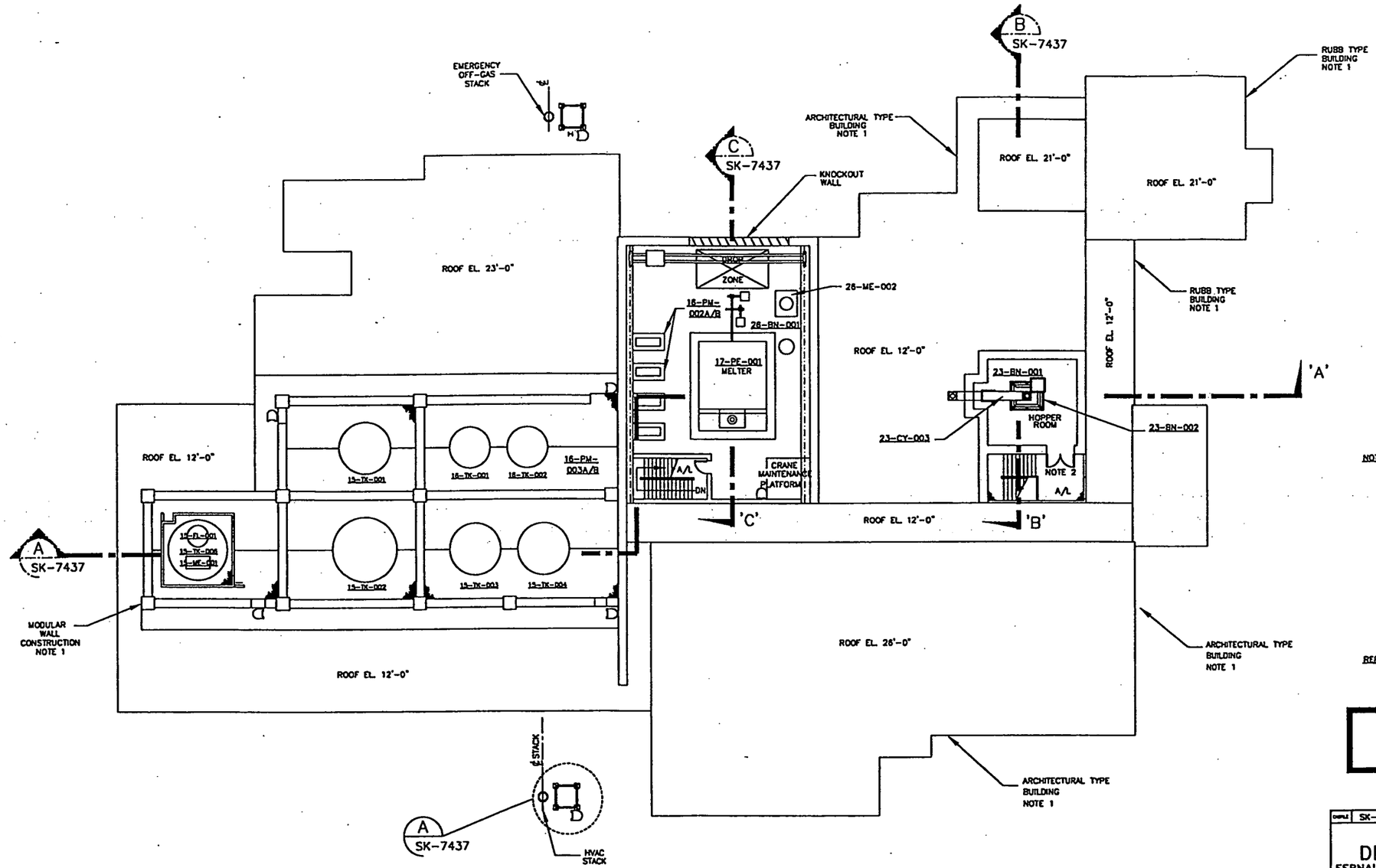


PLAN @ EL. 15'-0"

NOTES:

1. BUILDING CONSTRUCTION
   - CONCRETE FLOOR SLAB AND FOUNDATIONS.
   - ARCHITECTURAL TYPE WALLS CONSIST OF STEEL FRAME STRUCTURE, INSULATED METAL SIDING, MEMBRANE ROOFING SUPPORTED BY STEEL DECKING AND INSULATION BOARD.
   - MODULAR WALL CONSTRUCTION CONSISTS OF INTERLOCKING PREFABRICATED SHEILDING WALLS AND COLUMNS.
   - ALL OTHER SHEILDING WALLS ARE 2'-0" THICK CONCRETE.
   - RUBB TYPE BUILDING CONSISTS OF INSULATED MEMBRANE COVERING STEEL FRAMING.
2. SHEILD DOOR.

REFERENCE DRAWINGS

94X-5500-P-SK-7407
94X-5500-P-SK-7437

PRELIMINARY DRAWING

000075

0 10 20 40 60 80 100

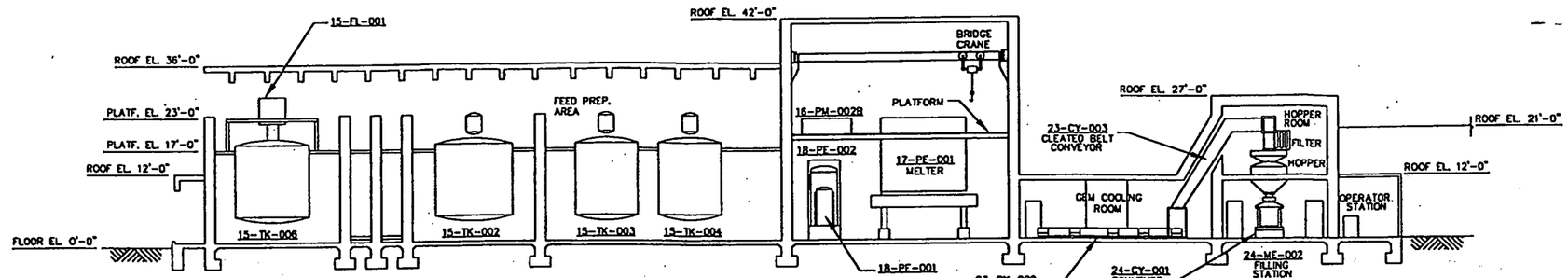
GRAPHIC SCALE IN FEET
3/64" = 1'-0"

Figure A-5 Gem Waste Form General Arrangement Drawing, Sheet 2

SK-7436		ACAD R13	
UNITED STATES DEPARTMENT OF ENERGY FERNALD ENVIRONMENTAL MANAGEMENT PROJECT			
FLUOR DANIEL FERNALD SILOS PROJECT CINCINNATI, OHIO			
FACILITY LAYOUT VITRIFICATION FACILITY – GEMS PLAN @ 15'-0" EL. WASTEFORM STUDY			
S. M. YANKEY	1/15/99	R. LOWERY	
CU4		3/64" = 1'-0"	
40730	WBS2.1.3.G.P	94X-5500-P-SK-7436	1 B

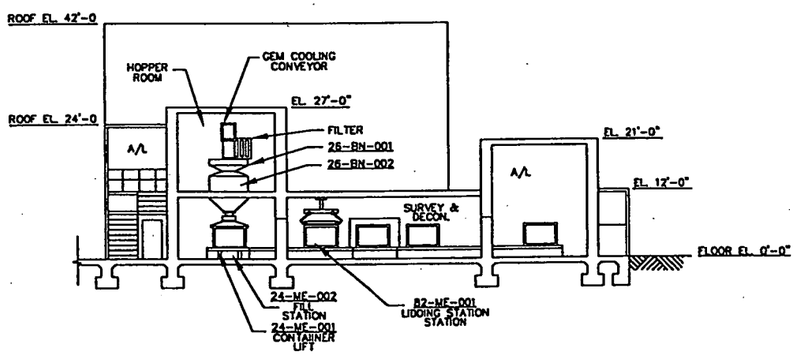
DISTRIBUTION CODE: XXX ACAD INITIALS: SMY DATE: 5/5/99

-- 8066



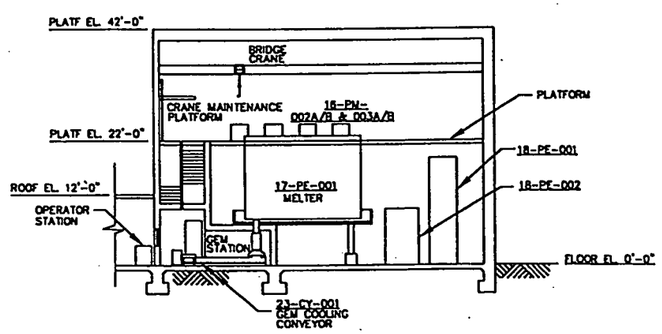
SECTION 'A' – 'A'

SEE SK-7407 & SK-7436



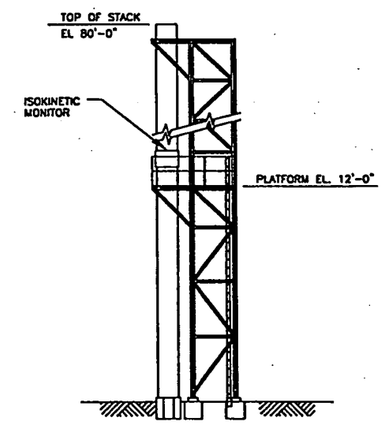
SECTION 'B' – 'B'

SEE SK-7407 & SK-7436



SECTION 'C' – 'C'

SEE SK-7407 & SK-7436



DETAIL A

N.T.S.

(TYP. EL. FOR HVAC & EMERGENCY OFF-GAS STACKS)

SEE SK-7407 & SK-7436

NOTES:

1. BUILDING CONSTRUCTION
   - CONCRETE FLOOR SLAB AND FOUNDATIONS.
   - ARCHITECTURAL TYPE WALLS CONSIST OF STEEL FRAME STRUCTURE, INSULATED METAL SIDING, MEMBRANE ROOFING SUPPORTED BY STEEL DECKING AND INSULATION BOARD.
   - MODULAR WALL CONSTRUCTION CONSISTS OF INTERLOCKING PREFABRICATED SHEILDING WALLS AND COLUMNS.
   - ALL OTHER SHEILDING WALLS ARE 2'-0" THICK CONCRETE.
   - RUBB TYPE BUILDING CONSISTS OF INSULATED MEMBRANE COVERING STEEL FRAMING.

REFERENCE DRAWINGS

94X-5500-P-SK-7436
94X-5500-P-SK-7407

PRELIMINARY DRAWING

000076

0 10 20 40 60 80 100

GRAPHIC SCALE IN FEET
3/64" = 1'-0"

DWG SK-7437		CHECKER ACAD R13	
UNITED STATES DEPARTMENT OF ENERGY FERNALD ENVIRONMENTAL MANAGEMENT PROJECT			
THIS DRAWING PREPARED BY FLUOR DANIEL FERNALD SILOS PROJECT CINCINNATI, OHIO			
DRAWING TITLE FACILITY LAYOUT VITRIFICATION FACILITY – GEMS SECTIONS AND DETAILS WASTEFORM STUDY			
DRAWN BY S. M. YANKEY	DATE 1/7/99	REVIEWED, CHECKED BY R. LOWERY	DATE
CHECKED BY	DATE	PLANT/BLDG. NO. DU4	PLANT
SCALE 3/64" = 1'-0"	CLASS	SUBMITTED FOR APPROVAL	DATE
APPROVAL RECOMMENDED	DATE	ENGINEERING CONTRACTOR	DATE
SITE PROJECT NO. 40730	SPECIAL DRAWING PROJ. NO. MBS2.1.3.G.P	DRAWING NO. 94X-5500-P-SK-7437	SHEET NO. 1
REV. NO. B			

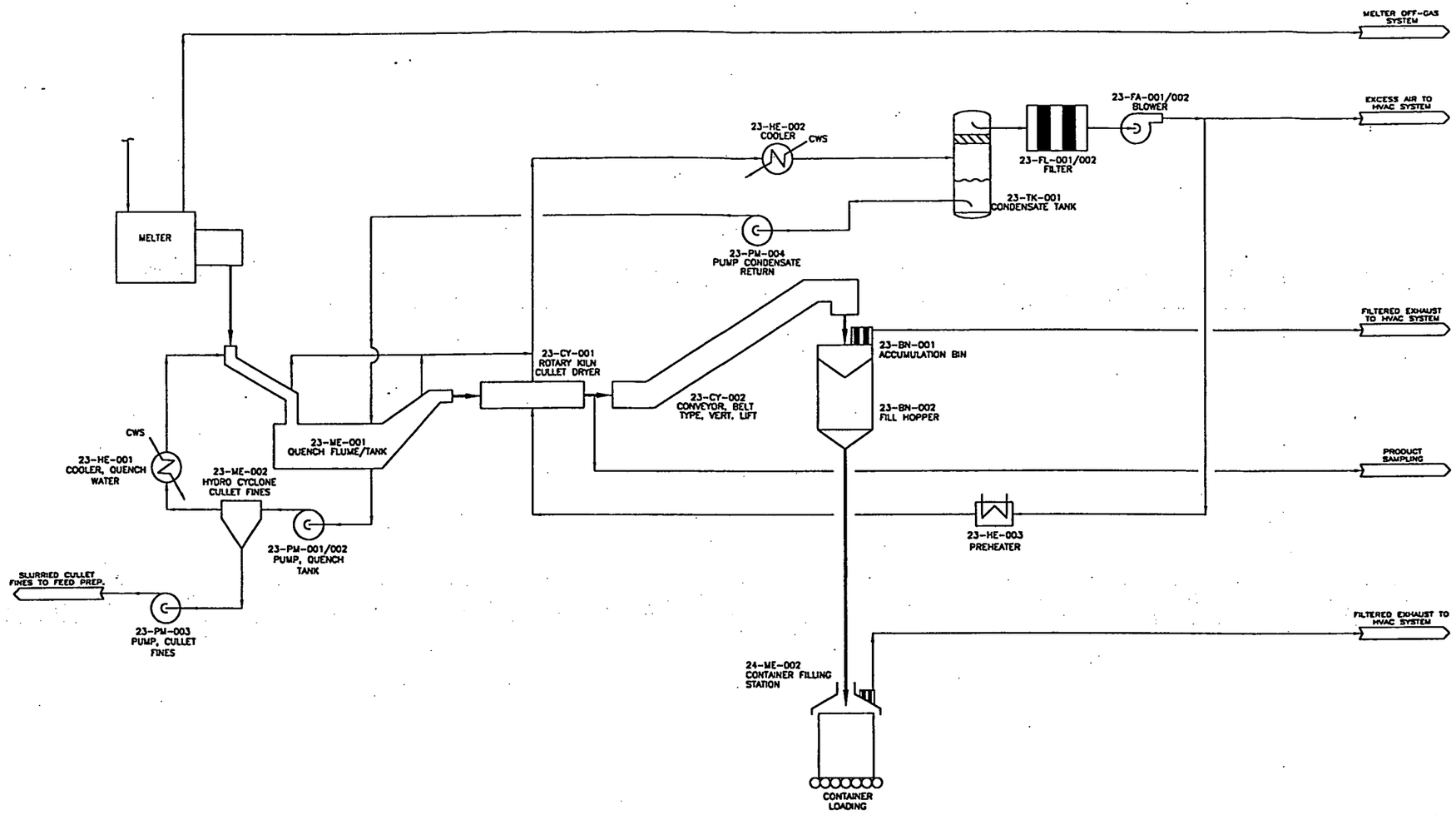
DISTRIBUTION CODE: XXX

ACAD

INITIALS: SMY
DATE: 3/3/99

Figure A-6 Gem Waste Form General Arrangement Drawing, Sheet 3

8066



PRELIMINARY DRAWING

DWG/LI SK-6021	CADD ACAD

UNITED STATES DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY
FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE
MECHANICAL FLOW DIAGRAM
CULLET PRODUCTION
VITRIFICATION – JOULE HEATED
WASTE FORM STUDY

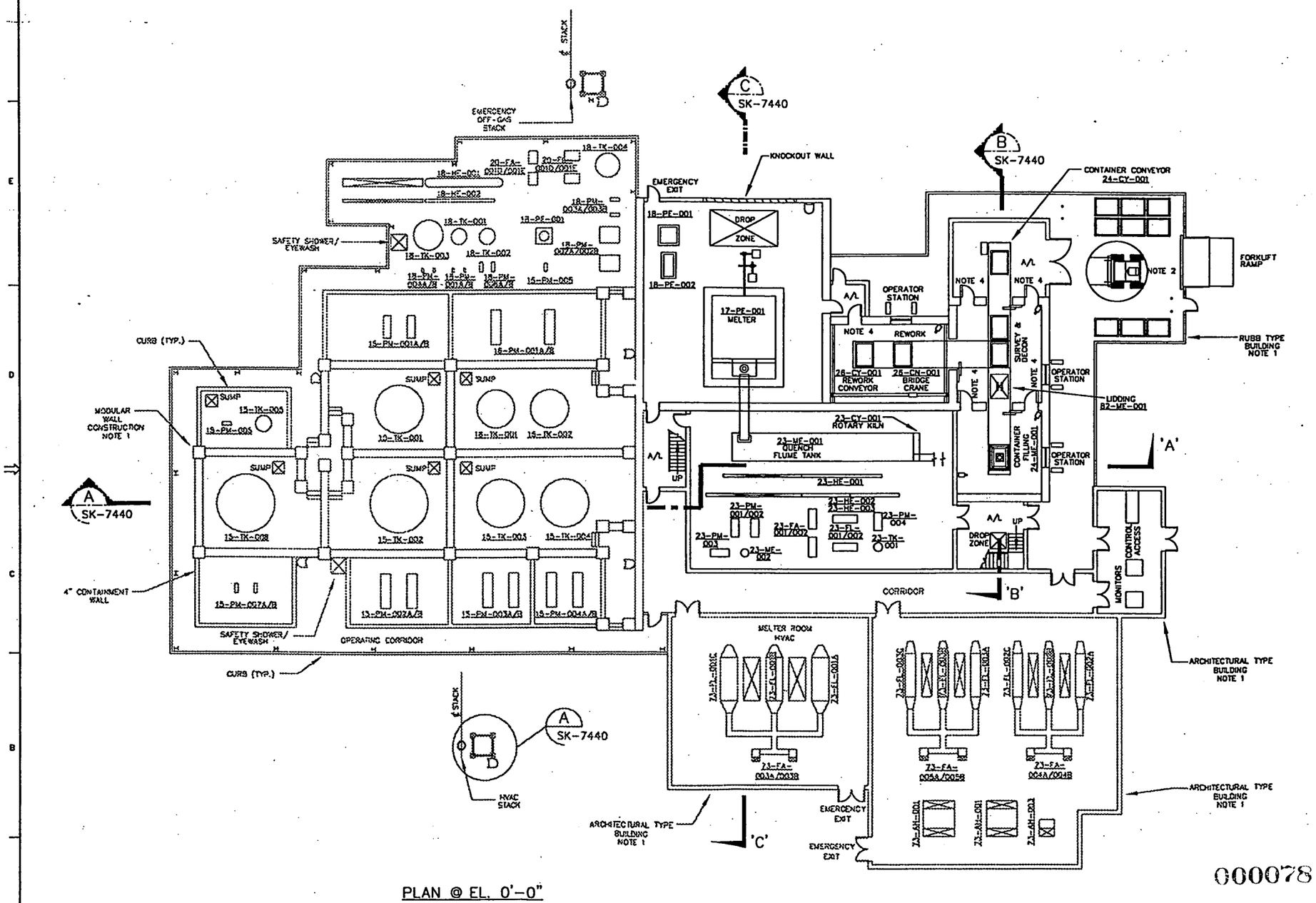
DRAWN BY S. M. YANKEY	DATE 05/03/99	SCHEMATIC CHECKED BY R. LOWERY	DATE	CHECKED BY S. YANKEY	DATE 7/7/99
FUNCTIONAL AREA DU4		AUTOCAD		SCALE NONE	CADD
SUBMITTED FOR APPROVAL		APPROVAL RECOMMENDED			
A-E DATE		ENGINEERING CONTROLS DATE			
SITE PROJECT NO. 40730	SYSTEM, CODE, PHASE, NO. NBS2.1.3.GP	DRAWING NO. 94X-5500-F-SK-6021		SHEET NO. 1	REV. NO. C

DISTRIBUTION CODE: XXX ACAD INITIALS: SMY DATE: 5/3/99

000077

Figure A-7 Cullet Waste Form MFD

-- 8066



PLAN @ EL. 0'-0"

NOTES:

1. BUILDING CONSTRUCTION
   - CONCRETE FLOOR SLAB AND FOUNDATIONS.
   - ARCHITECTURAL TYPE WALLS CONSIST OF STEEL FRAME STRUCTURE, INSULATED METAL SIDING, MEMBRANE ROOFING SUPPORTED BY STEEL DECKING AND INSULATION BOARD.
   - MODULAR WALL CONSTRUCTION CONSISTS OF INTERLOCKING PREFABRICATED SHIELDING WALLS AND COLUMNS.
   - ALL OTHER SHEILDING WALLS ARE 2'-0" THICK CONCRETE.
   - RUBB TYPE BUILDING CONSISTS OF INSULATED MEMBRANE COVERING STEEL FRAMING.
2. SHIELDED FORKLIFT DEDICATED TO VITRIFICATION FACILITY.
3. EMPTY CONTAINER STORAGE IS SINGLE STACK.
4. SHIELD DOOR.

REFERENCE DRAWINGS

94X-5500-P-SK-7439
94X-5500-P-SK-7440

LEGEND:

——— = REMAINS CONSTANT FOR ALL WASTE LOADING OPTIONS.

PRELIMINARY DRAWING

000078

0 10 20 40 60 80 100

GRAPHIC SCALE IN FEET
3/64" = 1'-0"

SK-7405 | ACAD R13

UNITED STATES DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY
FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE
FACILITY LAYOUT
VITRIFICATION FACILITY – CULLET
PLAN @ 0'-0" EL.
WASTEFORM STUDY

DRAWN BY E. M. MOORE	DATE 1/22/98	DESIGNED BY R. LOWERY	CHECKED BY S. M. YANKEY
SCALE 3/64" = 1'-0"			
40730	WBS2.1.3.G.P	94X-5500-P-SK-7405	SHEET NO. 1

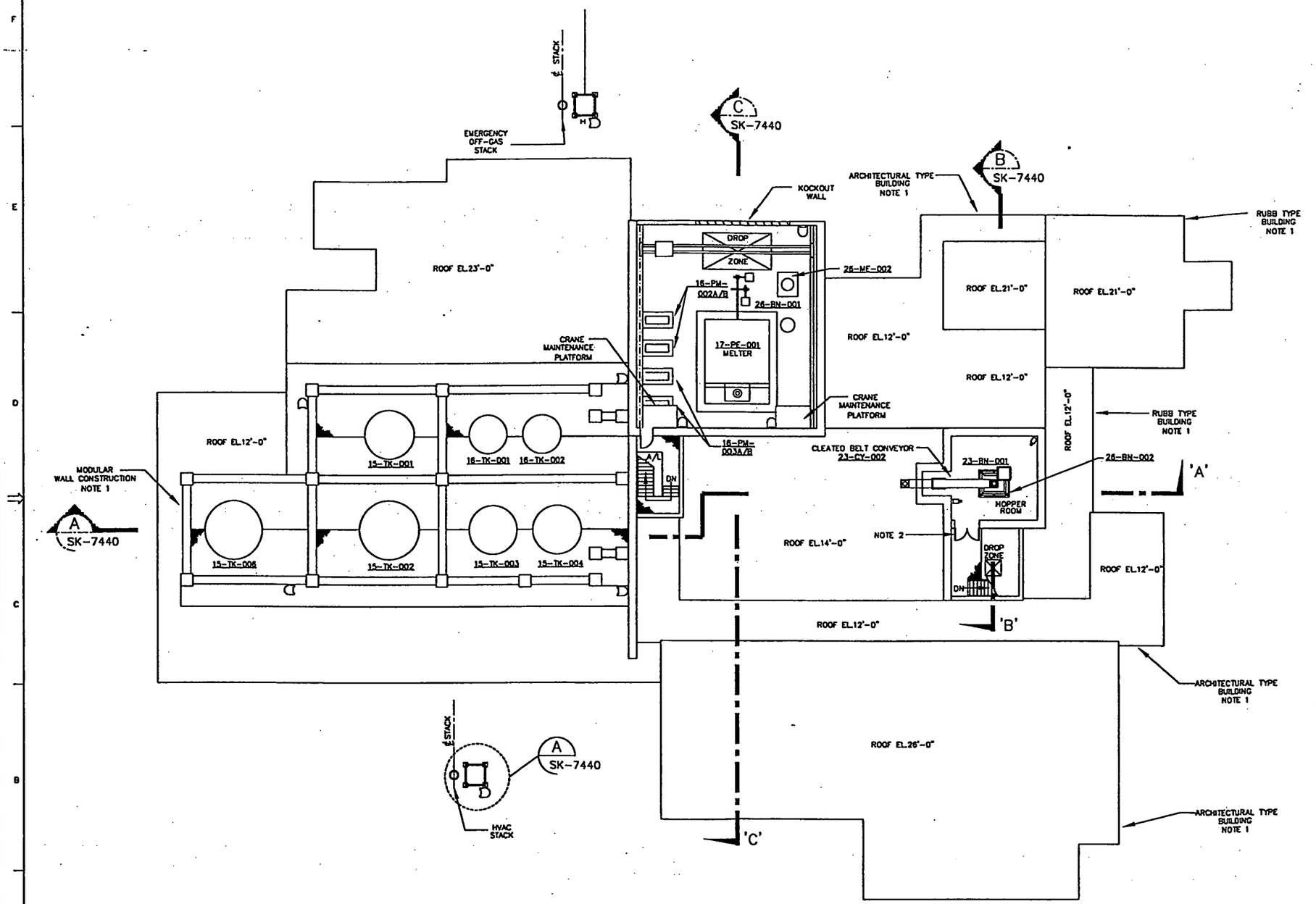
DISTRIBUTION CODE: XXX

ACAD

INITIALS: SHY
DATE: 3/3/99

Figure A-8 Cullet Waste Form General Arrangement Drawing, Sheet 1

8066



PLAN @ EL. 15'-0"

00079

0 10 20 40 60 80 100

GRAPHIC SCALE IN FEET
3/64" = 1'-0"

NOTES:

1. BUILDING CONSTRUCTION
   - CONCRETE FLOOR SLAB AND FOUNDATIONS.
   - ARCHITECTURAL TYPE WALLS CONSIST OF STEEL FRAME STRUCTURE, INSULATED METAL SIDING, MEMBRANE ROOFING SUPPORTED BY STEEL DECKING AND INSULATION BOARD.
   - MODULAR WALL CONSTRUCTION CONSISTS OF INTERLOCKING PREFABRICATED SHEILDING WALLS AND COLUMNS.
   - ALL OTHER SHEILDING WALLS ARE 2'-0" THICK CONCRETE.
   - RUBB TYPE BUILDING CONSISTS OF INSULATED MEMBRANE COVERING STEEL FRAMING.
2. SHEILD DOOR.

REFERENCE DRAWINGS

94X-5500-P-SK-7405
94X-5500-P-SK-7440

PRELIMINARY DRAWING

DWG SK-7439 CADD ACAD R13

UNITED STATES DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY
FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

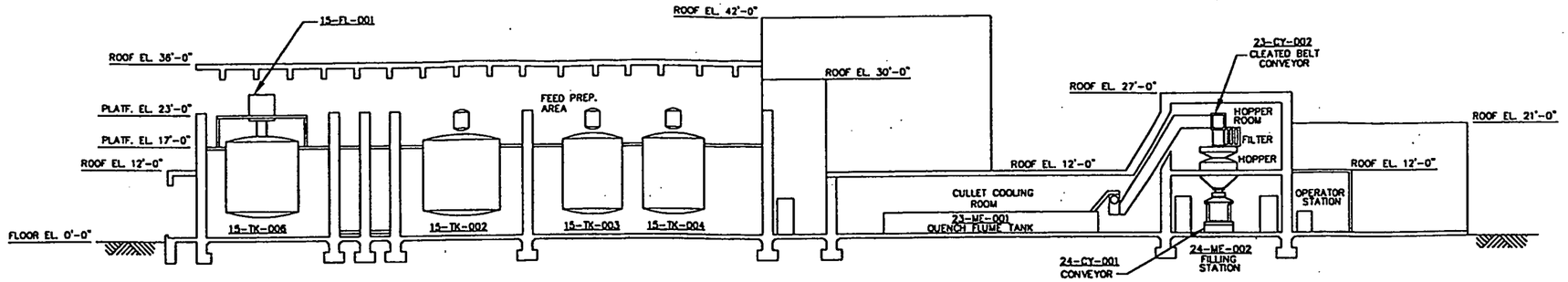
DRAWING TITLE
FACILITY LAYOUT
VITRIFICATION FACILITY - CULLET
PLAN @ 15'-0" EL.
WASTEFORM STUDY

DRAWN BY E. M. MOORE	DATE 1/22/99	ADMIN. CHECKED BY R. LOWERY	CHECKED BY S. M. YANKEY
PLANT/BLDG. NO. DU4		SCALE 3/64" = 1'-0"	
SUBMITTED FOR APPROVAL		APPROVAL RECOMMENDED	
SITE PROJECT NO. 40730	SITE CHART, PAGE, NO. H6S2.1.3.G.P	DRAWING NO. 94X-5500-P-SK-7439	SHEET NO. 1 REV. NO. B

DISTRIBUTION CODE: XXX ACAD INITIALS: SMT DATE: 3/3/99

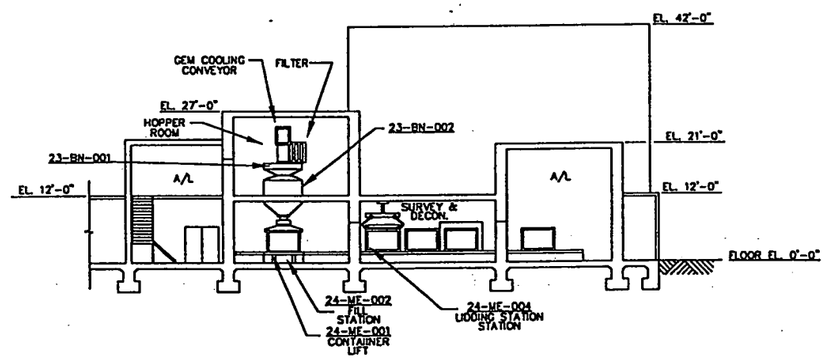
Figure A-9 Cullet Waste Form General Arrangement Drawing, Sheet 2

8066



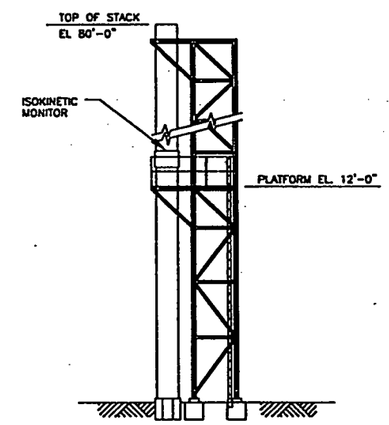
SECTION 'A' – 'A'

SEE SK-7405 & SK-7439



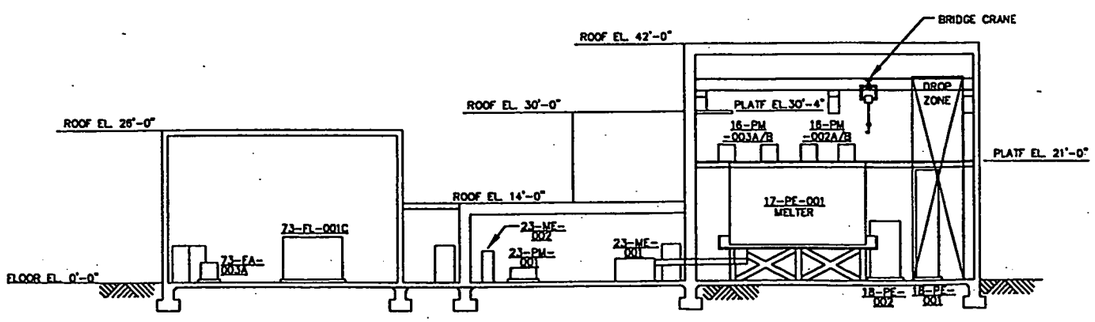
SECTION 'B' – 'B'

SEE SK-7405 & SK-7439



DETAIL A

N.T.S.
(TYP. EL. FOR
HVAC & EMERGENCY OFF-GAS STACKS)
SEE SK-7405 & SK-7439



SECTION 'C' – 'C'

SEE SK-7405 & SK-7439

000080

0 10 20 40 60 80 100

GRAPHIC SCALE IN FEET
3/64" = 1'-0"

NOTES:

1. BUILDING CONSTRUCTION
   - CONCRETE FLOOR SLAB AND FOUNDATIONS.
   - ARCHITECTURAL TYPE WALLS CONSIST OF STEEL FRAME STRUCTURE, INSULATED METAL SIDING, MEMBRANE ROOFING SUPPORTED BY STEEL DECKING AND INSULATION BOARD.
   - MODULAR WALL CONSTRUCTION CONSISTS OF INTERLOCKING PREFABRICATED SHEILDING WALLS AND COLUMNS.
   - ALL OTHER SHEILDING WALLS ARE 2'-0" THICK CONCRETE.
   - RUBB TYPE BUILDING CONSISTS OF INSULATED MEMBRANE COVERING STEEL FRAMING.

REFERENCE DRAWINGS

94X-5500-P-SK-7405
94X-5500-P-SK-7439

PRELIMINARY DRAWING

DWG NO. SK-7440 CADD ACAD R13

UNITED STATES
DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY
FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE
FACILITY LAYOUT
VITRIFICATION FACILITY – CULLET
SECTIONS AND DETAILS
WASTEFORM STUDY

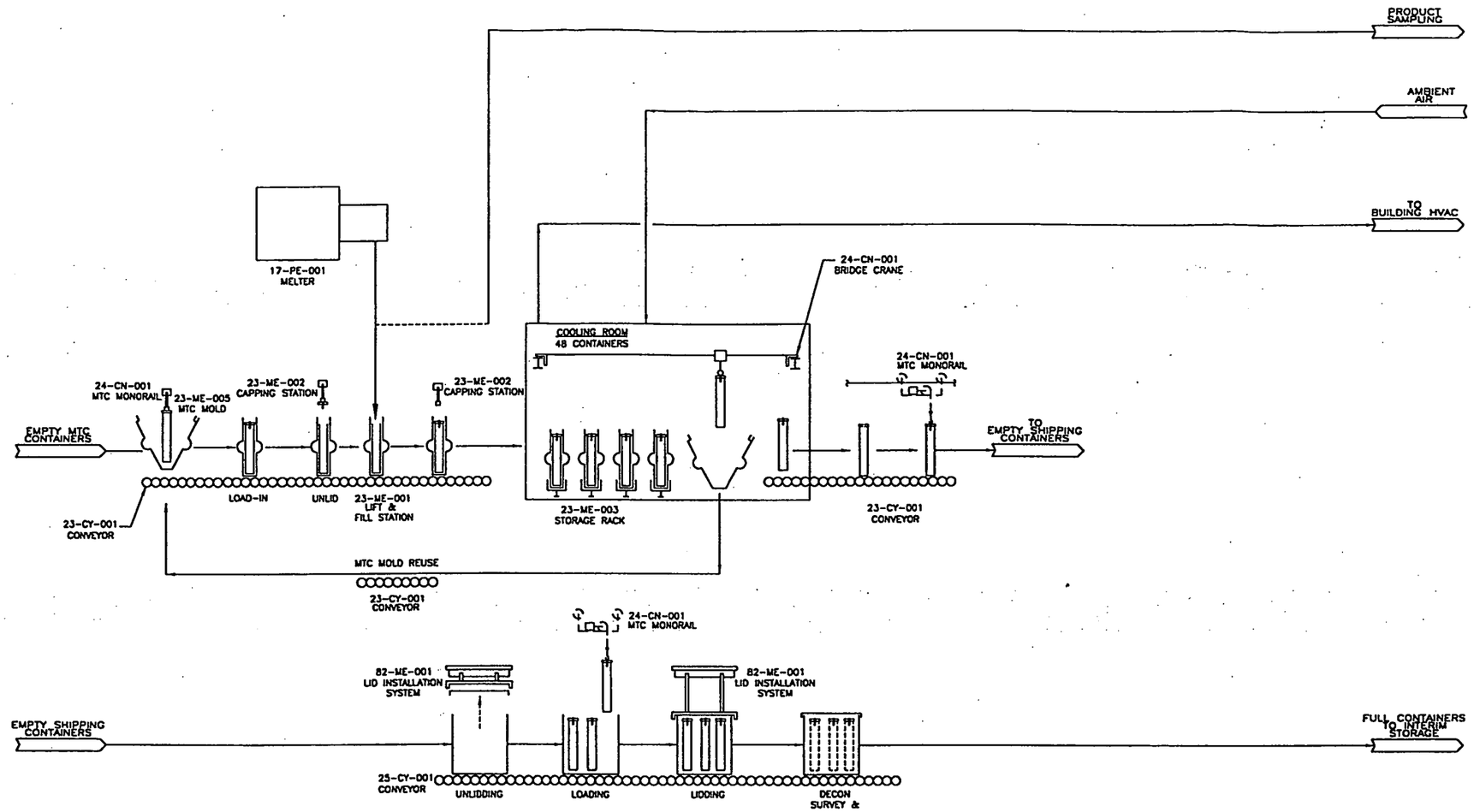
DRAWN BY	DATE	ENGINEER CHECKED BY	DATE	CHECKED BY	DATE
S. YANKEY	1/22/99	R. LOWERY	3/3/99		
WORKGROUP NO. OU4		FLOOR		SCALE 3/64" = 1'-0"	
SIGNATURE FOR APPROVAL		APPROVAL RECOMMENDED			
DATE	DATE	APPROVAL CONCURRENCE	DATE		

FMC PROJECT NO.	SPECIAL COMMEN. PROJ. NO.	DRAWING NO.	SHEET NO.	REV. NO.
40730	WBS2.1.3.G.P.	94X-5500-P-SK-7440	1	B

DISTRIBUTION CODE: XXX ACAD INITIALS: SMY DATE: 3/3/99

Figure A-10 Cullet Waste Form General Arrangement Drawing, Sheet 3

8066



PRELIMINARY DRAWING

DWG SK-6022	CODE ACAD

UNITED STATES DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY
FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE
MECHANICAL FLOW DIAGRAM
MONOLITH PRODUCTION
VITRIFICATION – JOULE HEATED
WASTE FORM STUDY

DRAWN BY S. M. YANKEY	DATE 1/5/99	ENGINEER CHECKED BY R. LOWERY	CHECKED BY
FUNCTIONAL NO. DU4		PLANT	SCALE NONE
SUBMITTED FOR APPROVAL		APPROVAL RECOMMENDED	
		APPROVAL CONCURRENCE	
SITE PROJECT NO. 40730	SYSTEM, STRUC, PHASE NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-F-SK-6022	SHEET NO. 1 REV. NO. C

DISTRIBUTION CODE: XXX

ACAD

INITIALS: SMT
DATE: 5/3/99

00081

Figure A-11 Monolith Waste Form MFD

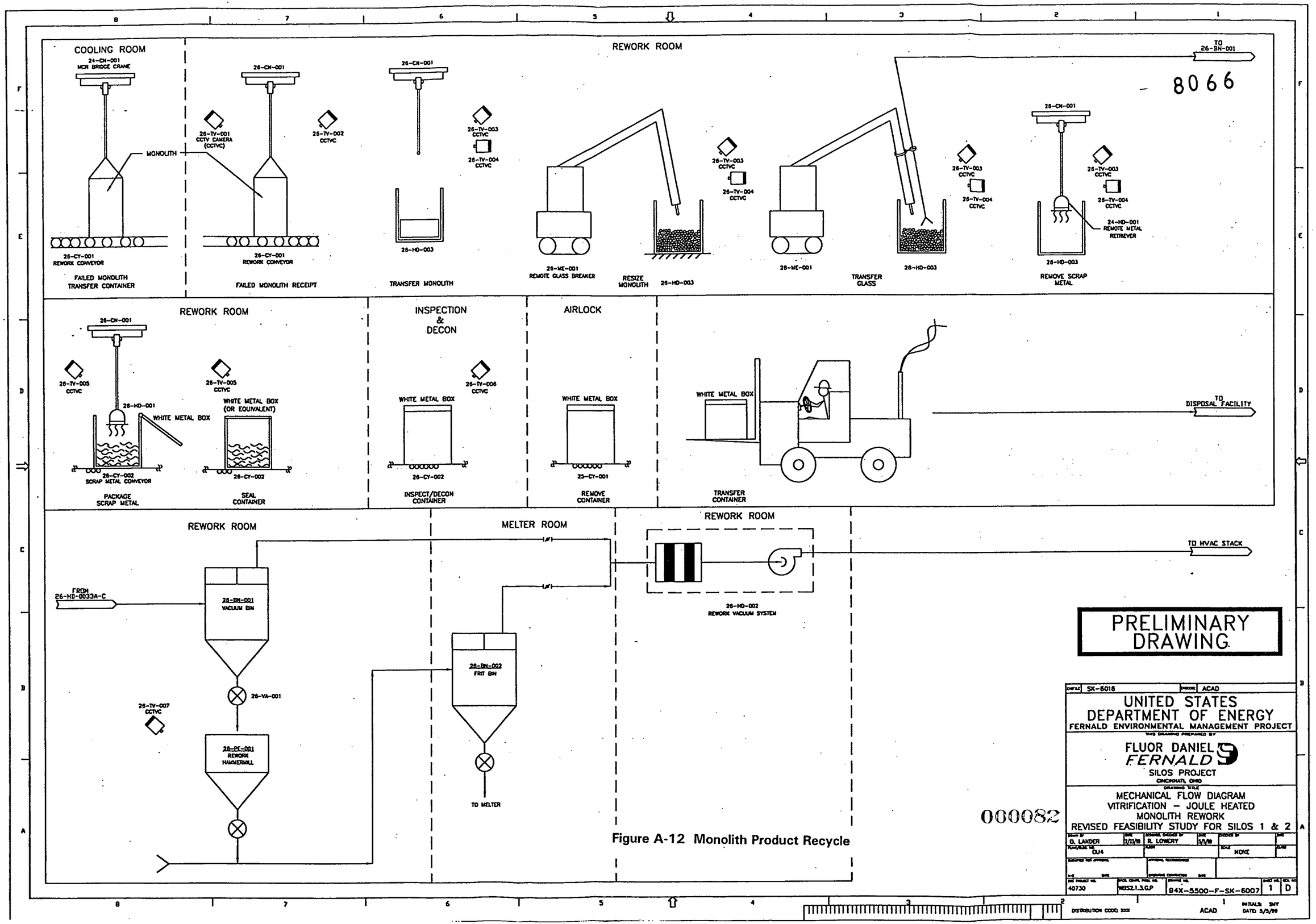
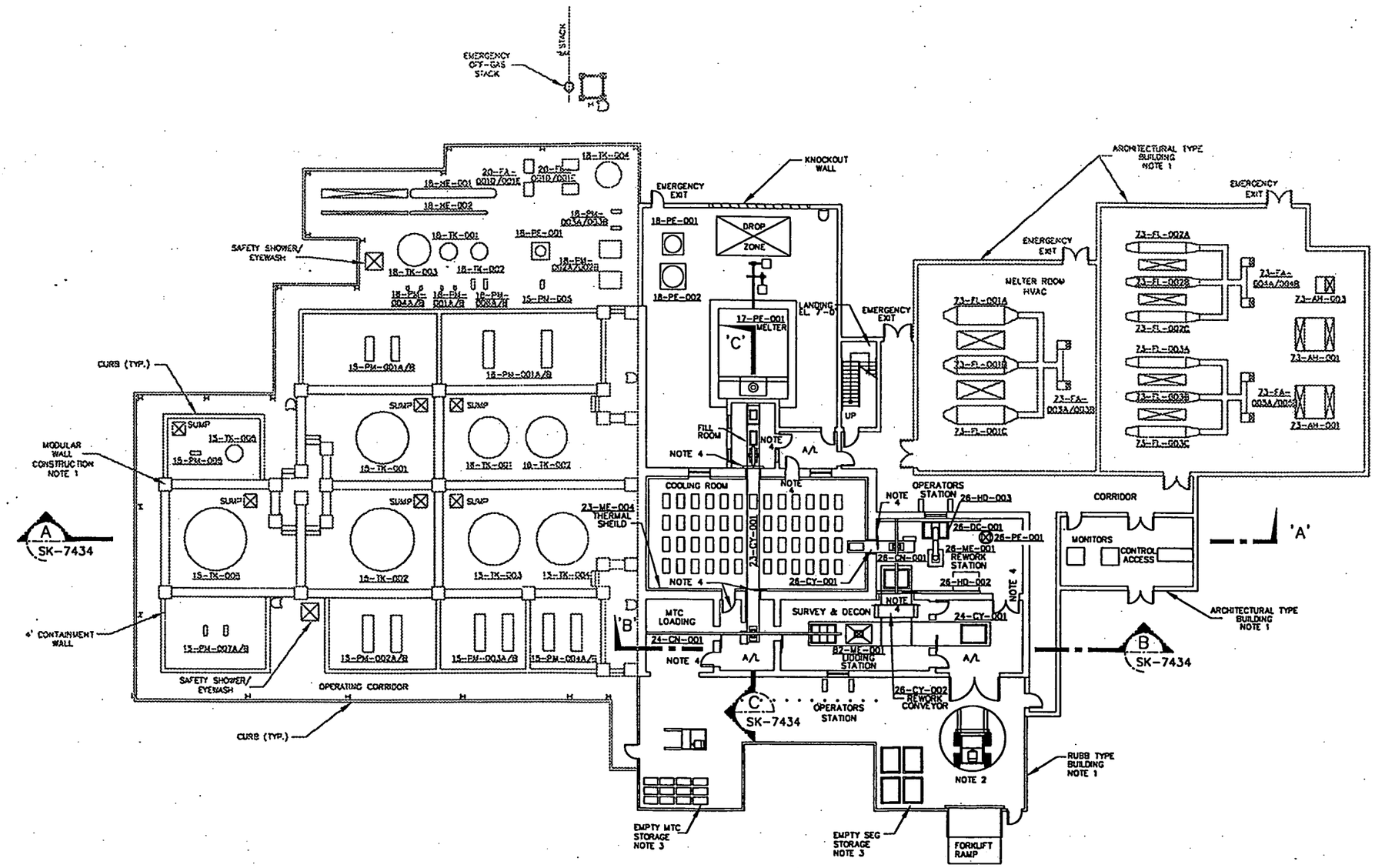


Figure A-12 Monolith Product Recycle

8066



PLAN @ EL. 0'-0"

000083

0 10 20 40 60 80 100

GRAPHIC SCALE IN FEET
3/64" = 1'-0"

NOTES:

1. BUILDING CONSTRUCTION
   - CONCRETE FLOOR SLAB AND FOUNDATIONS.
   - ARCHITECTURAL TYPE WALLS CONSIST OF STEEL FRAME STRUCTURE, INSULATED METAL SIDING, MEMBRANE ROOFING SUPPORTED BY STEEL DECKING AND INSULATION BOARD.
   - MODULAR WALL CONSTRUCTION CONSISTS OF INTERLOCKING PREFABRICATED SHEILDING WALLS AND COLUMNS.
   - ALL OTHER SHEILDING WALLS ARE 2'-0" THICK CONCRETE.
   - RUBB TYPE BUILDING CONSISTS OF INSULATED MEMBRANE COVERING STEEL FRAMING.
2. SHIELDED FORKLIFT DEDICATED TO VITRIFICATION FACILITY.
3. EMPTY CONTAINER STORAGE IS SINGLE STACK.
4. SHIELD DOOR.

REFERENCE DRAWINGS

94X-5500-P-SK-7433
94X-5500-P-SK-7434

LEGEND:

——— = REMAINS CONSTANT FOR ALL WASTE LOADING OPTIONS.

PRELIMINARY DRAWING

SK-7406 | ACAD R13

UNITED STATES DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY
FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

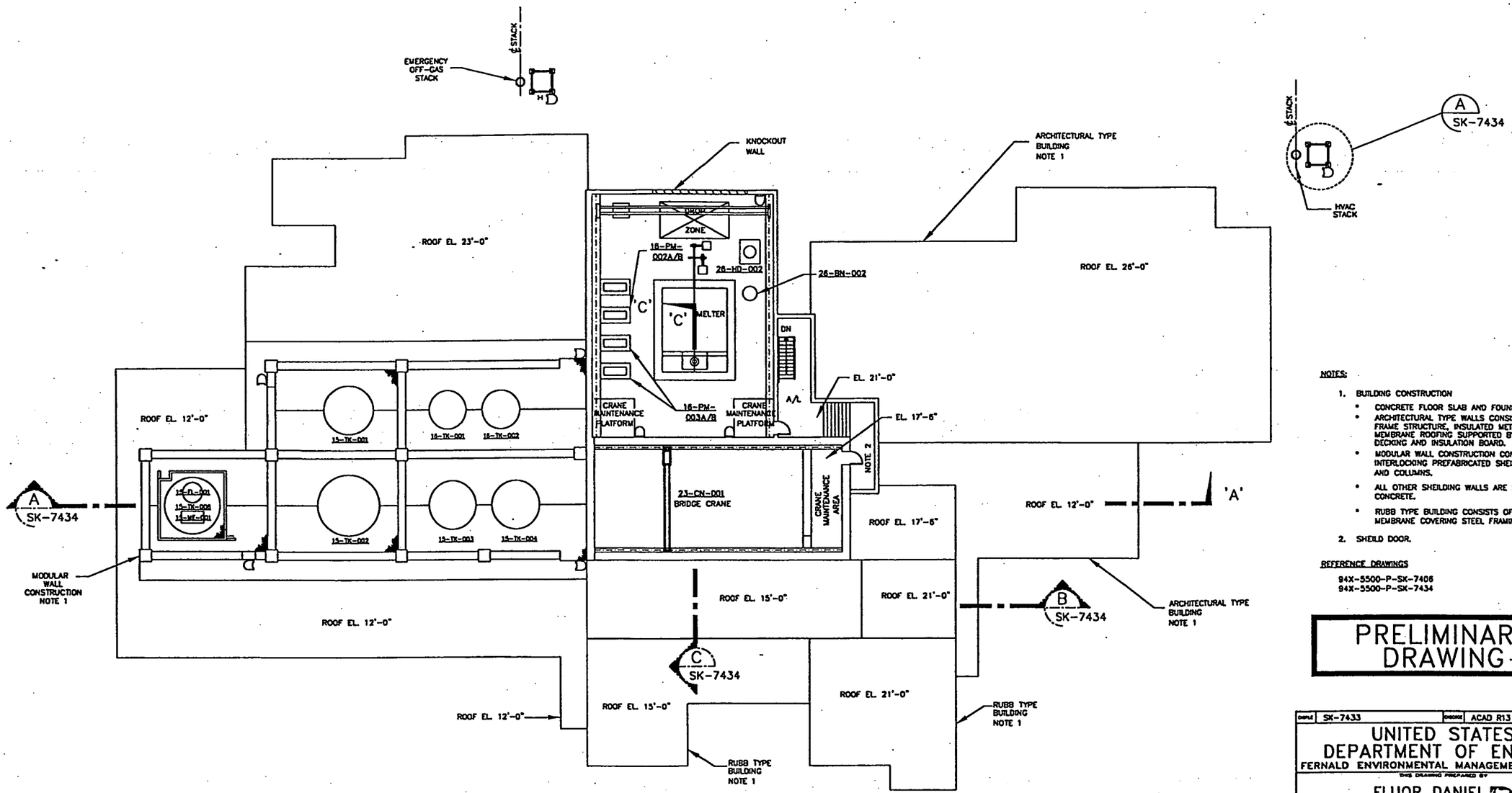
DRAWING TITLE
FACILITY LAYOUT
VITRIFICATION FACILITY – MONOLITH
PLAN @ 0'-0" EL.
WASTEFORM STUDY

S. M. YANKEY	1/7/99	R. LOWERY	E. MOORE 1/28/99
DU4			3/64" = 1'-0"
40730	WBS2.1.3.G.P	94X-5500-P-SK-7406	1 C

DISTRIBUTION CODE: XXX ACAD INITIALS: SMY DATE: 3/3/99

Figure A-13 Monolith Waste Form General Arrangement Drawing, Sheet 1

8066



PLAN @ EL. 14'-0" & ABOVE

NOTES:

1. BUILDING CONSTRUCTION
   - CONCRETE FLOOR SLAB AND FOUNDATIONS.
   - ARCHITECTURAL TYPE WALLS CONSIST OF STEEL FRAME STRUCTURE, INSULATED METAL SIDING, MEMBRANE ROOFING SUPPORTED BY STEEL DECKING AND INSULATION BOARD.
   - MODULAR WALL CONSTRUCTION CONSISTS OF INTERLOCKING PREFABRICATED SHEILDING WALLS AND COLUMNS.
   - ALL OTHER SHEILDING WALLS ARE 2'-0" THICK CONCRETE.
   - RUBB TYPE BUILDING CONSISTS OF INSULATED MEMBRANE COVERING STEEL FRAMING.
2. SHEILD DOOR.

REFERENCE DRAWINGS

94X-5500-P-SK-7406
94X-5500-P-SK-7434

PRELIMINARY DRAWING

DWG SK-7433	CHECKED ACAD R13

UNITED STATES DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY
FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

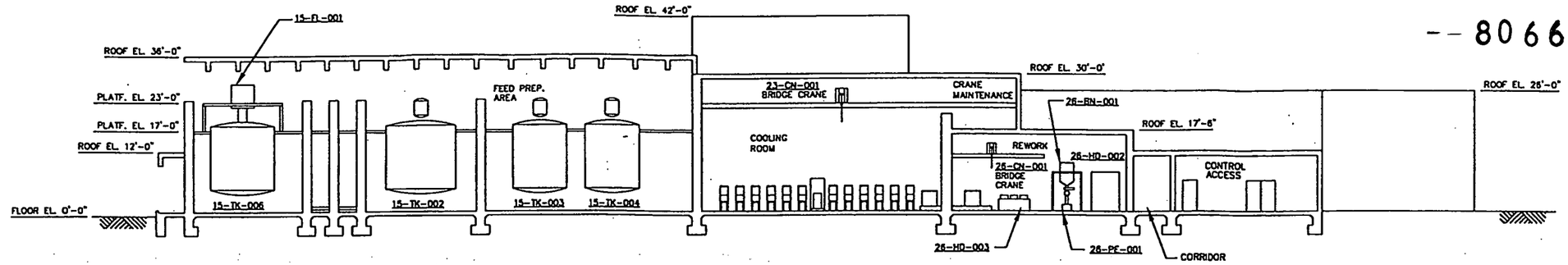
DRAWING TITLE
FACILITY LAYOUT
VITRIFICATION FACILITY - MONOLITH
PLAN @ EL. 14'-0"
WASTEFORM STUDY

DRAWN BY S. YANKEY	DATE 8/8/99	DESIGNED, CHECKED BY R. LOWERY	CHECKED BY E. MOORE DATE 1/2/99
PLANT/BLDG. NO. OU4		PLANT	SCALE 3/64" = 1'-0"
SUBMITTED FOR APPROVAL DATE		APPROVAL RECOMMENDED DATE	
DOE PROJECT NO. 40730	SYSTEM, COMPL. PROJ. NO. WESS2.1.3.G.P	DRAWING NO. 94X-5500-P-SK-7433	SHEET NO. 1 REV. NO. B

DISTRIBUTION CODE: XXX ACAD INITIALS: SMT DATE: 5/3/99

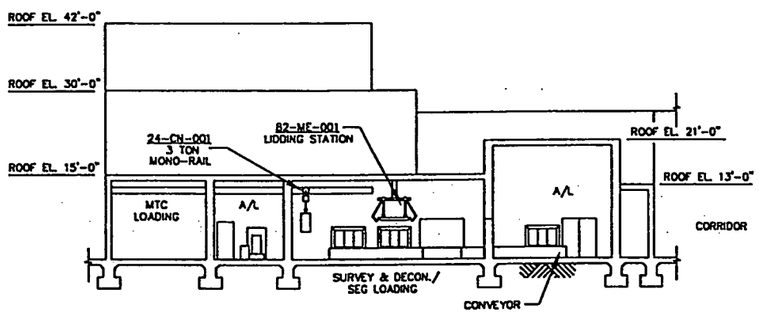
100084

Figure A-14 Monolith Waste Form General Arrangement Drawing, Sheet 2



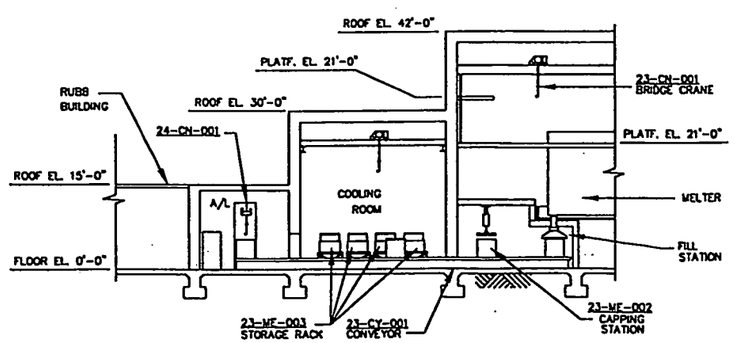
SECTION 'A' – 'A'

SEE SK-7406 & SK-7433



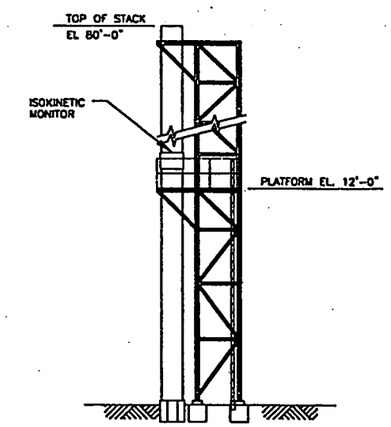
SECTION 'B' – 'B'

SEE SK-7406 & SK-7433



SECTION 'C' – 'C'

SEE SK-7406 & SK-7433



DETAIL A

N.T.S.

(TYP. EL. FOR HVAC & OFF-GAS STACKS)

SEE SK-7406 & SK-7433

NOTES:

1. BUILDING CONSTRUCTION
   - CONCRETE FLOOR SLAB AND FOUNDATIONS.
   - ARCHITECTURAL TYPE WALLS CONSIST OF STEEL FRAME STRUCTURE, INSULATED METAL SIDING, MEMBRANE ROOFING SUPPORTED BY STEEL DECKING AND INSULATION BOARD.
   - MODULAR WALL CONSTRUCTION CONSISTS OF INTERLOCKING PREFABRICATED SHEILDING WALLS AND COLUMNS.
   - ALL OTHER SHEILDING WALLS ARE 2'-0" THICK CONCRETE.
   - RUBB TYPE BUILDING CONSISTS OF INSULATED MEMBRANE COVERING STEEL FRAMING.

REFERENCE DRAWINGS

94X-5500-P-SK-7406
94X-5500-P-SK-7433

PRELIMINARY DRAWING

0 10 20 40 60 80 100

GRAPHIC SCALE IN FEET
3/64" = 1'-0"

000085

DWG SK-7434 | ACAD R13

UNITED STATES
DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY

FLUOR DANIEL FERNALD

SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE

FACILITY LAYOUT
VITRIFICATION FACILITY – MONOLITH
SECTIONS AND DETAILS
WASTEFORM STUDY

DRAWN BY S. YANCEY	DATE 1/8/99	DESIGNED, CHECKED BY R. LOWERY	DATE 1/10/99
PURCHASE NO. OU4		SCALE AS NOTED	
SUBMITTED FOR APPROVAL		APPROVAL RECOMMENDED	
DATE	DATE	DESIGNING ORGANIZATION	DATE

FMC PROJECT NO. 40730	SYSTEM, DRAWING, PHASE, NO. 16SS2.1.3.G.P	DRAWING NO. 94X-5500-P-SK-7434	SHEET NO. 1	REV. NO. B

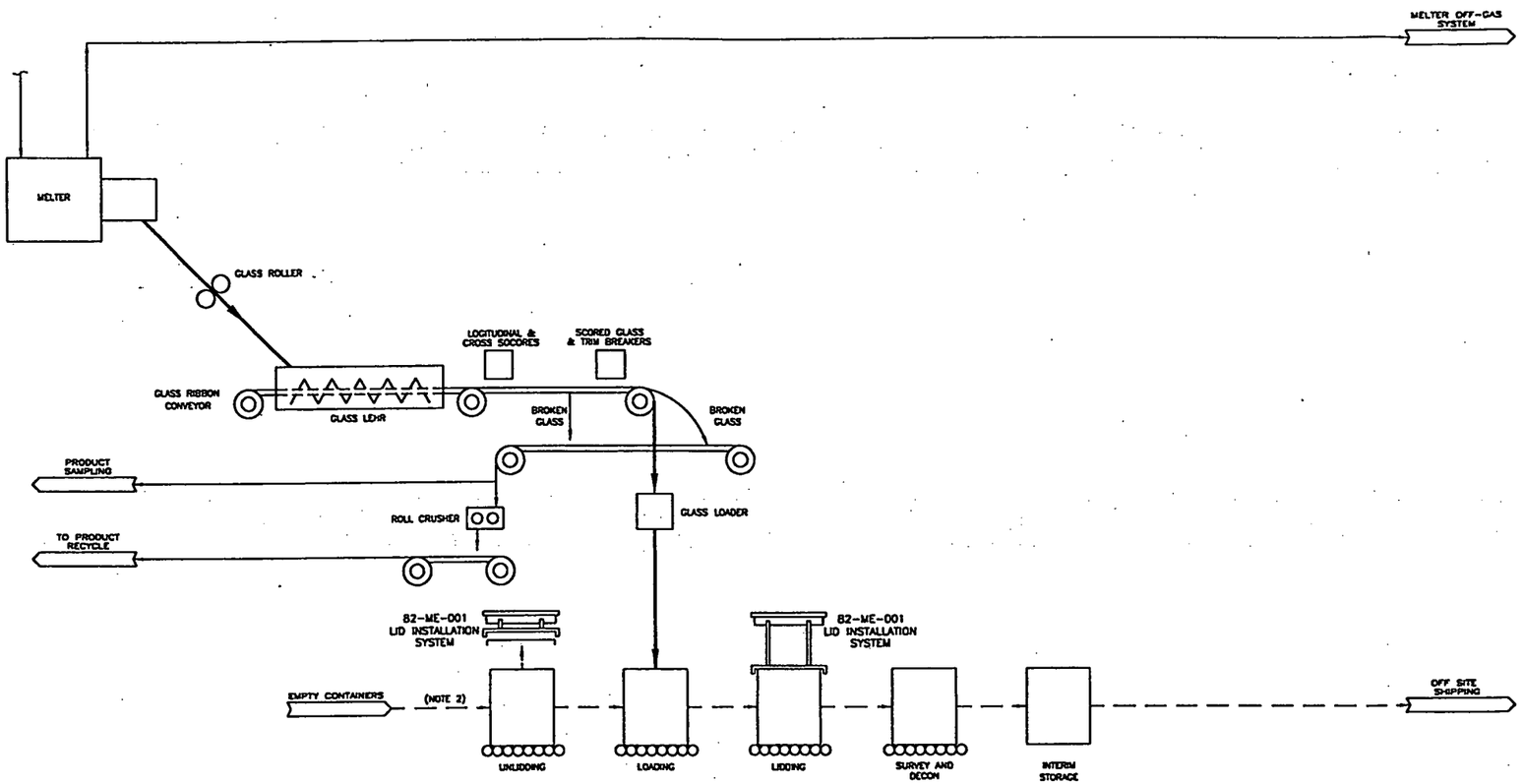
DISTRIBUTION CODE: XXX

ACAD

INITIALS: SWY
DATE: 3/3/99

Figure A-15 Monolith Waste Form General Arrangement Drawing, Sheet 3

8066



NOTE:

1. ALL PROCESS STEPS ARE ENCLOSED AND VENTED (NOT SHOWN).
2. FORKLIFT TO LOAD SHIPPING CONTAINER ONTO CONVEYOR.

PRELIMINARY DRAWING

000086

Figure A-16 Plate Glass Waste Form MFD

SK-6019 | ACAD

UNITED STATES DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY
FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE
MECHANICAL FLOW DIAGRAM
PLATE GLASS PRODUCTION
VITRIFICATION – JOULE HEATED
WASTE FORM STUDY

DRAWN BY S. M. YANKEY	DATE 03/03/99	REVIEWED, CHECKED BY R. LOWERY	DATE	CHECKED BY S. YANKEY	DATE
PLANT/BLDG. NO. DU4		AREA		SCALE NONE	CLASS
SUBMITTED FOR APPROVAL		APPROVAL RECOMMENDED			
O-E DATE		APPROVAL COMPLETED	DATE		
WBS PROJECT NO. 40730	OPER. CONTR. PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-F-SK-6019	SHEET NO. 1	SCH. NO. C	

DISTRIBUTION CODE: XXX

ACAD

INITIALS: SMY
DATE: 3/3/99

-- 8066

ATTACHMENT B

EQUIPMENT LISTING FOR GEM, CULLET, AND MONOLITH WASTE FORM ALTERNATIVES

WASTE FORM STUDY: GEMS

8066

EQUIP_ID	EQUIP_DESC	MATL COST	COMMENT
23-BN-001	HOPPER, ACCUMULATION	4,800	MOTORIZED CONTROLS. FRAME MOUNTED ONTOP OF 23-BN-002
23-BN-002	HOPPER, FILL	7,800	MOTORIZED CONTROLS. FRAME MOUNTED
23-CR-001	CONTROL STATION, CCTV	3,000	MICROPROCESSOR
23-CY-001	CONVEYOR, COOLING PLATE	38,000	INCLUDES CS ENCLOSURE
23-CY-002	CONVEYOR, PERFORATED	114,000	INCLUDES CS ENCLOSURE
23-CY-003	CONVEYOR, CLEATED BELT	7,000	VERTICAL CONVEYOR @ 45 DEGREE
23-FA-001	FAN, GEM COOLING	2,900	COOLS GEMS IN CONVEYOR. VARIABLE SPEED CONTROL
23-FA-002	FAN, GEM COOLING	2,900	BACKUP FAN UNIT
23-FL-001	HEPA FILTER, GEM COOLING	4,700	FILTERS GEM COOLING AIR
23-FL-002	HEPA FILTER, GEM COOLING	4,700	BACKUP FILTER
23-HE-001	HEAT EXCHANGER	1,200	REMOVES HEAT FROM MOLTEN GLASS
23-HE-002	HEAT EXCHANGER	1,200	REMOVES HEAT FROM MOLTEN GLASS
23-HE-003	HEAT EXCHANGER	1,200	REMOVES HEAT FROM MOLTEN GLASS
23-HE-004	HEAT EXCHANGER	1,200	REMOVES HEAT FROM MOLTEN GLASS
23-ME-001	GEM MACHINE	18,000	WATER COOLED GOB CUTTER, ROLLER, AND ENCLOSURE
23-ME-002	GEM MACHINE	18,000	WATER COOLED GOB CUTTER, ROLLER, AND ENCLOSURE
23-ME-003	GEM MACHINE	18,000	WATER COOLED GOB CUTTER, ROLLER, AND ENCLOSURE
23-ME-004	GEM MACHINE	18,000	WATER COOLED GOB CUTTER, ROLLER, AND ENCLOSURE
23-TV-001	CCTV, GEM-1	15,500	COLOR CAMERA SYSTEM w/PAN, TILT AND FULL ROTATION
23-TV-002	CCTV, GEM-2	15,500	COLOR CAMERA SYSTEM w/PAN, TILT AND FULL ROTATION
23-TV-003	CCTV, GEM-3	15,500	COLOR CAMERA SYSTEM w/PAN, TILT AND FULL ROTATION
23-TV-004	CCTV, GEM-4	15,500	COLOR CAMERA SYSTEM w/PAN, TILT AND FULL ROTATION
23-TV-005	CCTV, COOLING PLATE CNYR	15,500	COLOR CAMERA SYSTEM w/PAN, TILT AND FULL ROTATION
24-CY-001	CONVEYOR	114,300	2-WAY TRANSFER OF SHIPPING CONTAINER
24-ME-001	LIFT, HYDRAULIC	29,400	PROVIDES 1 FT LIFT TO MATE CONTAINER WITH FILL STATION (24-ME-002).
24-ME-002	CONTAINER FILLING STATION W/HEPA	9,000	CONNECTS THE FILL BIN TO CONTAINERS DURING FILLING
24-ME-003	VACUUM, HEPA	6,000	DECONTAMINATE SEG
24-SC-001	SCALE, CONTAINER	4,000	PROVIDES VERIFICATION OF CONTAINER WEIGHT
24-TV-001	CCTV, FILL ROOM	15,500	COLOR CAMERA SYSTEM w/PAN, TILT AND FULL ROTATION
24-TV-002	CCTV, INSPEC/DECON ROOM	15,500	COLOR CAMERA SYSTEM w/PAN, TILT AND FULL ROTATION
26-BN-001	FILTER/RECEIVER	4,800	MOUNTED ABOVE MELTER
26-CN-001	CRANE, REWORK	38,000	FLOOR OPERATED BRIDGE CRANE USED FOR REMOVING WASTE FORM FROM SHIPPING CONTAINER USING PNEUMATIC TOOLS
26-CY-001	CONVEYOR, REWORK	28,000	2-WAY TRANSFER OF SHIPPING CONTAINER TO REWORK
26-ME-001	GULPER TOOL	500	FLUIDIZE GEMS FOR TRANSFER
26-ME-002	VACUUM, HEPA	37,000	VACUUM SYSTEM WITH HEPA FILTERS. 6" DIAMETER HOSE FOR TRANSPORTING GEMS FROM CONTAINER TO 26-DC-001.
26-TV-001	CCTV, CONTAINER INSPECTION	15,500	COLOR CAMERA SYSTEM w/PAN, TILT AND FULL ROTATION
26-TV-002	CCTV, PRODUCT RETRIEVAL	15,500	COLOR CAMERA SYSTEM w/PAN, TILT AND FULL ROTATION

000088

WASTE FORM STUDY: GEMS

8066

EQUIP_ID	EQUIP_DESC	MATL COST	COMMENT
26-TV-003	CCTV, MELTER RECYCLE	15,500	COLOR CAMERA SYSTEM w/PAN, TILT AND FULL ROTATION
26-VA-001	FEEDER, ROTARY STAR	2,300	ISOLATES 26-DC-001 AND FEEDS MELTER
82-ME-001	LIDDING STATION	225,500	REMOTELY TIGHTEND BOLTS ON SHIPPING CONTAINER

000089

WASTE FORM STUDY: CULLET

EQUIP_ID	EQUIP_DESC	MATL COST	COMMENT - 8066
23-BN-001	HOPPER, ACCUMULATION	5,300	MOTORIZED CONTROLS. FRAME MOUNTED ONTOP OF 23-BN-002
23-BN-002	HOPPER, FILL	8,100	MOTORIZED CONTROLS. FRAME MOUNTED
23-CR-001	CONTROL STATION, CCTV	3,000	MICROPROCESSOR
23-CY-001	CONVEYOR, ROTARY KILN TYPE	10,000	
23-CY-002	CONVEYOR, CLEATED BELT	7,000	VERTICAL CONVEYOR @ 45 DEGREE
23-FA-001	FAN, CULLET DRYER	3,500	PRIMARY FAN
23-FA-002	FAN, CULLET DRYER	3,500	BACKUP FAN
23-FL-001	FILTER, CULLET DRYER SYSTEM	2,500	
23-FL-002	FILTER, CULLET DRYER SYSTEM	2,500	BACKUP FILTER
23-HE-001	HEAT EXCHANGER, QUENCH WATER	9,600	REMOVES HEAT FROM QUENCH TANK TO COOLING TOWER
23-HE-002	HEAT EXCHANGER, CULLET DRYER	40,800	FINNED AIR TUBE TYPE. REMOVES HEAT FROM CULLET DRYER AIR
23-HE-003	PREHEATER, CULLET DRYER	6,600	ELECTRIC RESISTANT. HEATS AIR FOR CULLET DRYING
23-ME-001	QUENCH SYSTEM	250,000	INCLUDES QUENCH TANK AND FLUME
23-ME-002	HYDROCYCLONE	1,700	REMOVE BULK OF CULLET FINES
23-PM-001	PUMP, QUENCH TANK		PRIMARY PUMP. COST INCLD IN 23-ME-001
23-PM-002	PUMP, QUENCH TANK		BACKUP PUMP. COST INCLD IN 23-ME-001
23-PM-003	PUMP, CULLET FINES	2,200	RETURNS CULLET FINES TO FEED PREP TANK
23-PM-004	PUMP, CONDENSATE RTN	3,300	
23-PM-005	PUMP, COOLING TOWER WATER	1,900	PROVIDES COOLING TOWER WATER FOR COOLING QUENCH TANK
23-PM-006	PUMP, COOLING TOWER WATER	1,900	PROVIDES COOLING TOWER WATER FOR COOLING QUENCH TANK
23-TK-001	TANK, CONDENSATE	200	
23-TV-001	CCTV, CULLET	15,500	COLOR CAMERA SYSTEM w/PAN, TILT AND FULL ROTATION
23-TV-002	CCTV, ROTARY KILN	15,500	COLOR CAMERA SYSTEM w/PAN, TILT AND FULL ROTATION
24-CY-001	CONVEYOR	114,300	2-WAY TRANSFER OF SHIPPING CONTAINER
24-ME-001	LIFT, HYDRAULIC	29,400	PROVIDES 1 FT LIFT TO MATE CONTAINER WITH FILL STATION (24-ME-002).
24-ME-002	CONTAINER FILLING STATION W/HEPA	9,000	CONNECTS THE FILL BIN TO CONTAINERS DURING FILLING
24-ME-003	VACUUM, HEPA	6,000	DECONTAMINATE SEG
24-SC-001	SCALE, CONTAINER	4,000	PROVIDES VERIFICATION OF CONTAINER WEIGHT
24-TV-001	CCTV, FILL ROOM	15,500	COLOR CAMERA SYSTEM w/PAN, TILT AND FULL ROTATION
24-TV-002	CCTV, INSPEC/DECON ROOM	15,500	COLOR CAMERA SYSTEM w/PAN, TILT AND FULL ROTATION
26-BN-001	FILTER/RECEIVER	4,800	MOUNTED ABOVE MELTER
26-CN-001	CRANE, REWORK	38,000	FLOOR OPERATED BRIDGE CRANE USED FOR REMOVING WASTE FORM FROM SHIPPING CONTAINER USING PNEUMATIC TOOLS
26-CY-001	CONVEYOR, REWORK	28,000	2-WAY TRANSFER OF SHIPPING CONTAINER TO REWORK
26-ME-001	GULPER TOOL	500	FLUIDIZE CULLET FOR TRANSFER
26-ME-002	VACUUM, HEPA	37,000	VACUUM SYSTEM WITH HEPA FILTERS. 6" DIAMETER HOSE FOR TRANSPORTING CULLET FROM CONTAINER TO 26-DC-001.
26-TV-001	CCTV, CONTAINER INSPECTION	15,500	COLOR CAMERA SYSTEM w/PAN, TILT AND FULL ROTATION
26-TV-002	CCTV, PRODUCT RETRIEVAL	15,500	COLOR CAMERA SYSTEM w/PAN, TILT AND FULL ROTATION

000090

WASTE FORM STUDY: CULLET

EQUIP_ID	EQUIP_DESC	MATL COST	COMMENT 8066
26-TV-003	CCTV, MELTER RECYCLE	15,500	COLOR CAMERA SYSTEM w/PAN, TILT AND FULL ROTATION
26-VA-001	FEEDER, ROTARY STAR	2,300	ISOLATES 26-DC-001 AND FEEDS MELTER
82-ME-001	LIDDING STATION	225,500	REMOTELY TIGHTEND BOLTS ON SHIPPING CONTAINER

000091

WASTE FORM STUDY: MONOLITH

8066

EQUIP_ID	EQUIP_DESC	MATL COST	COMMENT
23-CN-001	BRIDGE CRANE	88,000	REMOTE OPERATED, 5-TON
23-CR-001	CONTROL STATION, CCTV	3,000	MICROPROCESSOR
23-CY-001	CONVEYOR, MTC	124,000	PRICE INCLUDES 4 INDEPENDENT SECTIONS (15' EA) OF CONVEYOR FOR ENHANCED MTC HANDLING
23-ME-001	LIFT STATION, MTC	10,000	LIFTS/LOWERS MTC TO/FROM MELTER
23-ME-002	CAPPING STATION	12,500	PROVIDES CLOSURE FOR MONOLITH TRANSFER
23-ME-003	STORAGE RACKS (4)	16,000	4 RACKS FOR MONOLITH AND BASKET
23-ME-004	THERMAL SHIELD PANEL	14,250	w/INSULATION TO PROTECT CONCRETE WALLS
23-ME-005	MTC MOLD	135,000	75-SPRING LOADED MTC MOLDS
23-TV-001	CCTV, MONOLITH POUR	15,500	COLOR CAMERA SYSTEM w/PAN, TILT AND FULL ROTATION
23-TV-002	CCTV, CAPPING	15,500	COLOR CAMERA SYSTEM w/PAN, TILT AND FULL ROTATION
23-TV-003	CCTV, COOLING ROOM-1	15,500	COLOR CAMERA SYSTEM w/PAN, TILT AND FULL ROTATION
23-TV-004	CCTV, COOLING ROOM-2	15,500	COLOR CAMERA SYSTEM w/PAN, TILT AND FULL ROTATION
23-TV-005	CCTV, COOLING ROOM-3	15,500	COLOR CAMERA SYSTEM w/PAN, TILT AND FULL ROTATION
23-TV-006	CCTV, COOLING ROOM-4	15,500	COLOR CAMERA SYSTEM w/PAN, TILT AND FULL ROTATION
23-TV-007	CCTV, COOLING ROOM-5	15,500	COLOR CAMERA SYSTEM w/PAN, TILT AND FULL ROTATION
24-CN-001	MONORAIL w/TROLLEY&HOIST	12,500	15' LIFT, 2-TON
24-CY-001	CONVEYOR	92,000	2-WAY TRANSFER OF SHIPPING CONTAINER
24-ME-001	HEPA VACUUM	6,000	DECONTAMINATE SEG
24-SC-001	SCALE, CONTAINER	4,000	PROVIDES VERIFICATION OF CONTAINER WEIGHT
24-TV-001	CCTV, LOAD ROOM-1	15,500	COLOR CAMERA SYSTEM w/PAN, TILT AND FULL ROTATION
24-TV-002	CCTV, LOAD ROOM-2	15,500	COLOR CAMERA SYSTEM w/PAN, TILT AND FULL ROTATION
24-TV-003	CCTV, INSPECT/DECON ROOM	15,500	COLOR CAMERA SYSTEM w/PAN, TILT AND FULL ROTATION
26-BN-001	FILTER/RECEIVER	4,800	MOUNTED ABOVE HAMMERMILL
26-BN-002	FILTER/RECEIVER	4,800	MOUNTED ABOVE MELTER
26-CN-001	BRIDGE CRANE, REWORK AREA	68,000	15' LIFT, 5-TON
26-CY-001	CONVEYOR, REWORK	13,000	GRAVITY CONVEYOR TO TRANSFER MONOLITH TO RECYCLE
26-CY-002	CONVEYOR, REWORK	20,000	TRANSFER 26-HD-004 (WMB) TO INSPECT/DECON
26-HD-001	METAL RETRIEVER	6,000	ELECTROMAGNET ATTACHMENT TO 26-CN-001
26-HD-002	VACUUM, HEPA	75,000	VACUUM SYSTEM WITH HEPA FILTERS. 6" DIAMETER HOSE FOR TRANSPORTING RECYCLE GLASS UPTO 3" DIAMETER
26-HD-003	ENCLOSURES (3, A-C)	9,000	CONTAINS MONOLITHS DURING BULK SIZE REDUCTION BY 26-ME-001
26-ME-001	REMOTE BREAKER	100,000	OPENS MTC, REDUCES MONOLITH TO CULLET, VACUUM ATTACHMENT
26-ME-002	HEPA VACUUM	13,000	DECONTAMINATE 26-HD-004 IN VESTIBULE, HEPA FILTER INCLUDED
26-PE-001	HAMMERMILL, REWORK	18,000	REDUCES CULLET TO FRIT FOR RECYCLE
26-TV-001	CCTV, RECYCLE ROOM-1	15,500	COLOR CAMERA SYSTEM w/PAN, TILT AND FULL ROTATION
26-TV-002	CCTV, RECYCLE ROOM-2	15,500	COLOR CAMERA SYSTEM w/PAN, TILT AND FULL ROTATION
26-TV-003	CCTV, RECYCLE ROOM-3	15,500	COLOR CAMERA SYSTEM w/PAN, TILT AND FULL ROTATION
26-TV-004	CCTV, CRUSHER ROOM-4	15,500	COLOR CAMERA SYSTEM w/PAN, TILT AND FULL ROTATION

000092

WASTE FORM STUDY: MONOLITH

-- 8066

EQUIP_ID	EQUIP_DESC	MATL COST	COMMENT
26-TV-005	CCTV, SCRAP METAL	15,500	COLOR CAMERA SYSTEM w/PAN, TILT AND FULL ROTATION
26-TV-006	CCTV, INSPECT/DECON	15,500	COLOR CAMERA SYSTEM w/PAN, TILT AND FULL ROTATION
26-TV-007	CCTV, MELTER FEED	15,500	COLOR CAMERA SYSTEM w/PAN, TILT AND FULL ROTATION
26-VA-001	FEEDER, ROTARY STAR	2,300	ISOLATE 26-DC-001
26-VA-002	FEEDER, ROTARY STAR	2,300	ISOLATE 26-PE-001
26-VA-003	FEEDER, ROTARY STAR	2,300	ISOLATE 26-DC-002
82-ME-001	LIDDING STATION	225,500	AUTOMATED BOLTING MECHANISM FOR SHIPPING CONTAINER

000093