Commonwealth Edison
One First National Plaza, Chicago, Illinois
Address Reply to: Post Office Box 767
Chicago, Illinois 60690

June 28, 1982

Mr. Harold R. Denton, Director
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Subject: Byron Station Units 1 and 2
Braidwood Station Units 1 and 2
Advance FSAR Information
NRC Docket Nos. 50-454, 50-455,
50-456 and 50-457

Dear Mr. Denton:

This is to provide advance copies of information which will be included in the Byron/Braidwood FSAR in the next amendment.

Enclosed is a revised response to FSAR question 010.40 regarding high energy line breaks. Review of this response should close out Outstanding Item 3 of the Byron SER.

Also enclosed in the response to FSAR question 321.42 regarding the radwaste system. This completes our response to the NRC's set of 29 questions on the volume reduction system. Review of this response should help close Outstanding Item 15 of the Byron SER. Additional FSAR information on the polymer waste drumming station is also provided.

Please direct questions regarding this material to this office.

One signed original and fifteen copies of this letter and the attachment are provided for your review.

Very truly yours,

F. G. Lentine
for T. R. Tramm
Nuclear Licensing Administrator

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Attachment A

List of Enclosed Information

Revised Response to Question 010.40

New Response to Question 321.42

New Subsection 11.4.4

QUESTION 010.40

"Provide a response to Question 010.17 and include the following in your response. Provide the results of analyses of the effects on safety-related systems of failures in any high or moderate energy piping system in accordance with the J. F. O'Leary letter of July 12, 1973, as defined in Branch Technical Position ASB 3-1, Appendix C. Provide a table which identifies the method of protection provided all safety-related systems listed in FSAR Table 3.6-1 from failures of any high or moderate energy systems listed in FSAR Table 3.6-2. Include figures depicting the locations of failures relative to the systems of FSAR Table 3.6-1 giving dimensions, locations and protective method for each postulated break or crack in a high or moderate energy system. Include the assumptions used in your analysis such as flowrates through postulated cracks, pump room areas, sump capacities, and floor drainage system capacities."

RESPONSE

I. INTRODUCTION

To ensure safe and reliable operation of the Byron and Braidwood Nuclear Power Stations, the possibility of high or moderate energy line breaks have been considered in the design. This response documents a confirmatory study of the potential high and moderate energy line breaks which demonstrates that all design features necessary to mitigate the results of line breaks have been incorporated.

Standard Review Plans (SRP) 3.6.1 and 3.6.2 were used as the basis for this study. SRP 3.6.1 includes Branch Technical Position (BTP) APCSB 3-1. Appendix B of the BTP, the attachment to letters sent to applicants and licensees by A. Giambusso in December 1972, and Appendix C to the BTP, the July 12, 1973 letter to applicants, reactor vendors and architect-engineers from J. F. O'Leary, provide the basis for identification of high energy line breaks and evaluation of their consequences.

Piping drawings which identify the high energy lines are included in the FSAR (Figures 3.6-1 through 3.6-12). Breaks have been postulated at the locations required by Branch Technical Position APCSB 3-1 for the purpose of assessing pipe whip and jet impingement effects. Pressure and temperatures in areas were calculated assuming the break occurs in the limiting location in the area. Locations of mitigating features such as pipe restraints and impingement shields are shown in Section 3.6 of the FSAR. Drawings showing the location of high energy lines have been provided to the NRC ASB reviewer. These drawings also indicate location of subcompartment walls and pipe tunnels.

II. SCOPE

The effects of high and moderate energy line breaks inside containment have been assessed as described in FSAR Sections 3.6 and 6.2. Additionally, an investigation into the effects of high and moderate energy line breaks outside containment has been made and is described in this response. Non-safety related areas, such as the turbine building, were not investigated because damage to or failure of equipment in these areas will not affect plant safety.

The possible effects considered are structural loads due to pressurization, increases in pressure and temperature which could affect environmental qualification of equipment, and damage due to pipe whip and jet impingement. Flooding is a potential effect but is not addressed in this response. The response to Question 010.47 demonstrates that high and moderate energy line breaks will not cause flooding which would adversely affect the plant safety.

Because of variations in requirements, techniques, and failure effects, high and moderate energy lines are addressed separately. Similarly, the pipe whip, subcompartment pressurization, and environmental analysis all have somewhat different approaches. The following sections are divided to reflect these distinctions.

III. HIGH ENERGY LINE ANALYSIS

Standard Review Plans 3.6.1 and 3.6.2 were followed in defining and identifying high energy lines. High energy lines are those larger than 1 inch diameter for which either:

a. The service temperature is greater than 200° F; or

b. The design pressure is greater than 275 psig.

Only a limited number of systems in the auxiliary building meet either of these criteria. The following systems have been identified as containing high energy lines in the auxiliary building:

Chemical and Volume Control	(CV)
Auxiliary Steam	(AS)
Steam Generator Blowdown	(SD)
Radioactive Waste Processing	(WX)
Boric Acid	(AB)
Main Steam	(MS)
Feedwater	(FW)
Auxiliary Feedwater	(AF)
Residual Heat Removal	(RH)
Safety Injection	(SI)

Systems which are normally not used or at reduced temperature and pressure are not necessarily required to be considered as high energy lines. A guideline has been established (Branch Technical Position MEB 3-1) that if the system is at high energy conditions less then 2% of the time, it may be considered a moderate energy line and its normal conditions applied to the line break analysis. On this basis, the last three systems (AF, RH, SI) are not considered as high energy systems. The Byron/Braidwood AF system is not used for normal startup as at some other plants. The only high energy line in the boric acid system is a steam supply line to the boric acid batching tank. This line is essentially a part of the auxiliary steam system and, as a result, was not identified in FSAR Table 3.6-2.

Subcompartment pressurization is investigated for all lines with temperatures above 200° F. Lower temperature lines do not have the potential for flashing to steam and thus will not increase the pressure of a subcompartment in the event of a break. Pressurization is of concern only in small subcompartments with relatively large high energy lines or subcompartments with limited pressure relief venting.

High energy lines below 200° F have only minor effects on the environmental conditions. The absence of steam and the ability to drain warm liquid from the break area limits the temperature rise from these breaks. The auxiliary building HVAC has sufficient capacity to accommodate these lower temperature breaks. Breaks of other high energy lines may influence the expected maximum temperature in some areas of the auxiliary building even if high pressures do not result. The auxiliary building contains several large areas with high energy lines that are not subject to pressurization but are investigated for environmental effects.

Certain postulated break locations in high energy piping systems are used to investigate the potential for damage due to pipe whip and jet impingement. The guidelines in Standard Review Plan 3.6.2 are used to determine the number and locations of the pipe breaks. Pipe restraints are added as required to prevent damage to structures and safety-related equipment.

IV. MODERATE ENERGY LINE BREAKS

Moderate energy line breaks are postulated and evaluated for potential flooding and jet impingement. Flooding is discussed in the response to Question 010.47.

Moderate energy lines do not cause subcompartment pressurization. The low temperature of a moderate energy line ensures that no steam will be produced and the pressure within the subcompartment will remain atmospheric.

Moderate energy line breaks will not cause increases in the environmental temperatures and pressures. The reduced break area applicable to these breaks and the absence of steam allows the auxiliary building HVAC to maintain temperatures within those specified in the environmental qualification program.

Moderate energy line breaks do not result in pipe whip.

A moderate energy line break in the component cooling system was given special consideration because the component cooling system is not supplied with a Category I source of makeup water. A leak in this system could theoretically drain the surge tanks and result in damage to the component cooling pumps.

A significant leakage in the component cooling system is not expected. The system is a moderate energy, low pressure system and is not subject to severe loading. In the event the system is inoperable, the plant may be safely maintained in a hot shutdown condition until the component cooling system is restored.

If a crack is postulated in one of the large lines in the system, the level in the surge tank of the affected unit will drop. When the level reaches the low setpoint level, alarms will sound and the affected units component cooling pumps will be automatically tripped to prevent damage to the pumps.

If reactor water or demineralized water makeup is available, the component cooling pumps may be restarted and the unit operated normally while the leak is located and isolated. Otherwise, the reactor will be tripped because of the interruption of component cooling to the reactor coolant pumps and the unit will be placed in a hot shutdown condition. Component cooling is not required to safely maintain the unit in hot shutdown mode. The component cooling system can be operated after a failure of the piping by closing the appropriate system valves to isolate the break location and maintain component cooling flow.

V. SUBCOMPARTMENT PRESSURIZATION

For the purpose of protecting subcompartments from overpressurization, the CV, AS, SD, WX, MS, and FW systems were traced through the auxiliary building and all subcompartments containing high energy lines were identified. The most severe break in the subcompartment was analyzed.

The main steam (MS) and feedwater (FW) systems are routed entirely in an enclosed tunnel in the auxiliary building. The limiting break in this tunnel is a main steam line rupture. Section C3.6 fully describes an analysis of a break in this tunnel.

The remainder of the auxiliary building was surveyed level by level to identify all subcompartments which could be pressurized by high energy line breaks. Figures Q10.40-1 through Q10.40-5 identify all areas containing high energy lines. The identification of the limiting line in each zone is also included. The zone numbers do not correspond to environmental qualification zones (Section 3.11).

Figure Q10.40-1 represents elevation 346 feet 0 inch. Zone 1, the recycle waste evaporator room, has been analyzed and the results are reported in Section A3.6 of the FSAR. Zones 2 and 3, letdown reheat heat exchanger rooms and valve areas, have been analyzed and the results are reported in Section A3.6. The assessment in A3.6 addressed Zone 3, the more limiting zone.

Figure Q10.40-2 represents elevation 364 feet 0 inch. Assessment of Zones 5A and 5B, the positive displacement charging pump areas, predict a peak pressure of 2.42 psid and a peak temperature of 190° F. These results are being added to Section A3.6 of the FSAR. Zones 6A, 6B, 7A, and 7B, the centrifugal charging pump rooms, contain high pressure, low temperature lines. Failure of these lines (normal temperature of 115° F) will not cause pressurization or increase temperatures. Pipe whip and impingement are considered. Zones 9A and 9B contain portions of the steam generator blowdown system. Control valves upstream of these lines limit the blowdown flow and prevent the postulated breaks from impacting plant design. Zones 8A and 8B, blowdown condenser rooms, have been analyzed and the results are included in FSAR Section A3.6. Zones 11 and 12, blowdown condenser rooms, have been analyzed and the results are reported in Section A3.6.

Figure Q10.40-3 represents elevation 383 feet 0 inch. Zones 11A, 11B, 11C, and 11D, letdown heat exchanger rooms, have been analyzed and the results are reported in Section A3.6. Zone 13, the auxiliary steamline piping tunnel, has been analyzed and the results are reported in Section A3.6. Zones 12A and 12B are very similar to Zones 11A through 11D in break size and subcompartment size and, therefore, the existing results are adequate. Zones 10A and 10B are large areas with only small high energy lines. The impact of a break in these areas is discussed in Section VI.

Figure A10.40-4 represents elevation 401 feet 0 inch. Zones 16A, 16B, and 16C, the surface condenser rooms, have been analyzed and the results have been reported in Section A3.6. Zone 15, boric acid tank room, has been analyzed and the results have been reported in Section A3.6. Zone 14 is a large open area. The limiting high energy line break is a 2-inch auxiliary steam line. This event is discussed in Section VI.

Figure Q10.40-5 represents elevation 426 feet 0 inch. Zones 18A, 18B, and 18C, radwaste evaporator rooms, have been analyzed and the results are reported in Section A3.6.

VI. ENVIRONMENTAL QUALIFICATION

A program to document the environmental qualification of electrical equipment is underway for Byron/Braidwood. The scheduled completion date for this program is June 1982. This program will establish that the equipment required to safely shut down the plant will be operable under potentially adverse environmental conditions.

One of the potential causes of severe environmental conditions is a break or crack in a high or moderate energy line. This could cause an increase in pressure, temperature, or humidity or a flooding condition in the area of the break. Flooding is addressed in the response to Question 10.47 and will not be discussed here.

The basic design of the Byron/Braidwood stations includes features to mitigate the impact of line breaks on the ability to safely shut the plant down. Some of the features are:

a. Essential safety systems are redundant or backed up by other safety systems;

b. The effectiveness of the redundancy is protected by separation of redundant systems to the greatest extent possible;

c. Walls and compartments have been included to both protect equipment and to isolate breaks;

d. Large high energy lines such as main steam, feedwater, and auxiliary steam are partially or completely enclosed in protective tunnels in the auxiliary building;

e. Efforts have been made to minimize the number of high energy lines in areas containing safety related equipment and to minimize the size and length of high energy lines. For example, Byron/Braidwood uses motor and diesel driven auxiliary feedwater pumps rather than turbine driven pumps, thereby eliminating the associated high energy steamlines.

The zones identified in Section V for high energy line breaks analysis are included in the environmental zones. Table 3.11-2 and Figure 3.11-1 have been updated to include these environmental conditions. The subcompartment transient conditions calculated in the pressurization analysis are used for qualification of equipment in the subcompartment required to safely shut down the plant following the postulated break.

The large general areas containing high energy lines are not subject to pressurization but the temperature in the area may be affected. The general areas were examined to locate limiting high energy lines and a conservative affected area was defined. Large areas separated from breaks by doorways or other restrictive passages were not evaluated because of the restricted flow and the relatively large areas which dilute the break flow. Only two areas were identified which contain high energy lines.

The areas identified as 4A, 4B, 10A, and 10B are actually interconnected. All are affected by breaks at various locations in a three inch letdown line in the chemical and volume control system. Orifices in the system limit the flow to a maximum of 120 gpm. The portion of the break which flashes to steam will rise to the upper portions of Zone 4A/4B and flow out through openings into the upper levels of the auxiliary building. The break flow duration will be limited because two main control board alarms (high flow and high letdown heat exchanger outlet temperature) will immediately sound. The break will be isolable with containment isolation valves. As a result of the limitied flow from this break and the dilution area which is extremely large, the temperature of the air in these zones will not exceed the maximum temperatures predicted during operating transients and an additional accident environment is not necessary If the break is in the upper portion of Zone 10A/10B, the potential exists for heating a restricted area with no natural ventilation. None of the equipment in this area is required for safe shutdown following a letdown line failure. This scenario is discussed further in the Byron/Braidwood equipment qualification report.

The other area investigated was Zone 15 at elevation 401 feet. This open area contains a two inch auxiliary steam line. Failure of this line would release steam into the general area. Plant safety would not be affected because no safe shutdown equipment is located in this area. Flow into adjacent areas would eventually occur but the dilution would be so great that the temperature of the adjacent areas would remain effectively unchanged.

Table 3.11-2 and Figure 3.11-1 have been updated to include the environmental conditions discussed here.

Moderate energy line breaks do not impact the equipment qualification parameters. For lines with operating temperatures significantly above the normal area temperature, the crack flow rate and potential for heat transfer has been checked to ensure that sufficient HVAC capacity exists to prevent failure of required safety related equipment.

VII. PIPE WHIP

The methodology employed in the analysis of pipe whip is explained in detail in Subsection 3.6.2. Standard Review Plan 3.6.2 is followed. As discussed in the previous section, plant design features eliminate most pipe whip concerns.

Break locations have been defined for all high energy lines following the procedures in Standard Review Plan Section 3.6.2. Structural, piping, and equipment targets have been located in the vicinity of the breaks and the potential for damage assessed. Restraints have been added where required to protect the plant structure or systems.

Of the systems listed in Section III, the main steam and feedwater are of most concern due to the large size and high pressure. The postulated break locations and the resulting restraint locations for the main steam and feedwater lines in the auxiliary building (main steam tunnel) are shown in Figures 3.6-43 and 3.6-44.

In the remaining systems for which high energy line breaks must be postulated (CV, AS, SD, WX, [illegible] systems), the lines in many cases are not highly stressed or do not have the potential of impacting safety systems. The CV system, which contains high pressure lines, has been investigated and nine pipe restraints have been added.

VIII. JET IMPINGEMENT

The approach to jet impingement is described in FSAR Subsection 3.6.2. The break locations defined for the pipe whip investigation were also examined for jet impingement effects. The majority of locations had no effect on equipment required for safe shutdown. This was a result of the criteria used in design to maintain separation of redundant systems and the use of compartments to isolate high energy line break effects. Equipment which could be affected by jet impingement was analyzed and moved or protected if protection was required.

IX. CONCLUSION

High and moderate energy line breaks have been addressed following the guidelines of Standard Review Plan Sections 3.6.1 and 3.6.2. As a result of the plant design and the plant safety systems, failure of high or moderate energy lines will not prevent safe shutdown of the plant.

QUESTION 321.42

"Incineration of materials such as rubber will produce SO_2 which may 'poison' the charcoal absorbers used for radioiodine removal from the gaseous exhaust stream. Estimate the expected SO_2 concentrations in the gaseous exhaust stream and the impact of the SO_2 on radioiodine removal efficiency of the charcoal."

RESPONSE

A literature review was made to determine the potential impact of SO_2 on the VR's exhaust charcoal filter. Regulatory Guide 1.140 permits an elemental iodine removal efficiency up to 99.5% for impregnated charcoal which is filtering air with a relative humidity (RH) of 95% at 25° C. This guide also permits a methyl iodine removal efficiency of 99% for a deep bed impregnated charcoal filter when the RH is less than 70%. The iodine removal efficiencies used for the VR system in Section 12.2 of this FSAR are 99% for elemental iodine and 70% for methyl iodine at a RH of 30%.

The majority of the data in NRC sponsored research (as outlined in NUREG/CR-0025, March 1978, and NUREG/CR-2112, September 1981) for iodine removal by impregnated charcoal is at high relative humidities, between 50% and 95%. This same research only considered SO_2 contamination at 70% RH and 90% RH. This research indicates that 0.8 grams of SO_2 per 100 cu^3 of charcoal will decrease the methyl iodine removal efficiency from 95% to 92% for the first half inch of KI_2-TEDA impregnated charcoal (The impregnate in Topical Report AECC-2-P should be changed to KI_2-TEDA; this would result in the SO_2 influence being sinilar to that of G615 charcoal in NUREG/CR-2112.) In the above testing, SO_2 saturation was not attained, and the collected water pH was above 3.0 which is only moderatly acidic, indicating that more SO_2 removal is possible. If the SO_2 effect is linear, then the 70% methyl iodine removal efficiency would be reached at 1.5 grams of SO_2 per 100 cu^3 of charcoal. The VR system exhaust filter contains slightly more than 0.1 cubic meters of charcoal; therefore, a total of 1.5 kilograms of SO_2 could be collected on the filter before design assumptions are exceeded.

From Subsection 11.4.3, the approximate quantity of dry waste to be processed by the VR system is 29,000 ft^3 or 174,000 lb/yr.

From EPRI NP-2055, approximately 5% weight of the dry waste is rubber. The maximum quantity of sulfur in the rubber would be 1%. Therefore, a maximum of 87 pounds of sulfur/hr would result from the processing of the DAW. This corresponds to 174 pounds of SO_2/yr. It should be noted that the rubber goods normally used at the station will have a smaller concentration of sulfur.

From vendor test data, the DF for SO_2 in the VR scrubber system is greater then 99.87%; therefore, the maximum quantity of SO_2 entering the filter is approximately 0.23 lb/yr. This is only 7% of the quantity of SO_2 required to exceed the design assumptions.

11.4.4 Polymer Waste Drumming Station

11.4.4.1 Liquid Polymer Filling Station System

11.4.4.1.1 Systems Component Description

To accommodate the "Safe Side Chemistry" design features of this Radwaste Solidification System which utilizes polymer as a solidification agent, the following apparatus/equipment is provided.

11.4.4.1.2 Containers

The polymer drum filling station for dry waste is designed to utilize 55-gallon, tight-head, DOT 17-C drums. Each drum is fitted with a 4-inch nominal threaded bung insert which provides positive resistance to the torque incurred during remote capping operations. A disposable cap is provided to keep the inner portion of the drum free of foreign material before the polymer and associated chemicals are added.

11.4.4.1.3 Polymer Storage System

The solidification agent chemicals consist of polymer, promoter and catalyst. The polymer exists in a liquid state, and in combination with the promoter and catalyst, comprises the bulk of the three-element solidification agent.

Two polymer storage tanks are provided to store the polymer on-site. The tanks are atmospheric vessels, constructed and installed in accordance with the procedures of the Steel Tank Institute. The polymer storage tanks are located in the Unit 3&4 transfer pit area of the radwaste building.

The tanks are filled from bulk delivery trucks through piping connections leading into the tanks. The polymer vapors and displaced air are vented through a pipe and flame arrester system.

The polymer is transferred to the drum/polymer filling station by means of a continuous recirculation loop. Recirculation is essential to prevent the polymerization of the stored polymer. The recirculation and delivery pump for the stored polymer is located at the polymer filling station.

The shelf life of stored polymer is determined to be six months. To prolong polymer shelf life, the polymer must be kept at a temperature range of 50 to 70° F, periodically circulated and induced with air. Fire prevention techniques required by local and national codes are provided to ensure safe operation.

11.4.4.1.4 Polymer Fill Station

The polymer fill station is designed to accurately measure solidification agent into the radwaste shipping container (drum), in a non-radioactive environment, with no spillage.

The filling station consists of a conveyor (gravity-type) that transfers empty drums to the fill position, a drip-proof fill nozzle to place polymer and promoter into the drum, a scale assembly to verify that the correct amount of solidication agent is within the drum for a select waste stream, a station control console, and a conveyor to transfer prepared drums to the crane pick-up point for processing.

Filling the drum with solidification agent and preparing the drum for processing is both an automatic and manual procedure. The filling station is designed to handle the chemistry requirement of the radwaste solidification process.

11.4.4.1.5 Typical Operating Procedures

The polymer filling station system loads DOT-17C, 55-gallon drums, in a non-radioactive area, with solidification agent and in-drum mixing hardware, prior to drum processing.

A DOT-17C, 55-gallon drum, with a 4-inch nominal bung insert, centrally located in the drum top head, is inspected, labeled for identification and placed on the filling station conveyor. The disposable bung cap is discarded and the drum is transferred to the polymer fill nozzle position.

At the filling position, the polymer fill nozzle is inserted into the drum and the proper amounts of polymer and promotor metered into the drum. Automatic circuitry controls the amounts of solidification agent chemicals to be dispensed into the drum. The station operator will select the appropriate amounts by utilizing the fill station control console. Drum weight is monitored after filling to verify the quantity of solidification agents in the drum.

Once the solidification agent chemicals are metered into the drum, the nozzle is removed from the drum. The fill nozzle is drip-proof, and has a venting system incorporated into it to exhaust polymer fumes and displaced air. The drum advances down the conveyor. The fill station operator manually inserts the in-drum mixing hardware. The mixing tube is then inserted into the drum and screwed into the bung insert. The solidification agent catalyst containers are placed down the mixing tube. The cap removed from the mixing tube to insert the catalyst is then replaced.

The prepared drum is then transferred down the conveyor to the crane pick-up point for processing at the drumming station.

11.4.4.2 Dry Salt and Ash Storage and Transfer System

The storage and transfer system is located in a radiation area and is used to receive and store the dry product from the VR system and transfer the product to the polymer solidification system.

11.4.4.2.1 Surge Hopper

This is a small hopper sized to accept approximately 8 hours of VR system output, and it is located in the radiation area. The hopper design is compatible with the positive pressure operating requirements during product transfer.

A fluidizer is incorporated in the design, as well as appropriate valving to maintain pressure isolation during product receipt and during the periodic transfer of the product to the large storage hopper. The pressure isolation permits the fluidized product to be transferred to the larger storage vessel continuously at a low rate. This allows simultaneous operation of the VR and polymer solidification systems.

11.4.4.2.2 Dry Product Hopper

The dry product hopper, which is located in the radiation area and is operated at slightly negative pressure, is used to receive, store and transfer the dry waste from the surge hopper to the polymer solidification system. The product is stored in the area above the outlet feeder within the dry product hopper. The outlet feeder is a passive component for fluidizing and transferring the dry product to a gas solids separator which is located above the dry salt drumming station.

11.4.4.2.3 Gas Solids Separator

The gas solids separator is located above the drumming station in the radiation area. It will separate the dry particles of salt and ash from the fluidizing air, return the air to the dry product hopper, and allow a gravity feed of the dry salt and ash to the drumming station.

11.4.4.2.4 Blower

The blower for fluidizing and transfer of dry product is also used to pressurize the section of the drumming station that is external to the drum. The blower is located on the radiation side of a shield wall along with the piped manifold, while the blower motor is located on the non-radiation side for servicing and maintenance.

11.4.4.3 Dry Salts/Polymer Drumming Station

11.4.4.3.1 System Component Description

The Dry Salts/Polymer Drumming Station operates at less than atmospheric pressure and consists of code designed equipment which will receive the dry products from the volume reduction system, deposit them into a 55-gallon drum which has been pre-filled with polymer, and thoroughly coat the products with polymer. The major components of the station are the vessel, which serves as the containment chamber for the coating process; shield wall, to which the vessel is mounted; the pivot and lift mechanism used for positioning of the drum within the chamber; the capper/uncapper mechanism; the fill nozzle/mixer drive; a control system of pressure balance sensors for dust control; and a system of pipes and nozzles for emergency internal wash-down.

The drumming station enclosure is a pressure vessel which is capable of handling pressure greater than that available from the VR system. The access hatch will be of "pressure tight" design and the drain will be equipped with a full flow plug-type valve with remote manual actuator. The fill nozzle and pressure tight dry product valve separating the drumming station from the VR equipment is designed to handle dry product. The fill nozzle is heated to prevent condensation from accumulating and causing a build-up of dry waste on the nozzle. The primary seal that prevents the escape of dust is a diaphragm built into the drum which seals against the dry salt fill nozzle.

All chemicals involved with the polymer (binder) will be added to the drum before it is placed on the high radiation side of the shield wall. In this way, maintenance of the metering/dispensing equipment can be performed in a manner that will minimize radiation exposure to maintenance personnel. "In-drum" mixing will be utilized. The in-drum mixer assembly is manually inserted into the 55-gallon drum prior to drum processing. The mixing system design is for low-speed, high-torque rather than high-speed, high shear which is required for wet waste/polymer solidification. The in-drum mixer assembly will couple with the mixer drive assembly at the fill/mix position in the drum processing vessel.

Because the dry product is quite hygroscopic, no moisture will be present in the processing environment. An emergency decontamination spray system is provided for drum and vessel wash-down with manual connections on the non-radiation side of the shield wall. This system is manually controlled and cannot be activated from the radwaste control console.

The dry VR product is radioactive and quite fine. The processing vessel will be operated at a pressure slightly lower then the product transfer system pressure and the VR system pressure,

to ensure that product dust is contained in the fill nozzle and to avoid airborne contamination of the processing vessel environment. A venting system, which discharges to the VR system vent, is utilized for the removal of displaced air and solidification agent gases during drum filling. After the filling/mixing operation, the fill nozzle/mixer drive assembly is separated from the drum, vented to an offgas system and mechanically sealed. A second venting system is utilized to return the processing vessel to atmospheric pressure which will permit the opening of the hatch and the removal of the drum. A continuous air flow through the drum processing vessel to an offgas filter system is created when the vessel is depressurized to ensure that no airborne contamination will reach the radwaste building environment when the hatch is opened.

11.4.4.3.2 Shield Wall

The shield wall is a biological radiation shield, machined from carbon steel to a thickness of 12 inches, a height of 10 feet, and a width of 5 feet. It is provided to ensure that occupational radiation exposure conforms to ALARA guidelines as set forth in the Code of Federal Regulations. The shield wall serves as a machinery base to which the drumming station chamber is mounted. All mechanical operators and electric motors are bolted to the non-radiation side of the wall and function through stepped penetrations to the radiation side of the shield wall. The shield wall, to which the drumming station chamber is mounted, is bolted to the machined surface of a heavy structural weldment which is embedded in the concrete building structure.

11.4.4.3.3 Drum Processing Vessel

The drumming chamber is a pressure vessel with a domed top head and sloped bottom head. It is of welded stainless steel plate construction and all internal shell surfaces of the chamber are ground and polished to a #4 finish to prevent crud traps and facilitate decontamination. The dry product drumming chamber is flanged and bolted to the machined face of the shield wall. Outboard support of the vessel is achieved by a spring-loaded jack screw arrangement. Primary access to the chamber is provided through a hatch in the top head of the unit which is fitted with a hinge, a gasket and a remote mechanical operating mechanism that is driven by a motor installed on the non-radiation side of the shield wall. The hatch, of drop-down design, uses the internal chamber pressure to assist in sealing. Redundant maintenance access is provided through a flanged and bolted hatch which is located in the vessel wall. Head penetrations for the hatch and hatch cover operator are reinforced and sealed against the chamber atmosphere to prevent gas, vapor or dust leaks.

Fill Nozzle - The fill nozzle is a rotating cylindrical tube which interfaces with the drum mixer and is an integral part of the fill nozzle assembly. Its function is to receive the salt from the dry product valve and deposit it down the mixer tube. Additionally, the fill nozzle is constructed with a vent annulus which is designed to vent vapor and dust when the drum mixer is disengaged from the mixer drive. The exhausted products are drawn through a filter arrangement. Fitted to the discharge end of the nozzle is a mechanical, retractable conical seal. When a drum is not present at the fill location, the seal is in place and provides a mechanical barrier to any salt which may have been dislodged after the dry product valve closed. As a drum is presented to the nozzle, the seal is lowered slightly to permit a rush of air into the tube which will carry any transient dust up and out the vent annulus. The mechanical seal is operated vertically and radially through a system of gears by a shaft and universal joint driven by a non-radiation-side motor. Located at the vent annulus is a decontamination medium entrance pipe. This pipe is arranged tangent to the inside of the annulus chamber such that a swirling action of the decontamination medium will dislodge and dissolve any dust trapped, or clinging to the inside of the nozzle surface. All internal surfaces of the nozzle assembly are polished to a #4 finish to prevent crud traps and to assist the flow of dry product. Pressures within the fill nozzle are continually monitored and balanced to a differential with the drumming chamber to assure that dust will not escape into the drumming chamber. All head penetrations are reinforced and sealed against the chamber atmosphere to prevent gas, vapor or dust leaks.

Mixer Drive - The mixer drive is a hollow shaft gear reducer located in the drumming chamber head, above the fill position. Its function is to engage and rotate the in-drum mixer tube through a lug and detent arrangement. The mixer drive shaft/tube serves as the fill nozzles flow tube through which dry salt is delivered to the drum. The mixer drive, located between the fill nozzle chamber and the vessel head, is driven through a system of shafts and universal joints from a non-radiation-side motor. Components of the mixer drive are sealed against dry product and washdown fluids. All head penetrations are reinforced and sealed against the chamber atmosphere to prevent gas, vapor or dust leakage.

Dry Product Valve - The dry product valve is the boundary between the solidification system gas/solids separator and the drumming chamber. It is mounted to and is an integral part of the dry salt nozzle assembly. The valve is essentially a rotary gate which is captured between two lapped, spring loaded plates. As the gate is rotated from its full open position, a series of air jets, located in the lower plate, blows air into the "goggle" of the valve to scavenge the free dust into the fill nozzle. This action continues progressively until the valve assumes a full closed position thus sweeping the valve clean

and preventing abrasive build-up between the surfaces of the plates. The upper plate is connected to the delivery tube through a bellows type static seal. The valve bonnet pressure is monitored and balanced against the pressure of the drumming chamber to assure that no dust leaks to the atmosphere. The rotating shaft penetration through the valve bonnet is sealed with a rotating shaft seal as an additional assurance that radioactive dust will not escape to the atmosphere. All internal surfaces exposed to the dry product are highly polished and free from crud traps. Head penetrations for the dry salt nozzle assembly are reinforced and sealed against the chamber atmosphere to prevent gas, vapor, or dust leaks.

11.4.4.3.7 Emergency Internal Washdown Equipment

The drumming chamber contains an arrangement of pipes and nozzles which can be connected to a non-radiation-side water source. When charged with water, the system will thoroughly rinse the vessel interior and the drum surface free of dust. Water and dissolved salt can be drained awav through a remote, manually operated drain valve centrally located in the bottom head of the vessel.

11.4.4.3.8 Process Verification/Drum Monitor Station

Essential to the dry salt/polymer solidification is verification that solidification has occurred. Heat of reaction or "exotherm" is an intrinsic feature of the polymerization process. After the mixed drum has been removed from the chamber, it is presented to a verification station where it is weighed and the surface radiation is measured. It remains at this station until a temperature increase is detected by a remote thermal sensor. Within a known time frame, the predicted temperature increase will peak thus verifying completion of the solidification reaction.

11.4.4.3.9 Typical Operating Procedures

The Dry Salt/Polymer Drumming Station is operated remotely by pushbuttons, selector switches and a microprocessor unit from the control station. A graphics display panel, located on the vertical portion of the control console, will give the radwaste operator a mimic presentation of the piping, valves, pumps, motors, etc. Indicating lights show the operating status of the various system components.

A vertical row of indicators, with process descriptions, will light to represent the various steps in the automatic drumming process and verify that the automatic drumming sequence is progressing as programmed. The microprocessor unit controls the automatic drumming sequence along with the feedback permissives for various limit switches and sensors on the drumming station.

The drumming sequence operates in two modes, automatic and manual. The automatic mode is initiated with a single push-button (Auto On) and the manual mode, which will advance the drumming sequence one step at a time, is activated by depressing the (Manual Advance) pushbutton for each step. Once a drum has been loaded into the processing vessel and the amount of dry waste to be delivered to the drum prepared, the drumming sequence can be initiated for automatic processing. The automatic cycle will continue as long as all the feedback permissives are satisfied.

In the event of a process fault, an audible alarm and flashing annunciator will activate, halting the automatic operation, and indicate which point in the system is in fault. When the fault is corrected, the drumming sequence may be resumed in either the manual mode or the automatic mode. If the fault occurs during a drum processing sequence, the appropriate drumming sequence step will be indicated on the graphics display.

A Skip Operation mode is provided, which allows the operator to advance the microprocessor cycle sequence without actually performing the operation in the cycle. The microprocessor has a battery supply power back-up to maintain memory circuits in the event of a power interruption.

11.4.4.3.9.1 Process Set-Up

The Polymer/Dry Waste Drumming Station is energized by closing the station's circuit breaker at the electrical cabinet. Before energizing the system circuitry, verify the following:

a. All controls are in their OFF or neutral position.

b. All console and electrical cabinet doors are closed.

At the control console, turn on the drumming station selector switch to energize the Graphics Display and control circuitry. Verify the working condition of all indicating lights by depressing the lamp test pushbutton.

By operating the controls at the control console, the drumming process for dry waste utilizing polymer may proceed.

11.4.4.3.9.2 Process Description

A closed top, DOT 17-C, 55-gallon drum, with a centrally located 4-inch bung and disposable cap is visually inspected and labeled for identification purposes. The drum is placed on a conveyor at the solidification agent filling station and filled with the appropriate amounts of liquid polymer and promoter. The drum is then manually fitted with a disposable mixing assembly which consists of an expandable tripod base, helix and cone

assembly. The tripod base contacts the drum perimeter, locking the helix and cone ensemble in place. Next a mixing tube which surrounds the helix/cone assembly is inserted into the drum and screwed into the 4-inch drum top bung. The mixing tube is equipped with a diaphragm and removable cap. The diaphragm seals around the fill nozzle/mixer drive in the drum processing vessel to ensure no seepage of dry product into the processing vessel during the drum filling/mix operation. The cap is removed and replaced by the capper mechanism within the drum processing vessel.

After insertion of the in-drum mixer assembly, the chemical catalyst is added to the drum by dropping breakable containers, which hold predetermined amounts of catalyst, down the mixer tube and replacing the screw cap. All the solidication agents are now within the drum and will be combined during the fill/mix sequence of the drumming operation. The prepared drum is transferred down a conveyor to the crane pick-up point where the crane removes it from the conveyor and places it in the drumming vessel. This completes the non-radiation-side chemistry process for the drumming operation.

At the drumming station, the drum is centered over the processing vessel hatch by utilizing the overhead grid system and grid camera. The vessel hatch pivots into the vessel and the drum cradle and raises upward to accept the drum. As the drum is lowered onto the cradle, centering devices will position the drum and grasp the drum to prevent it from rotating during the mixing operation. The drum cradle is then lowered and the hatch closed.

Once the drum is placed in the processing vessel and the hatch closed, the automatic drum processing cycle begins, provided all permissives are met.

The drum processing vessel is pressurized to a value slightly higher than the dry product feed point. The pressure differential (ΔP) is continuously monitored to ensure that no dry product escapes into the processing vessel, thus resulting in airborne contamination.

When the drum processing vessel is depressurized, a continuous air flow through the drum processing vessel to an off-gas filtering system is created to ensure that no airborne contamination escapes to the radwaste building environment when the veseel hatch is opened.

Once the processing vessel is sealed (hatch closed), the drum cradle is pivoted and raised to the capper mechanism for drum cap removal. The capper mechanism lowers, the air operated collet expands to grasp the caps inner perimeter, the capper reverses direction and unscrews the cap. If no cap is in the drum, a process fault alarm is tripped thereby stopping the drumming cycle. Mechanical locating fingers which center the

drum for cap removal and replacement also ensure the correct alignment of capper, cap and drum bung internal threads.

The drum cradle lowers to an intermediate position and pivots to the fill nozzle/mixer drive position. The cradle will raise to allow the fill nozzle/mixer drive to enter the drum and engage with the in-drum mixing tube. Before nozzle/drum engagement, the drum processing vessel is pressurized and the nozzle exhaust system activated. The mechanical nozzle dust cap/seal is lowered and pivoted away from the nozzle. Any dry product present in the fill nozzle assembly is exhausted. The nozzle and drum are then engaged.

After the drum/nozzle engagement, a pressure differential is initiated between the drum connected to the fill nozzle and the processing vessel. The nozzle exhaust system is deactivated and the drum/system integrity checked to verify that no leakage exists.

The mixer drive is started and the dry product valve opened. The dry product feed screw drive is activated. Dry product is delivered down the fill nozzle line into the drum at a feed rate of approximately 55 pounds per minute. The mixer drive, designed for low speed, high torque mixing, turns the mixing tube which distributes the dry product and combines it with the solidification agent. The torque output of the mixer drive and the drum off-gas displacement are monitored to determine the quantity of waste/binder mixture in the drum. When the drum is determined to be full, the dry product feed screw is stopped and the dry product valve closed. Mixing will continue for a predetermined period. A process delay occurs to allow dry product dust to settle inside the drum.

Drum and processing vessel pressures are equalized and the nozzle exhaust system activated. The processed drum is lowered to a distance of 1/4 inch from the fill nozzle and any dust present is removed by the nozzle exhaust system. The drum descends to its intermediate level and the fill nozzle mechanical cap/seal repositioned at the nozzle outlet.

The nozzle exhaust system is deactivated and the processing vessel pressure valves closed. The vessel venting valve to the HEPA Filter System is opened and the pressurized vessel returned to atmospheric pressure.

The drum cradle is pivoted and raised to the capper mechanism. The drum cap is replaced. A stream of air is directed over the processed drum top and passed by a radiation monitor to determine if the drum exterior is contaminated. If contamination exists, the processed drum and vessel will be washed down. This is accomplished by manually opening the vessel drain valve and connecting the high pressure water lines to the station/vessel washdown spray system from the non-radiation-side of the drumming station wall.

The automatic process sequencing is stopped if washdown becomes necessary. An alarm will be given. The washdown process is not a part of the drum processing cycle. The processing vessel drain valve must be closed for the cycle to continue. Under normal operating conditions, drum washdown is not necessary.

If drum contamination is not detected, the drum processing cycle is completed and an indication is given at the control console. The hatch is opened and the processed drum is pivoted and raised to the load/unload position. The overhead crane grab retrieves the drum and transfers it to the drumming station monitoring station which is adjacent to the drum processing vessel. Drum weight, radiation level, and temperature increase are monitored. Within a known time frame, the drum temperature will peak thereby verifying the completion of the solidification process.

The processed drum will be transferred to the shielded drum storage area by the radwaste crane.

11.4.4.4 Process Control Program for Polymer Solidification

The protested solidification formulas for the process control program are based upon information provided by the station as to the types of wastes to be encountered and their physical and chemical characteristics and constituents.

Adjustments or modifications to pretested solidification formulas based on actual operating conditions may be required to maximize processing efficiency. In all cases, solidification formulas will meet the following criteria:

a. Formulas will meet technical solidification criteria within known operating parameters of the plant.

b. Where possible, formulas will provide a means for establishing control of the radiation level of solidified drums in order to match them with their intended method of shipment (example: shipping casks).

c. Formula specifications per item a will be directed at maximizing operating efficiency at minimum cost and remaining consistent with the federal guidelines.

There are several differences between the solidification of dry salts and the solidification of liquid wastes. The most important of these is the absence of water from the waste stream. It is this difference that dictates solidification be achieved with an agent which is not activated by water.

11.4.4.4.1 Solidification of Dry Salt

The solidifcation of dry salt is achieved by the use of a three component polymeric system developed by Dow Chemical Company. It consists of a promoter, a catalyst and a polymer binder which is a modified vinyl ester resin. Dry salts are mixed with the polymer so that each salt particle is coated. The presence of the promoter and catalyst result in the individual polymer molecules reacting with each other forming a three dimensional network, and making the final product essentially a giant solid molecule with the waste material trapped inside it. This arrangement has mechanical and chemical stability and is tolerant to radiation damage.

Because of the multicomponent nature of this solidification agent, there are several factors of importance in the process:

a. Temperature of the Dry Salt

The curing of the polymer is a reaction which generates heat (exothermic). It is also a reaction whose rate is increased by heat and thus, is self-accelerating. It is important to note that any source of heat accelerates the reaction. Therefore, the temperature of the incoming dry salt is controlled so that it has a maximum upper limit of 130° F.

b. Component Proportions

The solidification agent is a multicomponent system whose component proportions require careful control. In addition to the basic polymer, there are a promoter and a catalyst. The promoter controls how soon the solidification begins. If too much promoter is used, the reactor begins before addition of the dry salt is complete whereas too little promoter results in long curing times. The catalyst controls the rate of reaction. Too much catalyst results in excessively high reaction rates which in turn can lead to a build up of internal stress and to the ultimate mechanical failure of the solidified product. Conversely, too little catalyst results in long cure times. The program of developing pretested formulas makes every effort to insure that the correct ratios of the three components are employed. Proper operation and functioning of the polymer fill station ensures that the correct amount of each component is used.

c. Polymer Storage Temperature and Age

Temperature and age have a similar effect on the polymer. They cause premature initiation of the polymerization reaction, albeit at a slow rate. Over time, this may result in a thickening of the polymer which would make handling it difficult. Extreme cases would result in the plugging of filters and in inducing the cavitation in the fill station transfer pump. A cavitating pump has poor volume control and amounts of polymer added to the drum would be incorrect. Over the short term, an unusually high viscosity would indicate a high temperature in the area. Therefore, heat sources will be excluded from areas used for the storage of the polymer or near the piping runs. The binder manufacturer's suggested storage conditions and shelf life will be observed.

d. Dry Salt Feed Rate

Since the first step in the solidification sequence is actually a coating step, the rate at which the dry salt is introduced into the drum containing the polymer is controlled. This is so that each particle of salt is coated with polymer before solidification occurs. The interface between the VRS Product Storage Hopper and the fill nozzle allows control of the salt feed rate.

e. Dry Salt Particle Size Distribution

Because mixing the dry salt with the polymer is actually a coating operation, the total surface area to be covered is a process parameter. However, since the particle size of the dry salt is not measured or changed in any way, it is an uncontrolled variable. It is an important consideration since two batches of dry salt of the same weight but of different particle size distributions will require different amounts of polymer to achieve uniform coating. Although the VR Product Solidification System does not alter the particle size distribution, the process assures an adequate amount of polymer is available for coating the dry salt.

f. Drum Component Assembly

The VR Product Solidification System is designed around an in-drum mixer that coats the dry salt with polymer. It is a single-use item. The mixer has two mechanical components, both of which are

placed in the drum. The polymer-promoter combination and the catalyst container are deposited into the drum in the appropriate sequence. These steps are of paramount importance and will be performed as described in this Process Control Plan.

g. Salt-to-Polymer Ratio

The VR Product Solidification System controls the weight ratio of dry salt-to-polymer to within a fairly narrow range (approximately 2.5/1).

11.4.4.4.2 <u>General Description of the Chemical Process</u>

Because of the nature of the chemistry involved in the solidification of dry salt with a polymer, it is possible to follow the course of the reaction by monitoring temperature as a function of time. These two variables can be combined to provide an accurate description of the events occurring inside the drum. The following discussion assumes that the drum under consideration represents the normal operating situation. Events are identified by their temporal sequence.

a. In The Beginning

The drum is assumed to be correctly loaded with the appropriate amount of promoter-polymer, the mixing hardware is correctly inserted, the correct amount of catalyst added, and the prepared drum is transferred to the processing enclosure. A detailed description of these steps is in the Operations section of the Process Control Program.

b. Time Zero (t_o)

The timed sequence of the events leading to solidification begins after all of the processing enclosure permissives are satisfied and starts when the mixing tube begins turning. At (t_o), the catalyst containers are crushed and the catalyst is released into the promoter-polymer mixture. This event initiates the sequence of steps leading to polymerization. It is important to note that, once the catalyst is released to the polymer, the reaction starts and proceeds to completion, regardless of whether the dry salt is ever added to the drum.

c. Dry Salt Addition (t_2)

Within the first two minutes after catalyst release, the valve isolating the VRS product storage hopper opens and the salt delivery system is started.

Dry salt begins to flow downward and into the mixing tube inside the drum. The apparatus inside the drum causes the dry salt to become initially coated in the mixing tube. This coated salt is extruded out the bottom of the mixer and displaces the unused polymer upward. As the polymer level in the drum raises, the soluable membrane sealing the re-entry ports on the upper portion of the mixing tube is dissolved thus allowing the return flow of unused polymer back into the mixing tube. Salt addition is complete within fifteen minutes of the beginning of salt flow. During this time period, there is only a moderate (few degrees) increase in the temperature of the bulk material inside the drum due to energy of mixing.

d. Onset of Exotherm (t_{45})

Because the chemical reaction releases energy (exothermic), the temperature of the mixture in the drum increases. This in turn increases the rate of reaction of the mixture. Thus the reaction is self-accelerating: energy is released, which causes the temperature to raise, which causes the reaction to go faster, which releases more energy and on through this accelerating cycle until polymerization is complete. The increase in temperature is readily detectable and can be used as a parameter to follow the course of the polymerization. Since the dry salt is inactive in this reaction, it acts as a heat sink and absorbs much of the heat generated. Thus, this thermal buffering effect prevents a rapid temperature rise. This temperature increase is readily detectable and is a definite indication that polymerization is proceeding normally. The period of temperature rise is usually referred to as the exothermic portion of the reaction and starts about 45 minutes after catalyst release and lasts about 20 minutes. The beginning of this exothermic period has been arbitrarily defined to be the point at which the rate of temperature increase is equal to 1° F/min.

e. Plateau Region (t_{65})

The plateau region of the temperature profile begins when the exothermic period ends. The beginning of this region can be defined as when the rate of temperature increase falls below 1° F/min. The duration of this plateau phase is typically 4-6 hours. It is not a region of no temperature change but one of little temperature change. During this time, the rate of the reaction is slowing (because it is near completion) and so

the rate of energy release is also decreasing. By the time the temperature nears the end of this plateau phase, solidification is essentially complete and little additional polymerization occurs.

f. Cooling (t_{360})

At the end of the plateau region, when the reaction is complete, the temperature of the mass begins to fall. The time required for the solidified mass to return to ambient temperature is relatively long, 60-65 hours and is simply a function of heat transfer from the mass to the environment via radiation and convection. During this period, there is little or no change at the chemical level of the solidified mass.

11.4.4.4.3 Operational Procedure

The following discussion describes the step by step operation of the VR Product Solidification System.

A. Log Book

A log book will be established to provide a permanent record of the unique features of each drum. It will also contain selected pieces of information that would be of diagnostic value in the unlikely event of a solidification failure.

The following information will be recorded:

1. Verify that the drum and mixing hardware have been inspected.

2. Drum tare weight.

3. Drum identification label (unique for each drum).

4. The amount of promoter, polymer, and catalyst required by the pretested formula and verify that those amounts have been loaded into the drum.

5. Drum gross weight and volume of chemicals delivered to it.

6. Verify that the mixing hardware has been correctly loaded into the drum.

7. Temperature of the dry salt in the hopper.

8. Radiation level of the drum after the addition of salt is complete.

9. Total weight of the drum after the addition of salt is complete.

10. Verify the onset of the exotherm and record the maximum rate.

11. The peak temperature achieved and the time at which it occurred.

12. Drum storage location.

13. Date, time and operator.

B. Procedure

1. Inspection - Drums should be inspected on arrival. Drums should be ordered to tolerances and information supplied with the Operating and Maintenance Manual. For solidifying VR product, a new DOT 17-C, 16-gauge, closed-head drum with a special 4-inch screw cap bung located in the center of the top head will be used.

   The remotely operated processing equipment will handle drums which deviate from these tolerances. However, because most drums are built for commercial usage, it is possible to obtain drums with excessive deviation, thereby making it impossible to handle them remotely in the processing equipment.

   Drum tolerances will be verified upon receipt of the drum.

   Drums will be checked for defects such as holes or dents. Any hole is sufficient to cause that drum to be rejected. Rejection of a dented drum is at the discretion of the operator. Top and bottom chimes must not be dented or distorted.

   Waterproof numbers at least three inches high will be placed upon the top head of each drum. This allows the operator to verify that the correct drum is being processed by utilizing the crane's surveillance and/or drum grab TV camera. In addition, the assignment of drum numbers allows the operator to identify the location and status of each drum with the drum location board.

   The mixing hardware will be inspected before insertion into the drum. The helix will be inspected for the presence of the bottom cone. The helix must have all three legs and the legs must be free swinging. The mixing tube must have

an intact membrane in place. The charcoal filter element near the top of the tube must be in place, intact and without punctures. Any variance is cause for rejection.

Log Entry - Verify drum and hardware inspection

The drum is labeled with the appropriate number

Log Entry - Drum number

2. Drum Preparation

The operator places the drum on the roller conveyor of the polymer fill station and the power is turned on. He then selects the remote or local operation mode. Typical drumming operations will be done in the local mode. The remote mode allows the drum to be filled with polymer in the event that a radioactive solid, such as a filter element, is to be encapsulated.

a. The drum is raised to the fill nozzle.

b. The metering valves are activated and the appropriate amounts of promoter and polymer are transferred to the drum.

c. After the filling operation is complete, the non-drip nozzle prevents further addition of the promoter-polymer mixture into the drum by eliminating runoff.

d. The drum is lowered from the fill nozzle.

The operator then uses the load scale on the drum elevator to measure the weight of the filled drum. Significant deviations (more than 5 pounds) will be reported to the supervisor and corrected before proceeding.

Log Entry - Record weight of promoter-polymer mixture required by pretested formula and verify that the appropriate amount of mixture was transferred to the drum.

The filled drum is moved from under the fill nozzle and the mixing hardware is inserted. The helix and cone assembly is inserted first and locked into place in the following manner: the operator lowers and spins the helix quickly to cause the three free swinging legs to fly outward before they come into contact with the

bottom of the drum; as the operator continues to lower the helix and cone assembly, the three legs spread outward as they slide across the bottom surface of the drum; the cone and helix assembly is locked into position by pushing downward on the helix until the assembly locks into place. The mixing tube is inserted into the drum next. It is positioned by inserting it into the 4-inch bung so that the helix is inside the mixing tube. The tube is inserted in the drum until the upper threads mesh with the threads inside the bung. It is then screwed into place. Care is exercised during insertion of the mixing tube so that the membrane covering the upper half of the tube is not punctured or torn.

After the mixing hardware is in place, the drum cap is removed and the appropriate number of catalyst containers are placed inside the mixing tube. After the drum cap is replaced (hand tight), drum preparation is considered to be complete.

Because of the close manufacturing tolerances, the weight of the mixing apparatus and the catalyst are essentially constant. This weight is added to the total drum weight to obtain the drum tare before dry salt addition. A note should be made of the tare weight.

Log Entry - Verify mixing hardware and catalyst correctly inserted and in place.

3. The operator establishes that several permissives of the VR Product Solidification System are satisfied after the power to the system is turned on and before drum processing can begin. These permissives are automatically tested by the system and they include:

   a. That the enclosure hatch is closed.

   b. That the cradle is in the home position.

   c. That the dry salt delivery valve is closed.

   d. That the dry salt temperature is less than 130° F.

   e. That the system air pressure is within prescribed limits.

   f. That the hopper contains enough dry salt for the processing of one complete drum.

If any one of the conditions is not satisfied, a fault condition exists and drum processing is automatically prevented. The console will give the operator a positive indication when drum processing may continue. When this occurs, the operator initiates the operation: For the first drum of a group, the operator remotely opens the enclosure hatch. The drum cradle will raise to the full up position. For succeeding drums in the group, the hatch and the drum cradle will be in the correct position as a result of removing the previous drum from the processing enclosure.

Using the remotely operated crane, the operator picks up the drum at the end of the roller conveyor of the polymer fill station. If it is the first drum of a group, it is set directly on the drum cradle; otherwise, the drum is placed on the staging platform of the processing enclosure until the processing of the current drum is complete and is removed from the cradle. The operator then uses the remotely operated crane to transfer the drum from the staging platform to the drum cradle. After the drum is placed on the drum cradle, the drum grab is raised away from the drum.

Once a correctly prepared drum is loaded onto the drum cradle which is in the full up position, the remainder of drum processing is automatic. The sequence is started by the operator when he presses the "Start Processing" button. The system goes through the following sequence of steps:

a. The drum cradle is lowered to the full down position and pivots to the capper position.

b. The processing enclosure hatch closes.

c. The cap is removed and stored on the capper until the end of the fill cycle.

   The absence of a bung cap or presence of an improper bung cap will be detected by the drum capper and result in a fault signal. The automatic drumming cycle will abort at this point and return the drum to the home position.

d. The drum cradle lowers and pivots to the fill position.

e. The drum is raised to mate with the fill port.

f. At this point a series of automatic tests are run to ensure the integrity of the drum. Any malfunction aborts the automatic fill cycle and returns drum to home position.

g. The mixer tube drive engages, the mixing starts turning, and the catalyst is released. This point is (t_o) in the discussion of the chemical process.

h. The drum is automatically filled.

i. The radiation level of the drum is measured and displayed continuously to the operator at the control console.

j. After the completion of filling, there is a time delay to allow any dust to settle.

Log Entry - Record radiation level of drum.

k. The drum cradle lowers, separating the drum from the fill port and pivots to the capper position.

l. The drum is capped.

m. The processing enclosure hatch opens.

n. The drum cradle pivots to the hatch and raises to the full up position. The automatic fill cycle is complete.

NOTE: A number of steps relative to venting and dust control have been omitted for clarity of basic functions.

Using the remotely operated crane, the operator transfers the drum from the drum cradle to the platform scale attached to the drum processing enclosure to obtain the gross weight of the drum.

Log Entry - Weight of dry salt transferred to drum.

The drum processing enclosure is now ready to receive the next drum in the group.

Using the remotely operated crane, the operator transfers the drum to the thermal monitoring station to follow the course of solidification.

Log Entry - Verify onset of exotherm (1° F/min) and record maximum rate.

When the onset of exotherm has been observed, solidification is assured and the drum may be transferred to the decay pit after the peak temperature has been measured and recorded.

Log Entry - Record peak temperature achieved and time of occurrence.

Log Entry - Drum storage location.

Log Entry - Date, time, and operator

4. Solidification Formula

The following combination of chemicals is the standard formulation for the solidification of dry salt:

200 lbs. Dow Solidification Binder 101
0.2 lbs. dimethyl-p-toluidine (promoter)

These two components are metered into the drum simultaneously and in the correct proportions.

2.5 lbs. Cadox 40E (catalyst)

Each drum will automatically be filled with approximately 500 lbs. of dry salt.