TOPICAL REPORT

ATI VOLUME REDUCTION AND BITUMEN SOLIDIFICATION SYSTEM

Report No. ATI-VR-001-NP

Prepared For

U.S. NUCLEAR REGULATORY COMMISSION

WASHINGTON, D.C.

By

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ATI

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ABSTRACT

The design and operation of the ATI Volume Reduction and Bitumen Solidification System (ATI System) are presented in this Topical Report. In addition, the characteristics of the ATI System's solidified waste product are described.

The ATI System is of a proven design presently operating successfully in France, Swede and Japan, processing radioactive wastes from power plants, research centers and military centers. The system uses a Luwa Thin-Film Evaporator to evaporate water from radioactive wastes and to simultaneously mix the waste solids with molten bitumen. Th mixture of solids and bitumen solidifies upon cooling, forming a stable, homogeneous, solid product with no free water.

The following conclusions can be drawn from the information contained in this Topical Report:

1. The ATI System is a reliable system that can safely volume reduce and solidify radioactive wastes from nuclear power plants. Existing installations, some in operation since 1971 with excellent safety records, have established the system as a viable volume reduction technology.

2. The ATI System is simple in its design and operation, composed of standardized equipment components available from the process equipment industry. The operation of the system is sufficiently instrumented, controlled and interlocked to minimize the opportunity for operator error.

3. By reducing the volume of radioactive wastes, the ATI System is effective in reducing the hazards associated with waste container handling, transportation and burial.

4. The bituminized product of the ATI System has a high leach resistance, greatly exceeding existing leaching standards.

5. The ATI System is designed so that all active components can be easily and effectively decontaminated, minimizing operator exposure during operation and maintenance. Equipment is designed and arranged so that maintenance can be performed easily and with a minimum of exposure.

6. Comprehensive fire prevention and suppression programs, along with redundant process instrumentation, make the possibility of a fire in the ATI System extremely remote.

DELETION OF PROPRIETARY INFORMATION

This is the non-proprietary version of this Topical Report. Some information included in the proprietary version has been deleted from this version. The areas in which information has been deleted within the text are identified by boxing as illustrated here.

In addition, the following pages have been deleted:

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1. INTRODUCTION

This Topical Report is a description of the design and operation of the Associated Technologies Incorporated Volume Reduction and Bitumen Solidification System (ATI System); a description of the research, development and operating experience utilized in the development of the ATI System design; and a safety analysis including postulated accidents for a typical ATI System installed in a light water reactor power plant.

The area of radioactive waste solidification has been the subject of considerable debate during the past several years. Operating waste solidification systems utilizing either cement or urea-formaldehyde as a binder material have demonstrated less than satisfactory performance. As a result, the industry has been actively searching for an alternative binder material.

To make the problem of radioactive solid waste management even more complex, available burial area has decreased considerably in the past few years. This decrease in burial site availability can be tied to two distinct factors. First, there is the fact that a number of licensed burial sites are being or have been closed. Of the four disposal sites in the eastern half of the United States, only one is accepting waste material and it has reduced the volume it will accept.

The second factor contributing to the decrease in available burial area is the simple fact that the volume of waste buried is increasing each year. Studies have concluded that projected waste volumes will fill existing burial sites before 1990. Clearly some type of volume reduction is necessary in order to preserve existing burial land for as long as possible.

The ATI System as outlined in this Topical Report will help to alleviate the problems outlined above. With the use of bitumen as a binding matrix, the complex chemical solidification processes of cement and urea-formaldehyde are replaced with a simple physical process — cooling. In addition, the ATI System serves to substantially reduce waste volumes by removing more than 99% of the water present in input waste streams.

The ATI System uses a Luwa Thin-Film Evaporator for processing radwastes. The System volume reduces wastes by evaporating water and mixes the remaining solids with bitumen to form a solid, homogeneous matrix upon cooling.

The system is capable of treating wastes from light water power reactors, nuclear research centers, fuel reprocessing plants and other types of power and research reactors.

The present ATI System design is the result of 20 years of operational experience that is made available to ATI through its license agreement with the French engineering firm SGN (General Society for New Technology), and with the French CEA (Atomic Energy Commission). Through this license agreement, ATI has access to the most up-to-date French technology on the bituminization of radwaste. This allows ATI to offer a treatment process that is thoroughly researched and tested. This license agreement has been executed so that ATI can provide American utilities with a proven volume reduction/bitumen solidification system which is based on considerable research, development and operational experience.

This report is provided to the NRC so that review of safety-related subjects can be completed prior to the NRC review associated with applications for a construction permit or an operating license for a specific plant. The ATI System should be reviewed for use in commercial nuclear power plants utilizing either boiling or pressurized water reactors.

A description of all systems of the ATI System design operating worldwide is presented in Section 12. Eight systems are presently in operation, some since 1971, successfully volume reducing and solidifying radioactive wastes from nuclear power plants, research centers, and military centers.

2. PROCESS DESCRIPTION

2.1 Abstract of Process

2.1.1 Introduction

The ATI concept is a simple chemical and physical process for reliably and economically reducing the volume of radwastes and for incorporating radwaste into a solidified bitumen matrix. The process uses a Luwa Thin-Film Evaporator, which operates at a waste product outlet temperature of 320°F. This results in the evaporation of all free water from waste influents (less than 1% water in final product). The remaining solids are homogeneously dispersed in a bitumen matrix. Solidification of the end product occurs upon the natural cooling of the binder.

The system is capable of processing a wide variety of waste types, including evaporator concentrates, spent bead and powdered ion exchange resins, filter sludges, chemical and floor drain wastes, laundry solutions, decontamination solutions and incinerator ash.

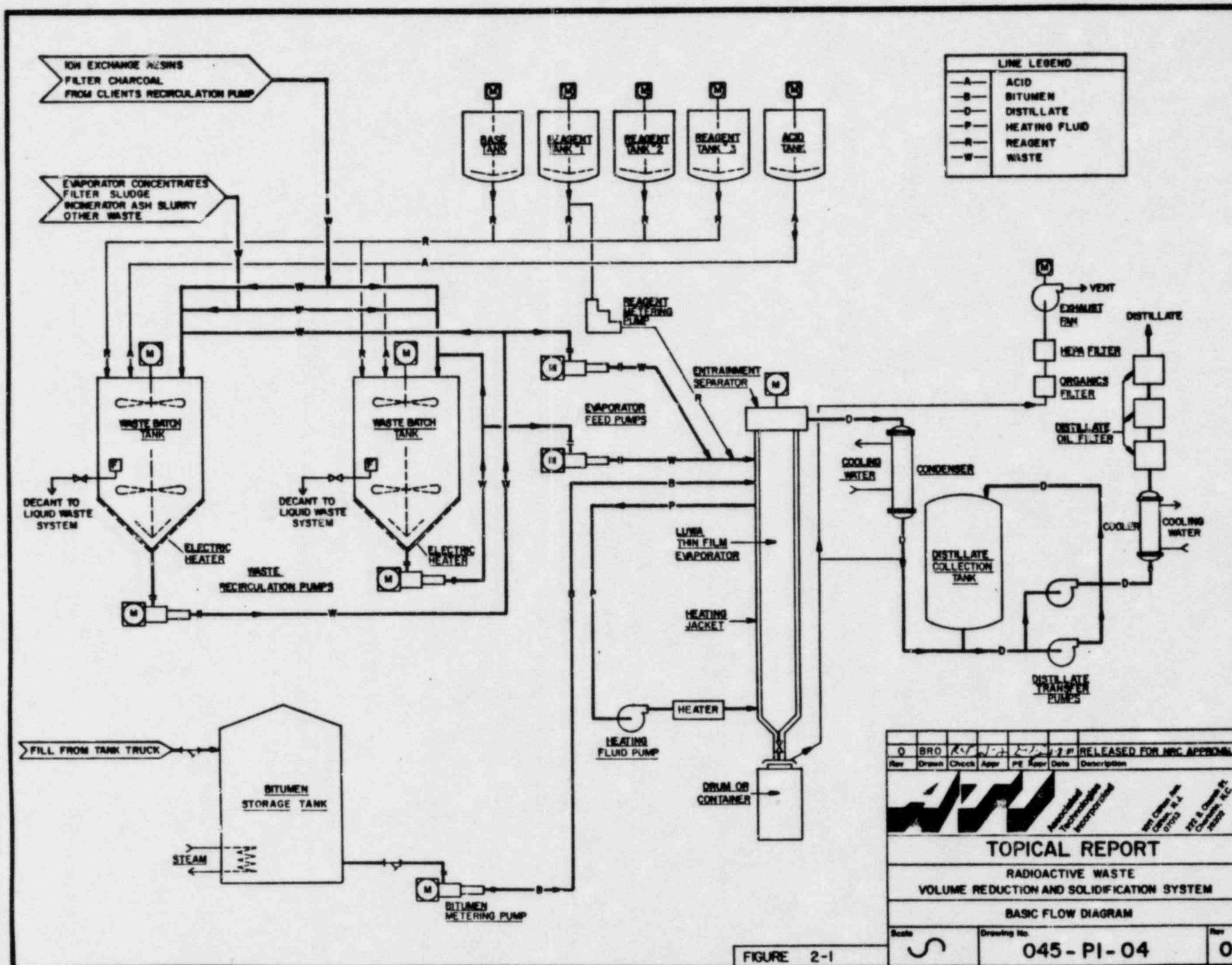
ATI provides a complete system for processing and solidifying radwaste. Waste concentrating and feed systems are supplied complete with tanks, pumps, agitators, piping, valves, instrumentation and controls as required. Similarly, a bitumen storage and supply system, a distillate collection and treatment system, and a complete container handling, capping, monitoring and decontamination system can be provided.

2.1.2 Abstract of Process (See Flow Diagram, Fig. 2-1)

Waste to be processed is charged into one of the Waste Batch Tanks. There it is sampled and chemically pretreated to prepare it for processing. Water is decanted or added as required to obtain the desired concentration for processing.

When the waste has been conditioned for processing, it is fed at a controlled rate to the Luwa Thin-Film Evaporator. Molten bitumen is also fed into the Evaporator through a second feed nozzle. The Evaporator is heated by means of a hot thermal fluid flowing through an external jacket. As the waste flows downward through the Evaporator, the water is evaporated and the water vapor flows countercurrently upward and out of the Evaporator. The waste solids are mixed with molten bitumen and exit the bottom of the Evaporator, flowing into a waste container. Upon cooling, the waste/bitumen mixture solidifies into a free-standing, monolithic, water-free solid.

The water vapor leaving the Evaporator is condensed in a shell-and-tube Condenser and flows into the Distillate Collection Tank. When this tank is filled, the distillate is pumped through a series of activated carbon filters and/or cartridge filters with organic absorbant to remove any light oils that may have been vaporized from the bitumen in the Evaporator. The cleaned distillate then enters the plant's liquid waste system.



ION EXCHANGE RESINS
FILTER CHARCOAL
FROM CLIENTS RECIRCULATION PUMP
EVAPORATOR CONCENTRATES
FILTER SLUDGE
INCINERATOR ASH SLURRY
OTHER WASTE
BASE TANK
REAGENT TANK 1
REAGENT TANK 2
REAGENT TANK 3
ACID TANK
LINE LEGEND
—A— ACID
—B— BITUMEN
—D— DISTILLATE
—P— HEATING FLUID
—R— REAGENT
—W— WASTE
REAGENT METERING PUMP
WASTE BATCH TANK
WASTE BATCH TANK
DECANT TO LIQUID WASTE SYSTEM
DECANT TO LIQUID WASTE SYSTEM
ELECTRIC HEATER
ELECTRIC HEATER
WASTE RECIRCULATION PUMPS
EVAPORATOR FEED PUMPS
ENTRAINMENT SEPARATOR
LUWA THIN FILM EVAPORATOR
HEATING JACKET
HEATER
HEATING FLUID PUMP
DRUM OR CONTAINER
EXHAUST FAN
VENT
HEPA FILTER
ORGANICS FILTER
DISTILLATE
DISTILLATE OIL FILTER
COOLING WATER
CONDENSER
DISTILLATE COLLECTION TANK
COOLER
COOLING WATER
DISTILLATE TRANSFER PUMPS
FILL FROM TANK TRUCK
BITUMEN STORAGE TANK
STEAM
BITUMEN METERING PUMP
0 | BRO | RELEASED FOR NRC APPROVAL
Rev | Drawn | Check | Appr | PE Appr | Date | Description
ATI
Associated Technologies Incorporated
TOPICAL REPORT
RADIOACTIVE WASTE
VOLUME REDUCTION AND SOLIDIFICATION SYSTEM
BASIC FLOW DIAGRAM
Scale
Drawing No. 045-PI-04
Rev 0

FIGURE 2-1

2.2 Waste Feed

2.2.1 Scope of Feed System

The ATI System is provided with equipment to collect, treat, decant, mix, sample and feed the radwaste to the Thin-Film Evaporator. The waste collection and feed system includes:

- two Waste Batch Tanks, typically 1000 to 1500 gallons each, with external electrical heating coils
- two Waste Recirculation Pumps, Moyno progressive cavity
- two Evaporator Feed Pumps, Moyno progressive cavity

Also included are all necessary valves, sample stations, flushing connections, instruments and controls to ensure proper operation of the waste feed system. Following are descriptions of how the various waste types will be collected, treated, sampled and fed to the Thin-Film Evaporator.

2.2.2 Concentrates Preparation and Feed

One of the Waste Batch Tanks is charged with concentrates to be processed. In order to prevent crystallization of solids, the temperature of the concentrates is maintained above the solution saturation temperature by automatically controlled electric heating coils mounted externally on the tank.

The agitator is started and a sample is taken from the sampler on the Waste Batch Tank. See the Process Control Program (PCP), Section 3.4 for analysis requirements.

After sample analysis, chemical treatments are prepared in the Reagent, Acid and Base Tanks as required by the PCP. These reagents are then fed to the Waste Batch Tank in the required volumes. After thorough mixing in the Waste Batch Tank, another sample is taken to determine the effectiveness of chemical treatment.

The co -ect waste feed rate and ratio of bitumen-to-waste flow are determined from the PCP and the set points of the flow rate controllers are set. The waste is now ready to feed to the Evaporator.

The turbine agitator is started, first at low speed, then at normal operating speed. The Waste Recirculation Pump is started and the waste is pumped through the recirculation line. Once the Evaporator has been started, bitumen flow has been established, and sufficient time has elapsed for the waste to reach the branch line to the Evaporator Feed Pump, the Evaporator Feed Pump is started and begins feeding waste to the Evaporator. The recirculation line and feed line are heated with electric heat tracing.

When waste processing is to be terminated or the Waste Batch Tank is at low level, the Waste Recirculation Pump stop button is pushed. Before the pump stops, flush water is automatically introduced to the pump suction and the pump runs for a period of time sufficient to flush the recirculation line. The pump then stops after this timed delay.

While concentrates are being fed from one Waste Batch Tank, waste is being charged, sampled and chemically treated in the other Waste Batch Tank. In this way, feed can be continuously maintained to the Evaporator.

2.2.3 Liquid Waste Preparation and Feed (Floor and Equipment Drains, Laundry, Chemical and Decontamination Wastes)

The procedure for preparing and feeding liquid wastes is identical to that described above for concentrates, with the following exceptions:

- Heat is not required on the Waste Batch Tank, the recirculation line or the feed line.
- If the liquid waste is very dilute (< 10% solids) it may be advantageous to mix this waste with a more concentrated waste rather than processing it alone. The compatibility of the two waste streams to be mixed must be determined prior to mixing.

2.2.4 Ion Exchange Resin and Filter Slurry Preparation and Feed

Slurry is charged into the Water Batch Tank being prepared for processing. After the slurry volume has been determined from the level indicator, the agitator is started, first at low speed and finally at full speed. The turbine agitators are used to maintain a homogeneous slurry.

The Waste Recirculation Pump is then started and slurry is recirculated through the recirculation line and back to the Waste Batch Tank for a period of time sufficient to ensure a homogeneous, well mixed waste slurry. A sample of the slurry is then taken from the recirculation line. There are two valves in the recirculation line which constitute the sample trap. During normal recirculation the liquid flows through the three-way valves. To take a sample, both valves are switched simultaneously, trapping a fixed volume between the two valves. The sample is then flushed with demineralized water into a sample bomb. By reading the final volume of the sample bomb, the flush volume is determined and thus the original concentration and density of the sample are determined. See the Process Control Program, Section 3.4, for sample analysis requirements.

A sidestream is continuously drawn from the Waste Recirculation Pump discharge line, circulated through a continuous density monitor, and returned to the inlet side of the Waste Recirculation Pump. This density monitor measures the density of the slurry and thereby provides an indication of the concentration of the slurry.

Water may be added or decanted to adjust the concentration of the slurry to that desired for processing. A filter is used in decanting.

Chemical treatments are prepared in the Reagent Tanks as required by the PCP. These reagents are then fed to the Waste Batch Tank in the required volumes. Another sample is taken to determine the effectiveness of chemical treatment.

The correct waste feed rate and ratio of bitumen-to-waste flow are determined from the PCP and the set points of the flow rate controllers are set. The waste is now ready to feed to the Evaporator.

Again the turbine agitator is started, first at low speed, then at normal operating speed. The Waste Recirculation Pump is started and the slurry is recirculated for a period of time sufficient to ensure a well-mixed slurry. After sufficient time has elapsed, the Evaporator is started and the Evaporator Feed Pump is started to feed slurry to the Evaporator.

When waste processing is to be terminated, the Waste Recirculation Pump stop button is pushed. Before the pump stops, flush water is automatically introduced to the pump suction and the pump runs for a period of time sufficient to flush the recirculation line. The pump then stops after this timed delay.

While slurry is being fed from one Waste Batch Tank, waste is being charged, sampled and chemically treated in the other Waste Batch Tank. In this way, feed can be continuously maintained to the Evaporator.

2.2.5 Ash Slurry Preparation and Feed

Incinerator ash is charged into the Waste Batch Tank from the incineration system's ash slurry storage tank. The feed system is the same as that described above for resins except that water is not added or decanted. The desired slurry concentration is attained before the slurry leaves the incineration system.

2.3 Volume Reduction and Encapsulation

In the ATI System, volume reduction is accomplished primarily by evaporating water from liquid solutions and slurries by means of a Luwa Thin-Film Evaporator. The Evaporator operates at a temperature high enough to evaporate more than 99% of the water from waste influents, including bound water associated with ion exchange resin slurries.

The Evaporator simultaneously mixes the remaining solids with a bitumen binder. Solidification of the solids/bitumen matrix occurs upon cooling of the binder. The resulting matrix is a homogeneous, freestanding, monolithic solid with no free water. Any residual moisture (<1 wt %) is bound water that can only be detected by laboratory analysis.

Waste and bitumen are fed to the Evaporator tangentially above the heated zone and are distributed evenly over the inner circumference of the body wall by a distribution ring mounted on the rotor. The rotor blades spread the waste and bitumen over the entire heated wall and generate highly turbulent flow conditions. The blades assure even distribution of the waste and bitumen over the metal heat transfer surface and they eliminate any channeling of waste as the waste flows down the Evaporator. The considerable shearing effect of the blades decreases the apparent viscosity of the waste, thus improving internal heat and mass transfer. Waste and bitumen spiral down the wall while bow waves developed by the rotor blades generate optimum heat flux, rapidly evaporating water. See Figure 2-2.

The water vapor generated in the thermal section of the Evaporator flows countercurrently upward into the entrainment separator, an integral part of the Evaporator. Here any entrained liquid droplets are removed from the vapor stream and are returned to the thermal processing section of the Evaporator. The cleaned vapor then passes through the vapor outlet of the Evaporator to the Condenser.

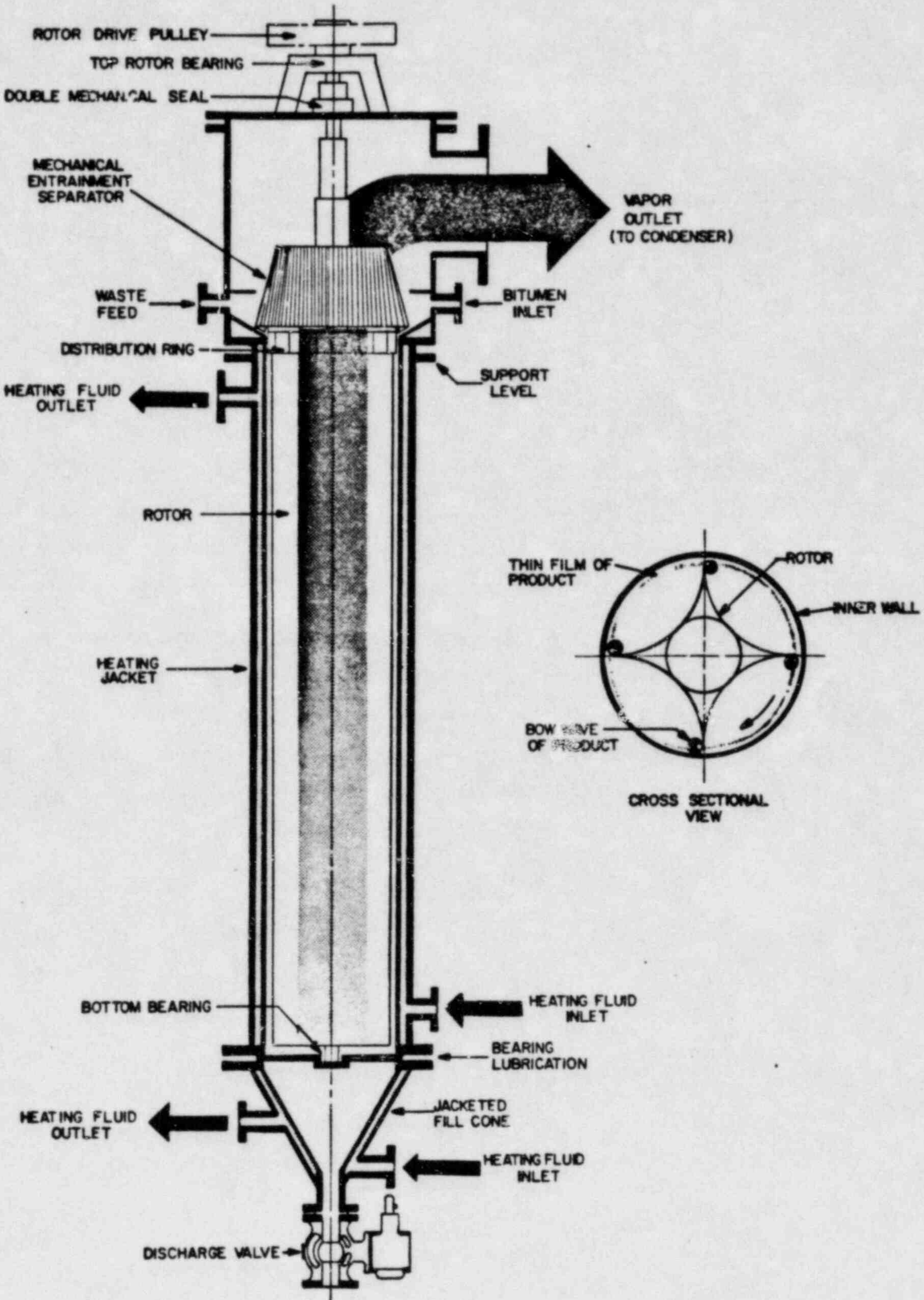


FIGURE 2-2

LUWA
THIN FILM EVAPORATOR
SCHEMATIC

2.4 Filling of Waste Containers

2.4.1 Discharge from the Evaporator

At the bottom of the LUWA Thin-Film Evaporator is a special heated fill cone, a heated, full port waste discharge valve and a container Ventilation Hood. The purpose of the Ventilation Hood is to capture any off-gas that may leave the surface of the bituminized waste product and also to act as a splash shield to contain any splashing of product that may occur during the filling of containers. The Ventilation Hood is connected to a small blower which pulls any off-gas through a cartridge filter containing absorbant and a HEPA filter to clean the gas of any organics or particulate before discharging to the plant ventilation system.

The waste discharge valve is closed whenever containers are indexed or changed and a remotely operated drip tray is positioned under the valve to ensure that waste dripping from the bottom of the valve is collected to prevent contamination. When soiled, the removable drip tray is removed from the holding arm and placed in a waste container for disposal.

The heated fill cone provides a reservoir for waste when containers are being indexed or changed. This allows processing to continue while material handling operations are being performed.

2.4.2 Container Filling and Handling

The bituminized waste product flows from the discharge valve of the Evaporator into the waste container. There are two separate level detection systems used for monitoring container fill level. The primary sensing device is used to continuously indicate fill level and to activate a high level switch when the level has reached the desired point. This switch closes the Evaporator discharge valve and provides a signal to the operator to position another container under the Evaporator for filling.

If the discharge valve remains closed for a period of time exceeding the predetermined time limit, an automatic sequence is initiated to stop feed to the Evaporator.

The secondary level detection system is used as a backup to the primary system to indicate high level. The secondary level detector is a steam or heated air probe which extends up to six inches into the top of the waste container.

Several types and sizes of waste containers are compatible with the ATI System, including 55-gallon drums, 50 ft^3 liners, and larger containers. When using 55-gallon drums, they can be positioned under the Evaporator by a Turntable. The typical ATI Turntable accommodates eight drums, but seven or nine-drum designs can be provided.

To obtain maximum filling efficiency of each drum, a two-pass filling procedure is used. Each drum is filled to 90% of its volume on the first pass. As it is rotated around the Turntable while succeeding drums are being filled, its contents cool and shrink. When it has completed one circuit and has arrived back to the fill position, it is "topped off" so that the filled volume after final cooling is maximized.

When using 50 ft^3 of larger containers, transfer carts or transfer tables are used to move and position the containers for filling.

Filled containers are capped, set aside to cool, monitored for contact dose rate and, if required, decontaminated. Equipment for capping, radiation monitoring, and decontamination can be provided by ATI as options.

Fig. 2-3 shows the filling cell of the SGN bituminization system at Barsebeck Nuclear Power Station, Malmo, Sweden. (Section 12.1 describes the Barsebeck installation.)

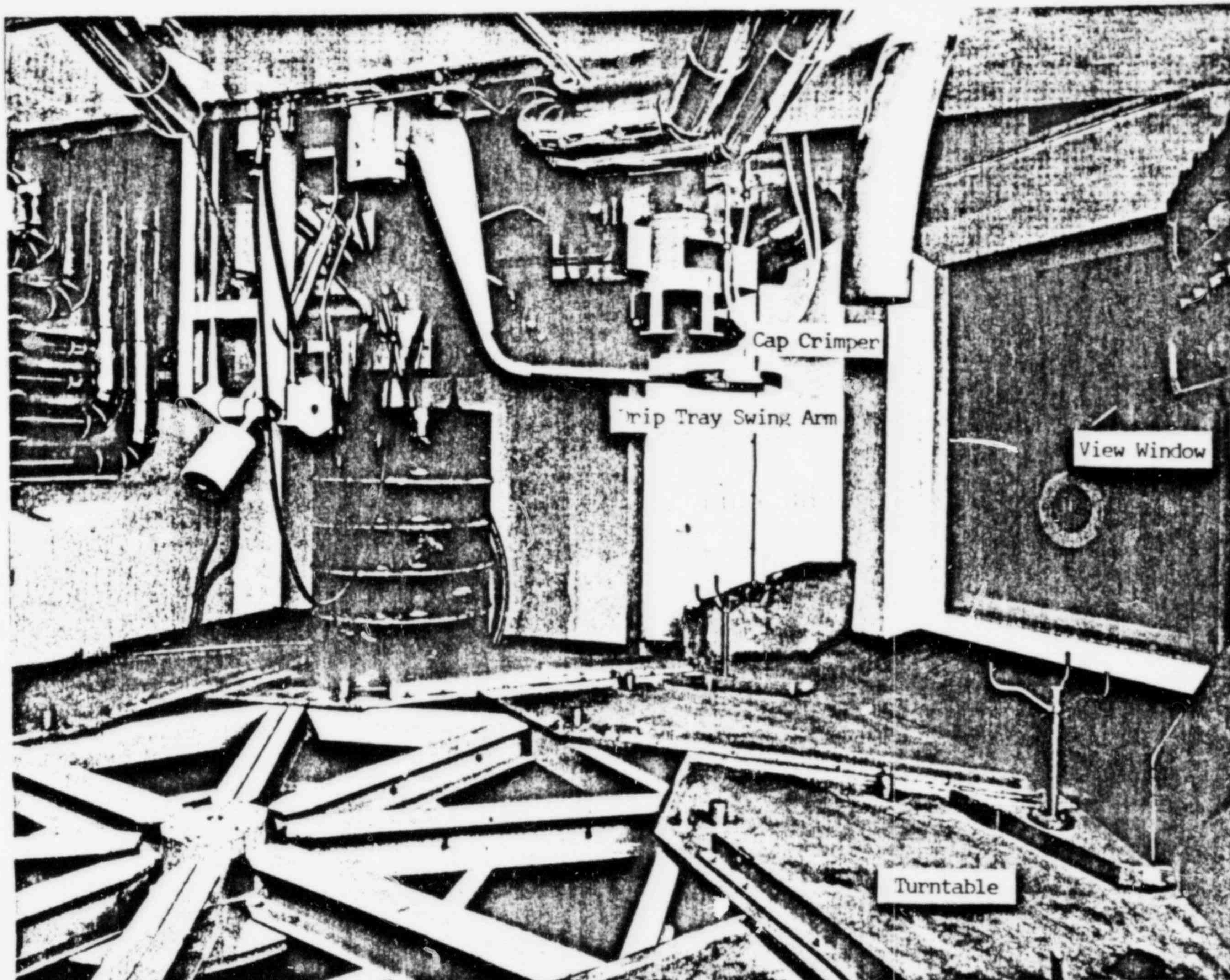


FIG. 2-3 FILLING CELL, BARSEBECK NUCLEAR POWER STATION

3. PROCESS PARAMETERS

This section describes quantitatively the process parameters of the ATI System.

3.1 Feed Characteristics

The ATI System can process a wide variety of waste types, including bead resins, powdered resins, filter demineralizer precoat sludges, boric acid evaporator concentrates, sodium sulfate evaporator concentrates, incinerator ash, chemical drains, floor and equipment drains, decontamination solutions, reverse osmosis laundry concentrates, spent activated carbon slurries, and other miscellaneous solutions, suspensions, slurries and sludges.

Table 3-1 outlines characteristics of typical waste streams as they would normally be generated by the nuclear utility. These wastes are then conditioned in the Waste Batch Tanks of the ATI System to prepare them for introduction into the Luwa Evaporator. The allowable waste concentrations and pH for feeding to the Evaporator are listed in the Process Control Program, Section 3.4, for the various waste types to be processed.

Wastes that are more concentrated than desired for feeding to the Evaporator are diluted in the Waste Batch Tank. Wastes that are more dilute than desired are decanted, if possible, or are mixed with compatible, more concentrated wastes to produce a mixture with the desired concentration.

TABLE 3-1

TYPICAL RAW WASTE CHARACTERISTICS

Waste Type	Typical Concentration (wt % dry solids)	Typical Components
Bead Resins	10-50%	polystyrene-divinyl benzene cation and anion resins, iron oxide, contaminants
Powdered Resins	10-50%	polystyrene-divinyl benzene cation and anion resins, iron oxide, contaminants
Evaporator Concentrates	6-50%	boric acid, sodium sulfate, ammonium sulfate, potassium chromates, halogens, oils, ammonium hydroxide, commercial decontamination solutions, lithium hydroxide, silica, cleaning agents, chemical drains, floor and equipment drains, metal oxides
Filter Sludge	10-50%	powdered resins, diatomaceous earth, dissolved and suspended solids, silica, metal oxides
Incinerator Ash Slurry	10-40%	alumina, calcium sulfate, iron oxides, silica
Chemical Drains	1-10%	mineral acids, commercial decontamination solutions, bases, salts, permanganate solutions, organics
Floor and Equipment Drain Filter Backwashes	1-10%	dissolved and suspended solids, decontamination solutions, metal oxides
Activated Carbon Slurries	10-50%	carbon, filtered solids, organic contaminants

3.2 Chemical Additives

Various chemical additives have been developed by CEA and SGN to improve the performance of the ATI System and the quality of its product. These additives are discussed below:

- Reagent #1 is a surfactant used to reduce the surface tension between the bitumen and the waste. This allows better coating of the waste with bitumen, yielding a homogeneous product. Reagent #1 is a soft waxy solid at room temperature and is added to the process in the form of a 25 wt % solution. The Chemical Engineering Catalog (CEC) lists eight major U.S. manufacturers of this type of surfactant. In addition, there are numerous small manufacturers across the country who specialize in making small batches of these surfactants.

- Reagent #2 is used to deflocculate resins and reduce their viscosity, making them easier to transport. [redacted] Reagent #2 is a common chemical compound. The CEC lists fifteen major U.S. manufacturers of this reagent, which is stocked by most chemical distributors.

- Reagent #3 may be added to sodium sulfate concentrates to increase the resistance of the bituminized product to swelling and leaching. Reagent #3 converts the waste to a form that does not swell and crack when exposed to water. A highly leach resistant product is obtained when Reagent #3 is used. The decision as to whether Reagent #3 should be added must be made by the user and should be based upon the activity of the waste and applicable leaching standards.

This reagent is also effective in increasing the leach resistance of sodium borate concentrates produced from the neutralization of boric acid concentrates. Sodium borates also exhibit a tendency to swell when exposed to water. This tendency is not nearly as strong as that of sodium sulfate, so the leach resistance of bituminized sodium borates is quite high without the addition of Reagent #3. However, should leaching standards become much more stringent in the future, the leach resistance of sodium borates can be increased by adding Reagent #3.

Reagent #3 is a common chemical compound. CEC lists eight U.S. manufacturers of this material.

- Caustic is added to boric acid wastes to convert the boric acid to sodium borates, which are non-volatile and will not evaporate in the Thin-Film Evaporator. Caustic is added as a 10N (normal) NaOH solution.

  Caustic is also added to acidic chemical drains or other acidic waste streams to neutralize the acid in the waste to non-volatile salts before processing in the Evaporator.

- Sulfuric acid is added to alkaline chemical drains or other alkaline wastes to neutralize the base in the waste to non-volatile salts before processing in the Evaporator.

- Special additives have been developed by SGN and CEA to insolubilize specific radionuclides such as Cs 137, Co 60, Sr 90, and Ru-Rh 103-106.

The reagents required for these special pretreatments are readily available from chemical distributors and are required in small quantities. The decision as to whether such pretreatment should be performed must be made by the user and should be based upon applicable leaching standards. At the present time, leaching standards in the U.S. can be easily met by the ATI product without the use of these pretreatments.

3.3 Solidification Agent

3.3.1 Selection Considerations

The proper choice of a solidification agent depends upon many factors:

a. Cost, source of supply, and long-term availability of the agent.

b. Flammability or ease of combustion.

c. Leach resistance.

d. Thermal stability, including stability after solidification.

e. Resistance to biological attack.

f. Freeze-thaw resistance.

g. Radiation resistance.

h. Quality of the product many years after it has been produced.

i. Compatibility with equipment, that is, the ease of decontamination of solidification agent from processing equipment.

SGN and CEA have researched the use of many thermoplastic and thermosetting solidification agent materials for nuclear center wastes, fuel reprocessing wastes, and power plant wastes. Potential binders that have been investigated include acrylates, paraffins, epoxy glues and resins, phenolic resin, polypropylene, polystyrene, urea formaldehyde resin, vinyl acetate, water soluble polymers, and others. The CEA concluded in the early 1960's that bitumen, either straight-distilled or oxidized, best met the criteria listed above.

3.3.2 Solidification Agent Characteristics

The solidification agent recommended for use in the ATI System is a straight distilled bitumen, commonly known in the United States as a viscosity graded asphalt cement, designation AC-20. The characteristics of the solidification agent are as follows:

Viscosity, 140°F, poises: 2000± 400
Viscosity, 275°F, centistokes, minimum: 210
Penetration, 77°F, 100 g, 5 sec, 0.1 mm, minimum: 40
Flash Point, Cleveland Open Cup, °F, minimum: 600 (buyer spec.)
Tests on Residue from Thin-Film Oven Test:
  Viscosity, 140°F, poises, maximum: 8000
  Ductility, 77°F, 5 cm/min, cm, minimum: 20

3.3.3 Tests Determining Bitumen Characteristics

A number of tests and measurements, specific to bitumens, make it possible to differentiate them and recognize certain physical characteristics. Some of these tests are described below.

a. Viscosity

Specifications for viscosity-graded asphalt cements normally are based on viscosity ranges at 60°C (140°F). A minimum viscosity at 135°C (275°F) also is usually specified.

The viscosity test at 60°C (140°F) employs a capillary tube viscometer. Two types are in common use. One is The Asphalt Institute Vacuum Viscometer. The other is a Cannon-Manning Vacuum Viscometer. Each viscometer is calibrated by use of standard calibrating oils. A "Calibration Factor" is thus developed for each viscometer.

The viscometer is mounted in a thermostatically controlled, constant temperature bath. Water may be used as the liquid medium in the bath. Preheated asphalt is then poured into the large side of the viscometer until its level reaches the filling line. The filled viscometer is kept in the bath for a prescribed period of time to allow the system to reach an equilibrium temperature of 60°C (140°F).

Because asphalt cement at 60°C (140°F) is too viscous to flow readily through capillary tube viscometers, a partial vacuum is applied to the efflux (small) side of the viscometer to induce flow.

After the bath, viscometer, and asphalt have reached temperature equilibrium at 60°C (140°F), the prescribed vacuum is applied and the time in seconds required for the asphalt cement to flow between two timing marks is measured by a stop watch. Multiplying this measured time by the calibration factor for the viscometer gives a value for viscosity in poises, which is the standard unit for measurement of absolute viscosity.

Paving grade asphalt cements at 135°C (275°F) are sufficiently fluid to flow through capillary tubes under gravitational forces alone. Thus, a vacuum is not required to induce flow and a different type of viscometer is used. The one most commonly used is the Zeitfuchs Cross-Arm Viscometer.

A suitable clear oil must be used as the bath medium for viscosity tests at 135°C (275°F). These viscometers also are calibrated with standard calibrating oils. The viscometer is mounted in the bath and asphalt is poured into the large opening until it reaches the filling line. The system is allowed to reach equilibrium temperature. A slight pressure is applied to the large opening of the tube or slight vacuum to the small opening. This causes asphalt to start flowing over the siphon section just above the filling line. Gravity pulls the asphalt downward in the vertical section of capillary tubing. A timer is started when the asphalt reaches the first timing mark and stopped when it reaches the second. The time interval, multiplied by a calibration factor for the viscometer, gives the kinematic viscosity in units of centistokes.

It will be noted that viscosity measurements at 135°C (275°F) are in units of centistokes where those at 60°C (140°F) are in units of poises. Gravitational forces induce flow in the kinematic viscosity test, where results are in centistokes, and density of the material affects the rate of flow through the capillary tube. In the absolute viscosity test, where results are in poises, flow through the capillary tube is induced by a partial vacuum and gravitational effects are negligible. The absolute viscosity may be calculated from the kinematic viscosity by multiplying the kinematic viscosity by the density of the asphalt at the test temperature.

b. Penetration

A container of asphalt cement is brought to the standard test temperature of 25°C (77°F) in a temperature-controlled water bath. A needle of prescribed dimensions, loaded to a total weight of

100 gm is allowed to bear on the surface of the asphalt cement for exactly five seconds. The distance, in units of 0.1 mm, which the needle penetrates into the asphalt cement is called the "penetration" of the asphalt cement.

c. Flash Point

The flash point of the asphalt cement indicates the temperature to which the material may be safely heated without danger of instantaneous flash in the presence of an open flame. The temperature, however, is usually well below that at which the material will burn. This latter temperature is called the "fire point" but is seldom included in specifications on asphalt cements.

The flash point of an asphalt cement is measured by the Cleveland Open Cup flash point test. A brass cup is partly filled with asphalt cement and heated at a prescribed rate. A small flame is played over the surface of the sample periodically, and the temperature at which sufficient vapors are released to produce an instantaneous flash is designated as the flash point.

d. Thin Film Oven Test

The Thin Film Oven (TFO) test actually is not a test. It is a procedure intended to subject a sample of asphalt to hardening conditions approximating those that occur in normal hot-mix plant operations. Viscosity or penetration tests made on the sample before and after the TFO test are considered to be a measure of the anticipated hardening.

The TFO test is made by placing a 50 cm^3 sample of asphalt cement into a cylindrical flat-bottom pan 14 cm (5.5 in.) in inside diameter and 1 cm (3/8 in.) deep. The asphalt layer is about 3 mm (1/8 in.) deep. The sample and container are placed on a rotating shelf in an oven maintained at a temperature of 163°C (325°F) for a period of five hours. The shelf rotates at approximately 5 to 6 revolutions per minute.

e. Ductility

In many applications, ductility is an important characteristic of asphalt cements. The presence or absence of ductility, however, is usually of more significance than the actual degree of ductility.

The ductility of an asphalt cement is measured by an "extension" type of test. A briquette of asphalt cement is molded under standard conditions and dimensions. It is then brought to standard test temperature and pulled or extended at a specified rate of speed until the thread connecting the two ends breaks. The elongation (in centimeters) at which the thread of material breaks is designated as ductility.

3.4 Process Control Program to Provide Complete Solidification

To ensure that there is no free water in the solidified waste, the process must be controlled so that critical parameters are maintained within allowable ranges. The following Process Control Program will ensure the production of a homogeneous, monolithic, water-free product.

3.4.1 Waste Preparation

a. The Waste Batch Tank is charged with waste from the concentrated waste storage tank, the sludge tank, the spent resin storage tank, the ash storage tank, or other waste holding tanks.

b. For solutions and suspensions, a sample is taken from the sampler located on the Waste Batch Tank. For slurries, the Waste Recirculation Pump is started to recirculate the slurry in a closed loop and a sample is taken from the recirculation line. (For sampling procedure, see Section 2.2.4).

c. The sample is analyzed for density, % solids, specific activity, radionuclides present, pH, . For slurries, pH can be measured by a pH monitor in the recirculation line.

d. Depending upon the type of waste being processed, pretreatment of the waste is performed:

(1) Boric Acid Concentrates

10N NaOH solution (caustic) is added to the waste to convert boric acid, which is volatile, to sodium borates, which are non-volatile. For the correct volume of caustic to be added, see Section 3.4.8.

(2) Sodium Sulfate Concentrates

Reagent #3 may be added, if desired, to increase the resistance of the final bituminized product to leaching and swelling. The amount to be added will depend upon the degree of leach resistance desired and applicable leaching standards in effect at the time of treatment. See Section 3.4.10 for further discussion.

(3) Spent Resins and Filter Sludges

A continuous density monitor in the recirculation line measures the density of the slurry. The desired density (and, therefore, the desired slurry concentration) is obtained by adding water to or decanting water from the Waste Batch Tank. A density above the normal operating density automatically sounds an alarm. A density above the maximum operating density closes the decant valve of the Waste Batch Tank. This density measurement feature prevents over-concentration of the slurry in the Waste Batch Tank, assuring flow from the tank to the Waste Recirculation Pump. Reagent #2 is added in the form of a 10% solution to deflocculate the resins [redacted]. See Section 3.4.9 for the volume of Reagent #2 to be added.

(4) Other Wastes

pH is adjusted by adding NaOH or H_2SO_4 solution.

e. A sample is taken and analyzed for density, % solids, specific activity, pH, . See Table 3-2 for allowable parameter ranges after pretreatment.

f. For all wastes, a surfactant must be added to ensure complete coating of the waste by bitumen. This surfactant, Reagent #1, decreases the interfacial tension between the waste particles and the bitumen, yielding a homogeneous mixture of bitumen and waste. The surfactant, a waxy material at room temperature, is mixed with water in Reagent Tank No. 1 to produce a 25% solution by weight. Reagent Tank #1 is heated with an electrical immersion heater to aid in the preparation of the solution. The temperature of the solution in the tank is continuously monitored and controlled by automatic adjustment of the power input to the immersion coil.

The surfactant is added to the waste by feeding it into the Waste Batch Tank. The volume drained from Reagent Tank #1 is measured by an electrical level transmitter and a panel mounted level indicator. Alternatively, Reagent #1 can be added to the waste by metering it with the Reagent Metering Pump into the evaporator feed line. See Section 3.4.7 for the volume of Reagent #1 to be added.

3.4.2 Feeding of Bitumen and Waste to the Evaporator

a. Bitumen Control

(1) The temperature of the bitumen in the Bitumen Storage Tank is automatically monitored at three locations within the tank. Should the temperature at any of the three points monitored fall below normal operating temperatures, an alarm is automatically sounded. Should the temperature fall below the minimum operating temperature, an automatic interlock prevents the Bitumen Metering Pump from operating.

Three internal steam coils supply heat to the bitumen. The coils are located in the bottom, up the side, and at the outlet of the tank. A self-contained temperature regulator (control valve with integral bulb) measures the temperature of the bitumen near mid-heighth of the tank and maintains the temperature at the set point by controlling the steam to the two coils located at the bottom and up the side of the tank. A second self-contained temperature regulator measures the temperature of the bitumen near the outlet of the tank and maintains it at the set point by controlling the steam to the coil located at the outlet. The steam pressure to these two temperature regulators is controlled by a pressure reducing valve.

(2) The level of bitumen in the Bitumen Storage Tank is continuously monitored. Should the level fall below or rise above normal operating levels, an alarm is automatically sounded. A redundant high level monitor provides an alarm on high level to prevent overflow.

(3) The temperature of the bitumen in the transfer line is continuously monitored and is automatically controlled by electrical heat tracing. Should the temperature of the bitumen fall below or rise above normal operating conditions, an alarm is automatically sounded. Should the temperature fall below the minimum operating temperature, an automatic interlock prevents the Bitumen Metering Pump from operating.

(4) The Bitumen Metering Pump discharge pressure is continuously monitored. Should the discharge pressure fall below minimum operating pressures (indicating loss of bitumen flow), an interlock prevents the Evaporator Feed Pump from operating. This prevents the feeding of waste to the Evaporator without simultaneously feeding bitumen.

(5) The bitumen flow rate is automatically monitored, recorded, and controlled in proportion to the flow rate of waste to the Evaporator. The desired ratio of bitumen to waste is maintained by automatic adjustment of the speed of the Bitumen Metering

Pump drive. The ratio is set according to the type, concentration, and activity of the waste. See Section 3.4.4.

<u>Note</u>: The bitumen temperature, level, pressure and flow control described in Paragraphs (1) - (5) above assure continuous flow of bitumen in the correct proportion to the Evaporator.

b. Waste Feed Rate Control

(1) The Waste Recirculation Pump recirculates the waste through the recirculation line at a sufficient flow rate to prevent settling of solids in the line. This recirculation line raises the slurry to the level of the Evaporator feed line. This level is chosen to allow downward flow from the recirculation line to the Evaporator feed inlet. This is desirable because the flow rate into the Evaporator is small compared to the recirculation rate, and velocities to prevent settling cannot be maintained in this feed line.

Recirculation also aids in mixing, assuring homogeneous waste concentration in the Waste Batch Tank and homogeneous waste samples.

A pH monitor in the recirculation line continuously measures the pH of the waste.

(2) The Evaporator Feed Pump takes waste from the recirculation line and meters it to the Evaporator. The flow rate to the Evaporator is continuously monitored, recorded, and

controlled. The set point of the flow rate controller is set according to the type and concentration of the waste to ensure complete water evaporation. The flow rate controller maintains the desired flow by adjusting the speed of the Evaporator Feed Pump drive. See Section 3.4.6 for operating flow rates. The Evaporator Feed Pump will not operate unless the Bitumen Metering Pump is operating. This prevents the feeding of waste to the Evaporator without simultaneous feeding of bitumen.

3.4.3 Processing in the Thin-Film Evaporator

Free and chemically bound water is evaporated from the waste as it flows through the Thin-Film Evaporator. The remaining solids are simultaneously mixed with molten bitumen.

a. Product Temperature Control

The temperature of the waste/bitumen mixture leaving the bottom of the Evaporator is continuously monitored and recorded. Should the temperature fall below normal operating temperatures, an alarm is automatically sounded. Should the temperature fall below minimum operating temperatures, the Evaporator stops and the Evaporator discharge valve closes automatically.

At atmospheric pressure, free liquid water cannot exist above 212°F. The temperature control features ensure that waste product is not discharged to the waste container below 285°F. Therefore, free water cannot exist in the waste container. However, a small amount of water vapor does get trapped in the product by not diffusing through the bitumen to the surface. Because of the thin-film process, however, with its high degree of agitation and high rate of surface renewal, diffusion requirements are minimal and only a very small amount of water is retained in the product (less than 1 wt %).

Should the product temperature rise above normal operating temperatures, an alarm is automatically sounded. Should the temperature rise above the maximum operating temperature, the Evaporator Feed Pump stops and the Evaporator discharge valve closes after a timed delay. These high temperature control features prevent the over-heating of discharge product.

b. Heating Fluid Control

(1) The temperature of the Evaporator heating fluid is continuously monitored, recorded, and controlled. Should the temperature fall below or rise above normal operating temperatures, an alarm is automatically sounded. Should the temperature fall below the minimum operating temperature, the Evaporator Feed Pump stops and the Evaporator discharge valve closes. Should the temperature rise above the maximum operating temperature, the heater and the Evaporator Feed Pump stop automatically. This high temperature interlock is backed up by an identical redundant loop. Heating temperature control, coupled with waste feed rate control, provides assurance that the operating temperature required for evaporation of all water is maintained.

(2) The flow rate of the heating fluid is continuously monitored. Should the flow rate fall below the minimum operating rate, an alarm is

automatically sounded, the Evaporator Feed Pump stops, and the Evaporator discharge valve closes. This control feature assures adequate flow of heating fluid to the Evaporator to maintain the heat transfer rates and heating fluid temperature required for complete evaporation of water in the waste.

c. Evaporator Control

(1) The electrical current drawn by the Evaporator drive is continuously monitored. Should the current rise above the maximum operating current, an alarm is automatically sounded and the Evaporator Feed Pump stops. This control feature is a redundant control of the bitumen-to-waste ratio. If the bitumen is fed at too low a flow rate, the solids content of the discharge product and the current drawn by the Evaporator drive will increase.

(2) The Evaporator Feed Pump will not operate unless the Evaporator drive is running. This control interlock prevents the feeding of waste into the Evaporator before it is operating.

Table 3-2

OPERATING PARAMETERS

Parameter	Normal Operation	Minimum[1] Operating Condition	Maximum[2] Operating Condition
Allowable pH to feed			
Evaporator			
Boric Acid Concentrates			
Chemical Drains			
Waste % solids to feed			
Evaporator			
Boric Acid Concentrates			
Sodium Sulfate Concentrates			
Resins & Filter Sludges			
Bitumen storage temperature			
Bitumen transfer temperature			
Final product temperature			
Heating fluid temperature			
Heating fluid flow rate			
Evaporator drive current			

1) Condition below which automatic interlock takes action.

2) Condition above which automatic interlock takes action.

3) % dry solids (excludes bound water).

4) Based upon Model LN 0200 Evaporator.

3.4.4 Ratio of Bitumen to Waste Feed

The optimum concentration of waste solids in the bituminized product is 40 to 50 weight % for most waste types. The optimum concentration for very abrasive materials, such as diatomaceous earth and incinerator ash, is 30 to 35%.

The bitumen flow rate is automatically controlled to maintain a constant ratio of bitumen flow to waste feed flow into the Evaporator.

The correct ratio of bitumen flow to waste feed flow, and thus the set point of the bitumen ratio controller, is determined from the following equation:

Where: R = Volumetric ratio of bitumen flow (gph) to waste feed flow (gph) into the Evaporator

W = Desired weight ratio of bitumen to waste solids in the bituminized product

C_f = Concentration of solids in waste feed, wt. fraction

ρ_f = Density of waste feed, lb/ft^3

ρ_B = Density of bitumen, lb/ft^3

The density of bitumen ρ_B is a constant, since the bitumen temperature is continuously controlled. This density, at the controlled temperature of $280^{\circ}F$, is 62.85 lb/ft^3. Thus, the bitumen ratio controller set point is a function of solids concentration in the waste feed and density of the waste feed. Figure 3 - 1 is a graphical representation of the above equation using a standard weight ratio W of 55/45. Knowing the waste feed concentration and density (from sample analysis or density monitor), the bitumen flow rate ratio controller set point can be selected from Figure 3-1. The use of Figure 3-1 for selecting the bitumen-to-waste flow rate ratio assumes that the specific activity of the final coated product will be acceptable at these ratios. For wastes with high activities, this may not be a valid assumption. Under certain conditions of high activity, it may be necessary to use a higher ratio of bitumen in order to reduce the specific activity of the final product to acceptable levels. This higher ratio is discussed in Section 3.4.5.

Note: Figures 3-1 through 3-7 are graphical representations of the equations used to determine required operating parameters. These graphs are presented for the purpose of visual explanation of the equations presented and are not to be construed as aids for the system operator. As described in Section 5.2, the process parameters for the waste to be handled are entered into the Programmable Controller (evaporative capacity of the Evaporator; concentration, density, volume and activity of the waste feed; and desired rates of bitumen to solids in bituminized product). The Programmable Controller then uses these inputs to solve the pre-programmed operating parameter equations and display the results for the operator's use. The Programmable Controller also uses these results to automatically set the set points of the waste feed rate controller and the bitumen ratio controller.

3.4.5 Ratio of Bitumen to Waste Feed for Higher Activity Wastes

There are two types of bitumen that can be used for solidifying radwaste. These are straight-distilled bitumen and blown (oxidized) bitumen. ATI recommends straight-distilled bitumen for use in the ATI System due to its comparably higher leach resistance, lower viscosity and lower cost. However, straight-distilled bitumen has a lower resistance to radiation than blown bitumen. For this reason, ATI recommends that the specific activity of the ATI bituminized product be limited to 1 Ci/liter. This limitation is a very conservative one and provides a large margin of safety between the radiation exposure and the radiation resistance of the bitumen.

The ratio of bitumen flow to waste feed flow required to ensure that the final product will have a specific activity no greater than 1 Ci/liter is calculated as follows:

Where: R = Volumetric ratio of bitumen flow (gph) to waste feed flow (gph) into the Evaporator

A_f = Activity of waste feed to the Evaporator, Ci/cc

ρ_p = Density of final coated product, lb/cu ft

ρ_B = Density of bitumen, lb/cu ft

ρ_f = Density of waste feed, lb/cu ft

C_f = Concentration of solids in waste feed, wt fraction

The density of bitumen at the controlled temperature of 280°F is 62.85 lb/cu ft. The density of the final product is not a continuously measured parameter (although it can be measured by positioning the drip tray under the Evaporator discharge to obtain a sample for analysis), so this value must be assumed for the use of the above equation. The highest bitumen ratio will result when ρ_p is at a maximum. Therefore, to be conservative, the highest expected value of ρ_p should be used when an actual value is not available.

Figure 3-2 is a graphical representation of the above equation,

The bitumen ratio R will normally be selected from Figure 3-1. Only when the activity level of the waste is high will the ratio from Figure 3-2 be used.

3.4.6 Flow Rate of Waste Feed to the Evaporator

The flow rate of waste feed to the Evaporator must be controlled to ensure complete evaporation of the water from the waste. The evaporative capacity E of the Luwa Thin-Film Evaporator, when processing various wastes, is listed below for the three Evaporator sizes most often considered for radwaste applications.

Table 3-3

EVAPORATIVE CAPACITY OF LUWA EVAPORATOR

	Evaporative Capacity E lb water/hr		
Waste Type	Model LN 0200	Model LN 0350	Model LN 0500
Borate concentrates (from 12% boric acid)			
Sodium sulfate concentrates, 20% solids			
Spent Resins and Filter Sludge, 20% dry solids			
Incinerator Ash Slurry, 25% solids			

The correct waste feed flow rate into the Evaporator to ensure complete evaporation of the water from the waste is determined from the following equation:

Where: F_f = Waste feed flow rate, gal/hr

E = Evaporative capacity, lb water/hr

C_f = Concentration of solids in waste feed, wt fraction

ρ_f = Density of waste feed, lb/cu ft

Figure 3-3 is a graphical representation of the above equation. For given waste feed concentration and density (from sample analysis or density monitor) and evaporative capacity (given above), the correct waste feed flow rate can be selected from Figure 3-3.

3.4.7 Reagent #1 Volume to be Added

Reagent #1 is a surfactant which reduces the surface tension between the bitumen and waste, ensuring good coating of waste solids with bitumen and a homogeneous solidified product. It is added to the waste in the form of a 25 wt % aqueous solution. The use of surfactants with bituminization is a patented process.

There are two methods used to introduce Reagent #1 to the waste. One method is to add a predetermined volume of reagent solution to the waste batch being prepared in the Waste Batch Tank. The other method is to meter the reagent solution at a predetermined rate into the Evaporator waste feed line as the waste is being fed to the Evaporator.

a. Metering Reagent #1 into the Evaporator Waste Feed Line

This method offers the operator the flexibility of being able to vary the ratio of reagent-to-waste during the processing of a waste batch. This method is used when the solids concentration of the waste feed is high enough to require a feed rate of Reagent #1 that is high enough to be accurately metered with the Reagent Metering Pump. When the solids concentration of the waste feed is very low, then the required feed rate of Reagent #1 can be less than the minimum controllable turndown of the Reagent Metering Pump. In that case, this method cannot be used.

The flow rate of Reagent #1 solution is automatically measured and is controlled by a flow controller which automatically adjusts the speed of the Reagent Metering Pump drive to maintain the desired flow rate.

The required flow rate of Reagent #1 is determined from the following equation:

where: F_R = Reagent #1 flow rate, gal/hr

F_f = Waste feed flow rate, gal/hr

C_f = Concentration of solids in waste feed, wt fraction

ρ_f = Density of waste feed, lb/ft^3

Figure 3-4 is a graphical representation of the above equation. For given waste feed flow rate (from Figure 3-3), concentration and density (from sample analysis or density monitor), the correct Reagent #1 flow rate can be determined from Figure 3-4.

b. Adding Reagent #1 Into the Waste Batch Tank

When the concentration of waste solids in the waste feed is very low, the required flow rate of Reagent #1 can be too low to be accurately metered by the Reagent Metering Pump. In this case, Reagent #1 is added to the waste by introducing a controlled volume of reagent solution into the Waste Batch Tank.

The required volume of Reagent #1 solution to be added to the Waste Batch Tank is determined from the following equation:

Where: V_R = Volume of 25 wt % Reagent No. 1 solution to be added, gal

V_f = Volume of waste feed to be treated, gal

C_f = Concentration of solids in waste feed to be treated, wt fraction

ρ_f = Density of waste feed to be treated, lb/cu ft

Figure 3-5 is a graphical representation of the above equation. This graph can be used to select the correct volume of Reagent #1 solution to be added for given waste feed volume (from level monitor), concentration and density (from sample analysis or density monitor).

3.4.8 NaOH Addition to Boric Acid Evaporator Concentrates

Because boric acid is volatile, it must be converted to a non-volatile form before processing in the Thin-Film Evaporator. By adding NaOH, the boric acid can be converted to sodium borates, which are non-volatile.

NaOH is added to the evaporator concentrates in the form of a 10N solution. The volume of NaOH solution to be added is calculated from the following equation:

Where: V_c = Volume of 10N caustic solution to be added, gal

V_f = Volume of waste feed to be treated, gal

ρ_f = Density of waste feed to be treated, lb/ft^3

C_f = Concentration of boric acid in waste feed to be treated, wt fraction

Figure 3-6 is a graphical representation of the above equation. For a given waste feed volume (from level monitor), density and concentration (from sample analysis), the volume of caustic solution to be added can be selected from Figure 3-6.

3.4.9 Addition of Reagent #2

Reagent #2 is added to spent resins to deflocculate the resins and to reduce their viscosity, making them easier to transport.

The following equation defines the volume of Reagent #2 solution that should be added:

Where: V_R = Volume of 10 wt % Reagent #2 solution to be added, gal

V_f = Volume of waste feed to be treated, gal

ρ_f = Density of waste feed to be treated, lb/ft^3

C_f = Concentration of dry solids in waste feed to be treated, wt fraction

Figure 3-7 is a graphical representation of the above equation. With given waste feed volume (from level monitor), density and concentration (from sample analysis or density monitor), the correct volume of Reagent #2 solution to be added can be selected from Figure 3-7.

3.4.10 Addition of Reagent #3 to Sodium Sulfate Concentrates

If desired, Reagent #3 may be added to sodium sulfate concentrates to increase the resistance of the final bituminized product to leaching and swelling.

Anhydrous sodium sulfate has a strong tendency to bind water to form a decahydrate. The formation of the hydrate causes the sodium sulfate to swell. This swelling force can cause the bituminized product to crack and break up when immersed in water, exposing the sodium sulfate to leaching by the water.

Reagent #3 reacts with the sodium sulfate to yield a product that does not form a hydrate and, thus, does not swell (see Section 3.7 for leaching characteristics after pretreatment with Reagent #3).

The amount of Reagent #3 to be added depends upon the degree of conversion desired. All of the sodium sulfate can be converted into a non-swelling form or only a portion of it can be converted depending upon the amount of Reagent #3 added. The leach resistance of the bituminized product increases with the degree of conversion. Therefore, Reagent #3 can be added as required to meet applicable leaching standards.

3.5 System Capacity

The controlling factor in the overall processing capacity of the ATI System is the evaporative capacity of the Luwa Thin-Film Evaporator. Luwa manufactures 13 different Evaporator sizes, listed below in Table 3-4, ranging from 0.13 m^2 to 40 m^2 of heat transfer surface area. This wide range allows ATI to offer a system for virtually any processing capacity desired.

The three Evaporator sizes typically required for most radwaste applications are the Model LN-0200 (2 m^2 of heating surface), Model LN-0350 (3.5 m^2) and Model LN-0500 (5 m^2). The evaporative capacities of these three Evaporators, when processing various waste types, are listed in the Process Control Program, Section 3.4.6. If higher or lower processing rates than those listed are required, then a more appropriate Evaporator size would be selected for use. Table 3-4 lists nominal evaporative capacities for the Evaporator standard sizes.

Table 3-4

LUWA EVAPORATOR STANDARD SIZES

Luwa Evaporator Model No.	Heat Transfer Area m^2	Heat Transfer Area ft^2	Nominal Evaporative Capacity, liters/hr
LN-0012	0.13	1.4	12
LN-0050	0.5	5.4	50
LN-0100	1.0	10.8	100
LN-0200	2.0	21.6	200
LN-0350	3.5	37.7	350
LN-0500	5.0	53.8	500
LN-0750	7.5	80.7	750
LN-1050	10.5	113	1050
LN-1400	14	150.7	1400
LN-1800	18	193.7	1800
LN-2400	24	258.2	2400
LN-3200	32	344.3	3200
LN-4000	40	430.4	4000

3.6 Free Liquid Detection Procedure

3.6.1 Inactive Performance Testing

The Process Control Program (Section 3.4) outlines the critical process parameter ranges within which a homogeneous, monolithic, water-free product will be produced. During preoperational performance testing of the ATI System, after installation on site, verification of the complete solidification of the product and the absence of free liquid in the product can be obtained by following the procedure outlined below:

a. Non-radioactive wastes similar to the radioactive wastes to be processed are used in the testing procedure. These wastes are as similar as possible to the actual wastes to be processed, including contaminants likely to be present in the actual wastes.

b. Each waste type is processed in the ATI System with process parameters controlled within the ranges specified in the Process Control Program for that waste type.

c. Bituminized waste is packaged in a container type similar to that to be used during actual operation.

d. After filling of each test container, the container is tested for the presence of free liquid as follows:

   (1) The container is stored for cooling for a time sufficient to allow complete solidification. The time required will depend upon the size and shape of the container.

   (2) After cooling, the container is opened and the test material is visually examined. There should be no free liquid within the

container as determined from visual inspection.

(3) After visual inspection, with the container still in the upright orientation, the bottom or low point of the container is breached by drilling or other suitable means. The minimum area of the opening should be one square inch. There should be no free liquid visible flowing or dripping from the breach. This procedure is repeated at the vertical midpoint of the container to assure the absence of free liquid at that point.

(4) By following this procedure, the absence of free liquid can be verified for all waste types to be processed when controlling process parameters within the allowable ranges of the Process Control Program.

3.6.2 Active Production Operation

In accordance with 10CFR50 Appendix I Model Technical Specifications, the following procedure is to be followed during operation of the ATI System to verify solidification.

a. At least one representative test specimen is obtained from at least every tenth batch of each type of radioactive waste processed in accordance with the Process Control Program. This specimen is obtained by positioning the drip tray under the discharge of the Evaporator and allowing a small quantity of bituminized waste to collect in the tray. This tray is set aside and the specimen is allowed to cool. It is then picked up again with the drip tray mechanism and moved to a position in clear view of the operator through the observation window. The specimen is visually inspected for solidification, homogeneity, and the absence of free water. After inspection, the specimen and drip tray are placed into a waste container to be filled with bituminized product.

b. If any test specimen fails to verify solidification, additional waste samples are taken from consecutive batches of the same type waste until five consecutive test specimens demonstrate solidification and the Process Control Program is modified as required.

3.7 Radioactivity Leachability

3.7.1 IAEA Test Procedure

To evaluate the leaching characteristics of a radioactive waste material, the IAEA developed a standard leach test procedure.[1] This procedure establishes standard parameters for leach testing, including materials of construction of the test equipment, dimensions of the test specimen, volume of leachant, conductivity of leachant, temperature of leachant, frequency of sampling and replacing leachant, and other parameters. This procedure specifies that the results of the leach testing should be reported as a plot of the cumulative fraction of radioactivity leached from the specimen as a function of the total time of leaching:

$$\left(\frac{\Sigma a_n}{A_o}\right) \left(\frac{V}{F}\right) \quad \text{versus} \quad \Sigma t_n$$

where: a_n = Radioactivity leached during the leachant renewal period

A_o = Radioactivity initially present in specimen

F = Exposed surface area of specimen, cm^2

V = Volume of specimen, cm^3

t_n = Duration of leachant renewal period, days

From this plot a cumulative leach rate R_c can be determined,

$$\text{where:} \quad R_c = \left(\frac{\Sigma a_n}{A_o}\right) \left(\frac{V}{F}\right) \left(\frac{1}{\Sigma t_n}\right) \quad \text{cm/day}$$

Using the IAEA test procedure, the CEA has done extensive testing of the bituminized products of the SGN/ATI process. The results of their tests are discussed below for the various types of wastes.

3.7.2 Sodium Sulfate Concentrates

In 1978, Brookhaven National Laboratory published the results of tests that indicated a low leach resistance for bituminized sodium sulfate concentrates.[2] Tests performed by CEA confirm these results. The deterioration of solidified sodium sulfate is due to the strong propensity of anhydrous sodium sulfate to bind water, forming a decahydrate, and in so doing to swell by a factor of four times its anhydrous volume. This swelling force can exceed the binding force of the binder and cause the product to crack.

However, CEA has developed a chemical pretreatment, Reagent #3, that transforms the sodium sulfate into a non-swelling form, so that this tendency to swell is eliminated. In a recent CEA test,[3] a 200 gram/liter solution of sodium sulfate was treated with Reagent #3 and the resulting suspension was bituminized in a Luwa Evaporator to yield a product containing approximately 40 wt % solids and 60 wt % bitumen. The product was tested for leach resistance per the IAEA test procedure. The results of the test are shown in Figure 3-8. The data from Figure 3-8 can be used to determine the percentage of solids leached from specimens of various sizes and shapes. For a specimen the size and shape of a 55-gallon drum (but without the drum itself), totally immersed in demineralized water per the IAEA procedure, the percentage of solids that will be leached is shown in Figure 3-9. After three months, the percentage of solids leached will be only 0.052%. This demonstrates the high leach resistance of bituminized sodium sulfate concentrates that have been properly pretreated.

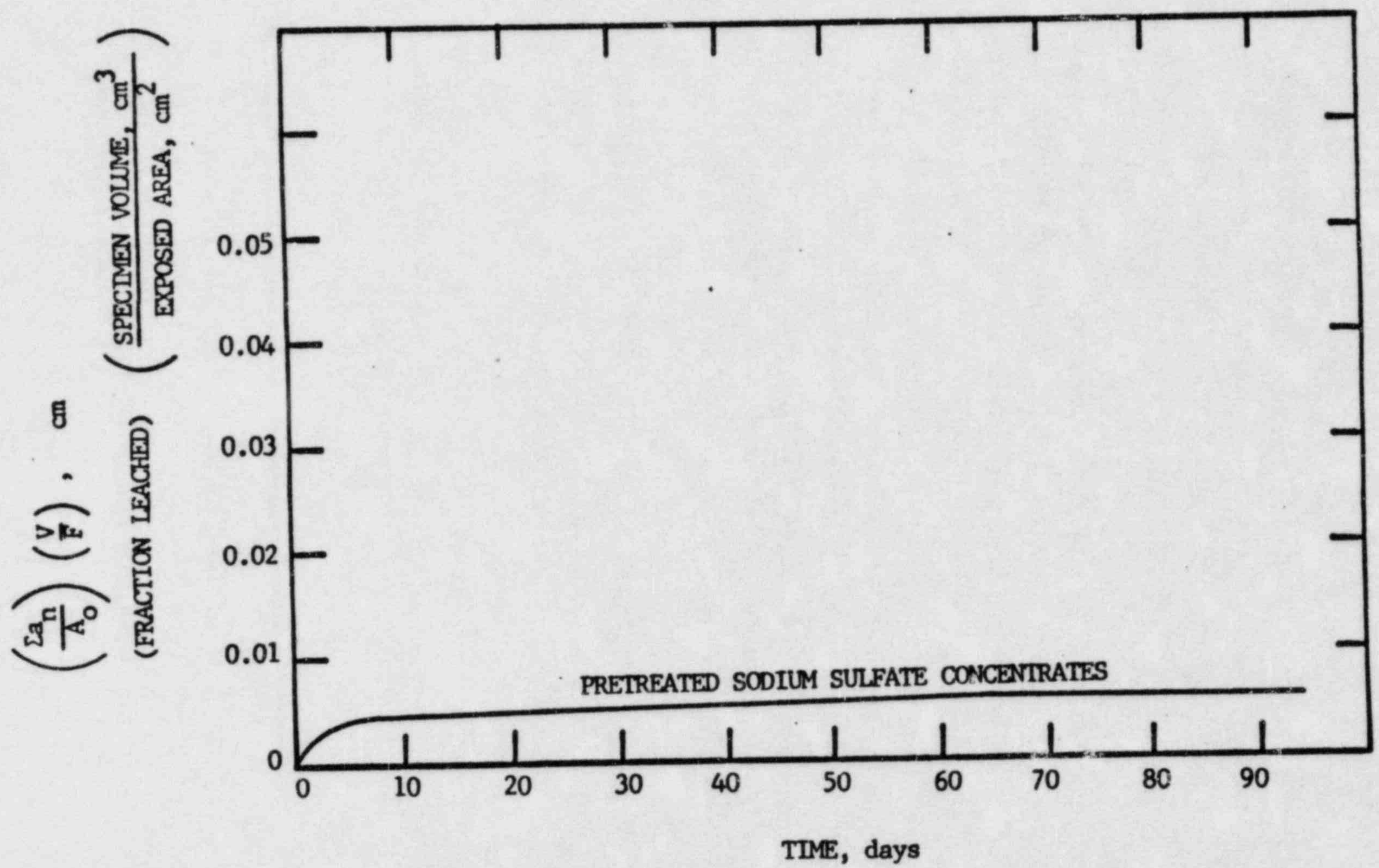


FIG. 3-8 - FRACTION OF SALT LEACHED FROM BITUMINIZED LAB SPECIMEN OF PRETREATED SODIUM SULFATE CONCENTRATES

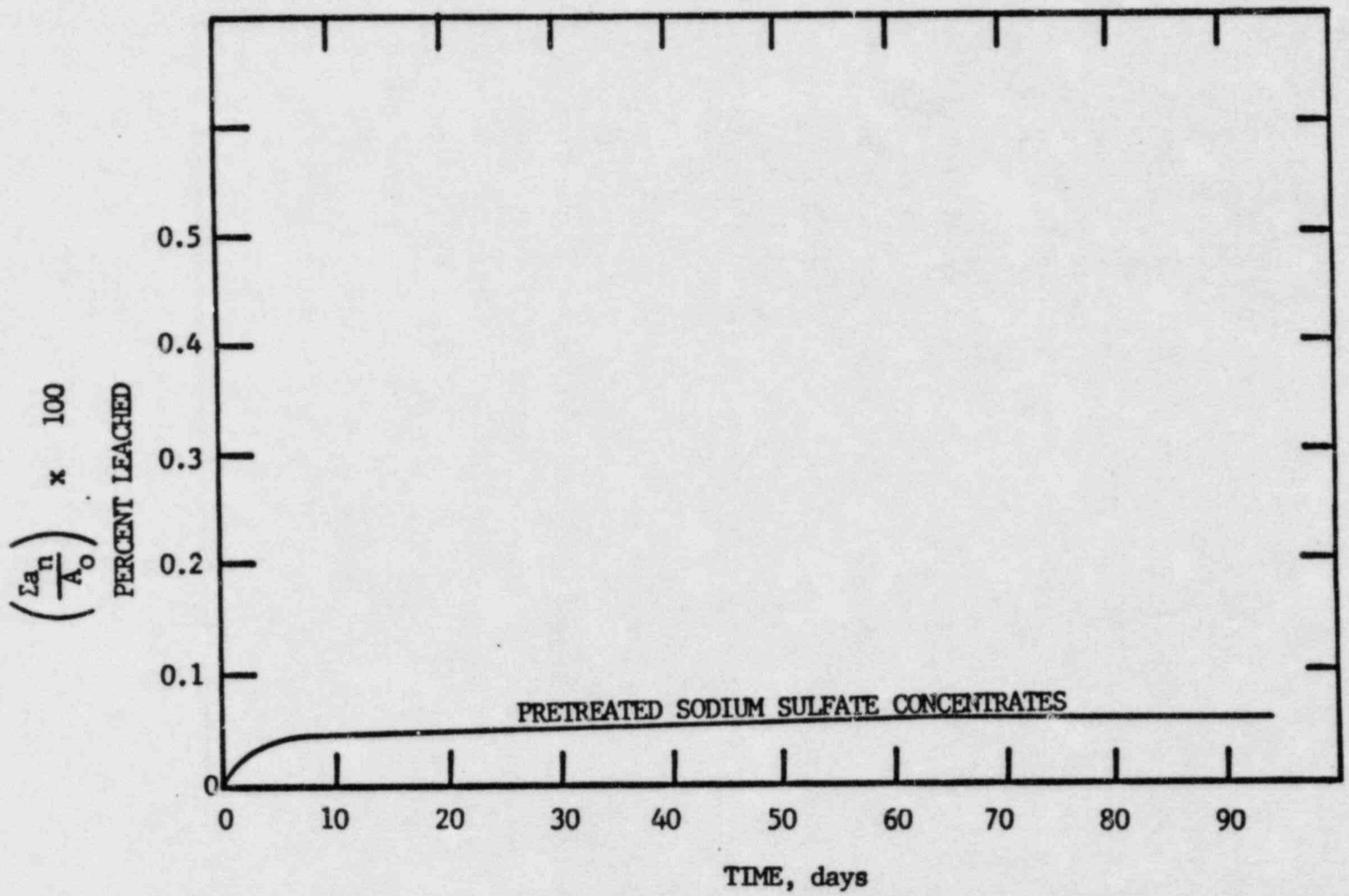


FIG. 3-9 - PERCENTAGE OF SALT LEACHED FROM BITUMINIZED 55-GALLON SAMPLE OF PRETREATED SODIUM SULFATE CONCENTRATES

3.7.3 Boric Acid Concentrates

In a recent CEA test performed at the Cadarache Research Center,[3] a 117 gram/liter boric acid solution was neutralized with caustic to produce a sodium borate solution, which was then bituminized in a Luwa Thin-Film Evaporator per the SGN/ATI process. The bituminized product, containing approximately 40 wt % sodium borate and 60 wt % bitumen, was then tested for leach resistance per the IAEA test procedure. The results of the leach tests are shown in Figure 3-10, which indicates the fraction of sodium borate leached from the samples tested. These results are corroborated by the results of similar tests performed by the Brookhaven National Laboratory.[4]

The data from Figure 3-10 can be used to determine the leach resistance of samples of various sizes and shapes. For instance, for a specimen the size and shape of a 55 gallon drum (but without the drum itself), totally immersed in demineralized water per the IAEA procedure, the percentage of sodium borate that will be leached is shown in Figure 3-11. After two months, the percentage of sodium borate leached will be only 0.015%.

Should it be desired to increase the leach resistance of the bituminized borates even further, Reagent #3 can be added to the solution prior to bituminization. This reagent converts the waste to a form that does not tend to form a hydrate. The results of leach tests performed on bituminized borates pretreated with Reagent #3 are shown in Figure 3-10. The percentage of solids leached from a 55 gallon specimen is shown in Figure 3-11. It can be seen that the addition of Reagent #3 increases the already high leach resistance of the bituminized borate product.

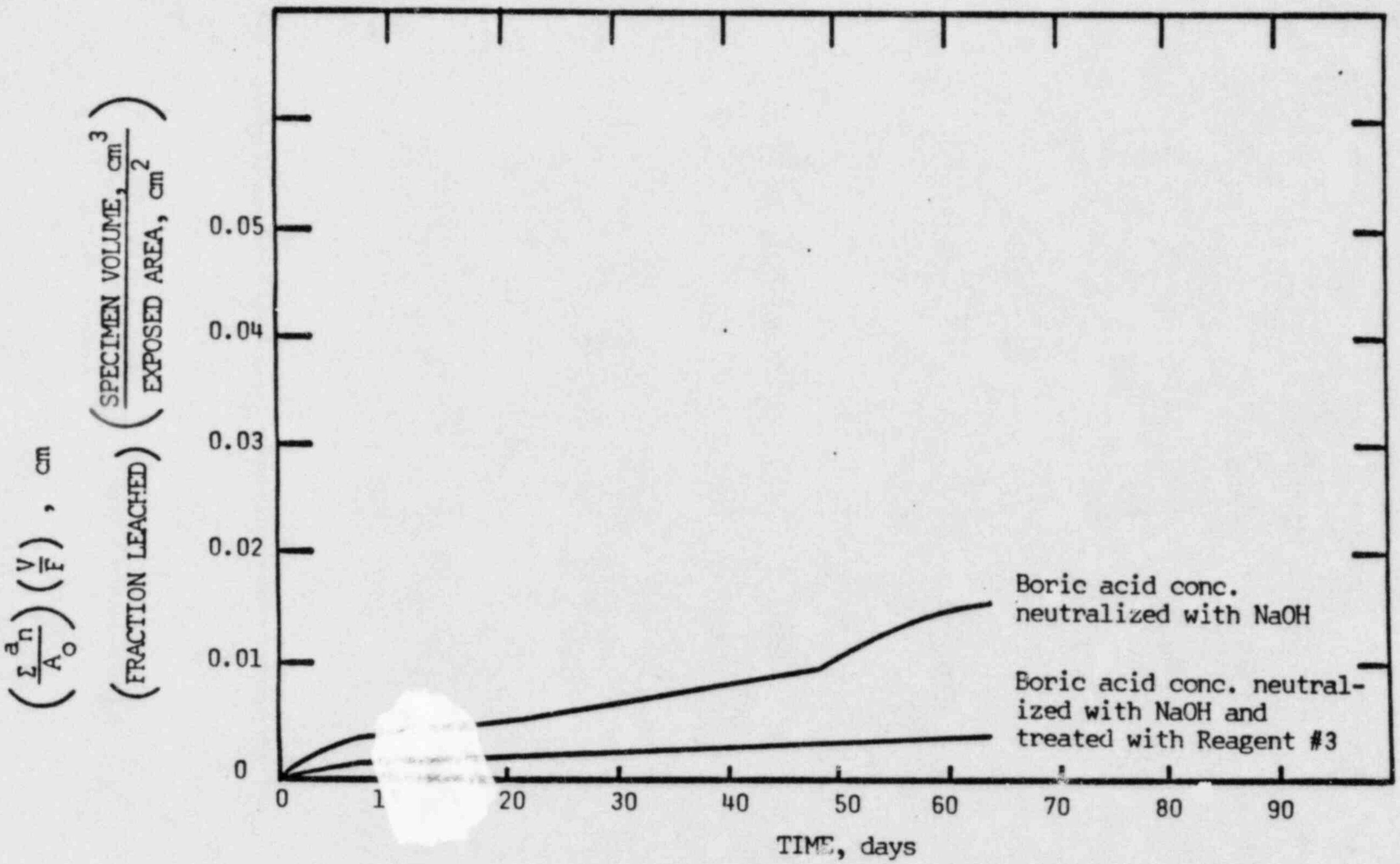


FIG. 3-10 - FRACTION OF SALT LEACHED FROM BITUMINIZED LAB SPECIMEN OF PRETREATED BORIC ACID CONCENTRATES

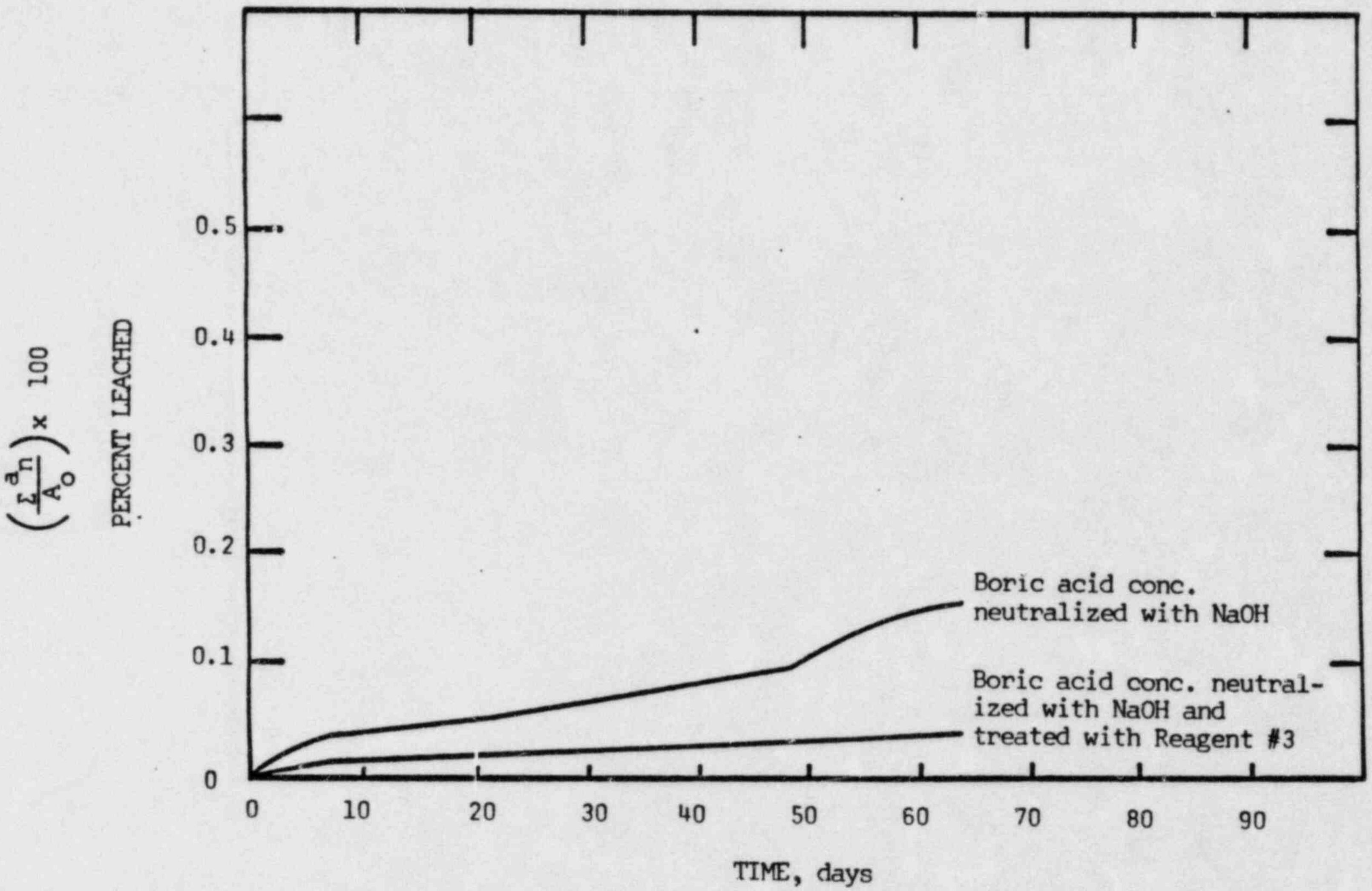


FIG. 3-11 - PERCENTAGE OF SALT LEACHED FROM BITUMINIZED 55-GALLON SAMPLE OF PRETREATED BORIC ACID CONCENTRATES

3.7.4 Radioactivity Leaching vs. Salt Leaching

Tests have shown that the leach rates of the specific nuclides Cs 137, Sr 90, Ru 106, Co 60, Pu 238, Pu 239, and Am 241 are significantly lower than the leach rates of the salts reported above for boric acid concentrates and sodium sulfate concentrates, typically by a factor of 100. In other words, it is much more difficult to leach the radioactive nuclides than it is to leach the nonradioactive solids.

3.7.5 Resins and Sludges

Recent CEA leach tests on bituminized ion exchange resins (40% resins, 60% bitumen), performed per the IAEA procedure, have shown that after 974 days of testing, the cumulative leach rates of Cs 137 and Sr 90 were as follows:

Cs 137: 3.7×10^{-5} cm/day

Sr 90: 3.1×10^{-6} cm/day

The results of CEA leach tests performed in the past ten years have consistently yielded cumulative leach rates for bituminized resins and sludges as follows:

Cs 137: 10^{-5} to 10^{-8} cm/day

Sr 90: 10^{-5} to 10^{-7} cm/day

Ru 106: 10^{-5} to 10^{-6} cm/day

Co 60: 10^{-5} to 10^{-6} cm/day

Total gamma activity: 10^{-5} to 10^{-7}

Alpha emitters (Pu 238, Pu 239, Am 241): 10^{-5} to 10^{-7}

To put these leach rates into perspective, using the results of the recent leach test performed on bituminized ion exchange resins, the

Cs 137 leach rate of 3.7×10^{-5} cm/day means that after 974 days (2.7 years) of immersion, only 0.34% of the Cs 137 initially present in the specimen will have leached out. This very small percentage illustrates the high leach resistance of the SGN/ATI bituminized product.

3.7.6 IAEA Leach Standards

The IAEA "Regulations for the Safe Transport of Radioactive Materials"[5] state that a low-level solid radioactive material is a solid in which "the activity is, and remains, insoluble so that, even under loss of packaging, the loss of radioactive material per package resulting from the effects of wind, rain, etc., and from total immersion in water is limited to less than 0.1 A_2 in a period of one week...". A_2 is defined in Section 109 of that document as "the maximum activity of radioactive material, other than special form radioactive material, permitted in a Type A package."

10CFR71 specifies this Type A quantity according to the radionuclides present, categorizing each nuclide into one of seven groups. The nuclides that could be expected to be present in most low level wastes should fall predominantly within Group III or Group IV. The Type A quantity for Group III is 3 curies and for Group IV is 20 curies. Assuming the worst case, in which all the radionuclides present would be in Group III, the Type A quantity would be 3 curies and, therefore, the maximum allowable IAEA leach rate would be (0.1)(3) = 0.3 curies leached in one week.

To compare the leaching characteristics of the SGN/ATI bituminized product with the IAEA leaching standards, consider a bituminized product containing 60% bitumen and 40% salts obtained by pretreating sodium sulfate concentrates with Reagent #3. From Figure 3-9, it can be seen that after 7 days of leaching, a 55 gallon specimen of bituminized product will have leached 0.04% of the salt initially in the specimen. Assuming that the percentage of activity leached is equal to the percentage of salt leached (as discussed previously, the percentage of activity leached is actually much less than the percentage of salt leached), and if the 55 gallon specimen contains the maximum allowable activity of 3 curies, then the activity leached from the specimen will be 0.0004 x 3 curies = 0.0012 curies after 7 days. This is less than the IAEA allowable of 0.3 curies by a factor of 250!

Similar analyses of other bituminized wastes produced by the SGN/ATI process show that they also easily meet the IAEA leaching standards.

3.7.7 Conclusion

The products of the SGN/ATI bituminization process are highly leach resistant and can easily meet IAEA leaching standards.

3.8 Utility Requirements

Utility requirements will vary depending upon the types of waste being processed and the capacity of the system. Typical requirements are listed below for three typical sizes of the ATI System based upon the size of the Evaporator.

Table 3-5

UTILITY REQUIREMENTS

UTILITY	QUANTITY REQUIRED		
	LN-0200	LN-0350	LN-0500
1. Electricity	285 KW connected 200 KW demand when operating	330 KW connected 225 KW demand when operating	440 KW connected 265 KW demand when operating
2. Compressed Air @ 90 psig	10 SCFM	10 SCFM	10 SCFM
3. Cooling Water	40 GPM	50 GPM	65 GPM
4. Steam @ 50 psig	50 lb/hr	50 lb/hr	50 lb/hr
5. Seal Water @ 50 psig	1 GPM	1 GPM	1 GPM
6. Flush Water @ 50 psig	30 GPM intermittent	30 GPM intermittent	30 GPM intermittent
7. Make-up Air for Process Ventilation	185 SCFM	185 SCFM	185 SCFM

4. EQUIPMENT DESCRIPTION

This section describes the equipment supplied with the ATI System. The ATI System is divided into a number of subsystems which are described individually.

4.1 Chemical Pretreatment Subsystem

The Chemical Pretreatment Subsystem is a set of agitated reagent tanks provided for the preparation of chemical pretreatment solutions and for the addition of these solutions in the required volumes to the waste being prepared for processing.

Each tank is equipped with a level monitor which provides a remote level indication, allowing remote addition of reagent solution to the Waste Batch Tank.

The Chemical Pretreatment Subsystem includes the equipment described below.

- Acid Tank, 100 gallon, Alloy 20, with agitator, used to prepare and meter sulfuric acid for adjusting the pH of alkaline wastes.

- Base Tank, 200 gallon, 316 S.S., with agitator, used to prepare and meter sodium hydroxide (NaOH) solution for converting boric acid concentrates to sodium borates, for adjusting the pH of other acidic wastes, and for adjusting the pH of acidic distillate produced when processing resins.

- Reagent Tank #1, 100 gallon, 304 S.S., with agitator, used to prepare and meter a 25% solution of Reagent #1, the surfactant added to reduce the surface tension between bitumen and waste and ensure a homogeneous product. Reagent Tank #1 is heated with an electrical immersion heater. The solution temperature is continuously monitored and automatically controlled.

- Reagent Tank #2, 200 gallon, Alloy 20, with agitator, used to prepare and meter a 10% solution of Reagent #2,

- Reagent Tank #3, 100 gallon, Alloy 20, with agitator, used to prepare and meter special reagents that may be used to increase the leach resistance of the bituminized product.

- Reagent Metering Pump, positive displacement, 316 S.S., to meter Reagent #1 into the feed line to the Evaporator.

If the building design permits, the reagent tanks are located at an elevation above the Waste Batch Tanks so that chemical pretreatments can be gravity drained into the Waste Batch Tanks. If this is not possible, then pumps are provided to transfer the chemical pretreatments from the reagent tanks to the Waste Batch Tanks.

4.2 Waste Feed Subsystem

The Waste Feed Subsystem is provided to collect, treat and feed waste to the Evaporator.

4.2.1 Waste Batch Tanks

a. Function

The two Waste Batch Tanks are provided for the collection, pretreatment and feeding of waste to the Evaporator.

b. Design Features of Each Tank

(1) Typical tank capacity is 1000-1500 gallons each.

(2) The tank is constructed of either 316 S.S., Alloy 20, Incoloy, or other alloys as are all wetted parts of the agitator.

(3) Well screens are provided for decanting.

(4) Operating pressure is atmospheric, design pressure is 15 psig.

(5) Internals are of all welded construction.

(6) The tank has a 45° cone bottom and 4 anti-swirl baffles welded inside the vessel.

(7) External electric heating pads are provided.

(8) Level indication is by differential bubbler (primary) and ultrasonic detector (secondary).

(9) The agitator is provided with a water-cooled double mechanical seal.

(10) The agitator drive is located on the floor above in a low radiation zone for ease of maintenance.

(11) Each agitator has, as a minimum, one impeller near the bottom of the tank, designed to prevent stagnant areas and to "pump" solids upward off the bottom of the tank, and one impeller near the middle of the tank, designed to provide thorough, uniform mixing.

(12) A two-speed drive is provided for each agitator. The slower speed is used for start-up and the higher speed for use during processing.

(13) Each tank is provided with a manhole.

(14) Each tank is equipped with a spray nozzle for internal flushing.

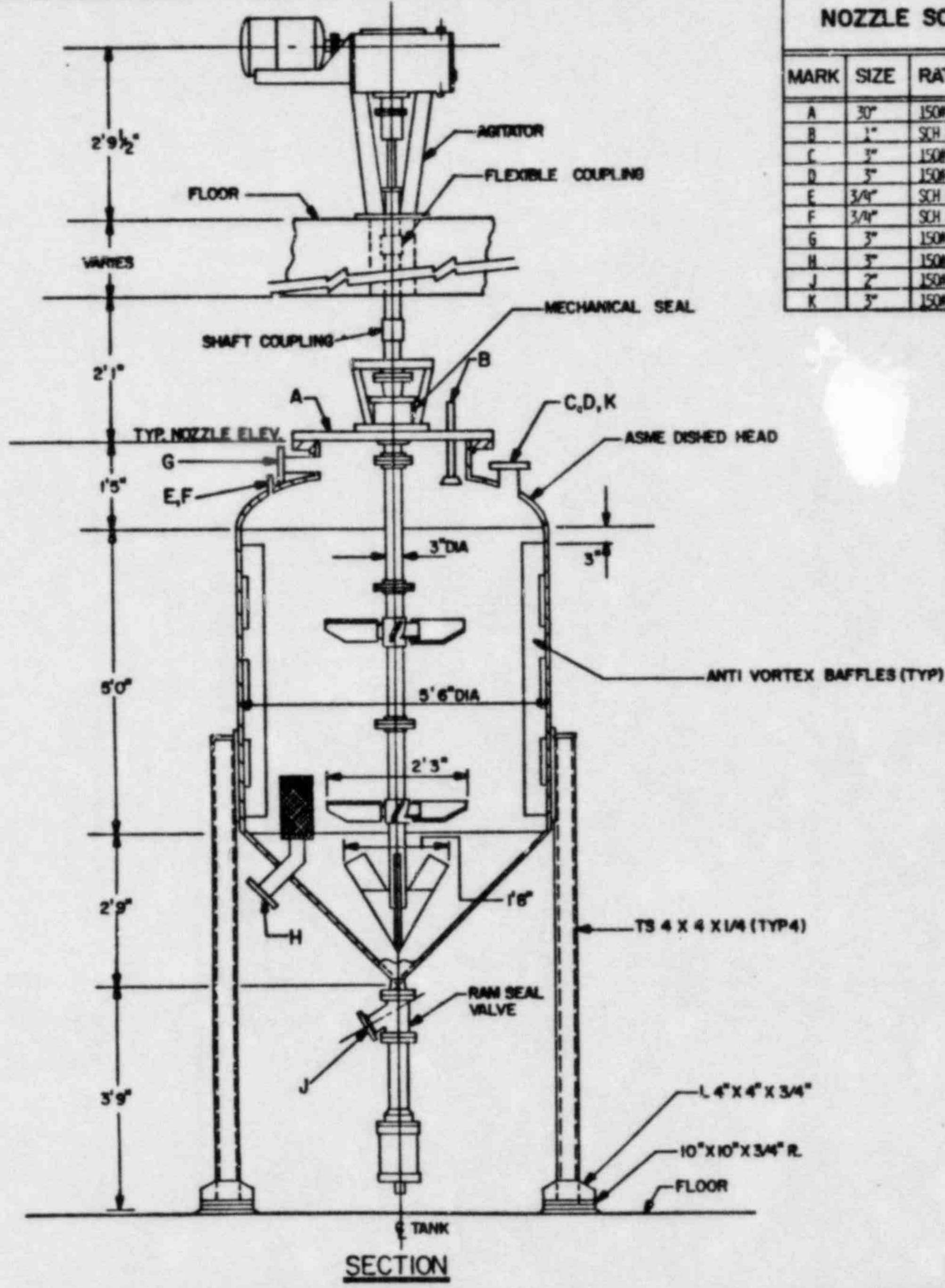
(15) A water flush connection is provided to backflush the outlet nozzle.

Figure 4-1 is an outline drawing of a typical Waste Batch Tank.

4.2.2 Waste Recirculation Pumps

a. Function

The two Waste Recirculation Pumps aid in maintaining a well mixed, homogeneous waste slurry in the Waste Batch Tanks by recirculating the waste in a closed loop. They provide flow rates sufficient to keep solids from settling out in the recirculation lines, delivering waste to the suction of the Evaporator Feed Pumps, which are located close to the Evaporator. The slurry is high in solids and thus necessitates the use of a pump which is unaffected in performance by abrasion or variations in solids content. For this service the type pump selected is a progressive cavity, positive displacement pump, in which the rotor turns



NOZZLE SCHEDULE

MARK	SIZE	RATING TYPE, SCHED.	REMARKS	SERVICE
A	30"	150# ANSI R.F. FLANGE		AGITATOR
B	1"	SCH 80 PIPE STUB		SPRAY NOZZLE
C	3"	150# ANSI R.F. FLANGE		INLET
D	3"	150# ANSI R.F. FLANGE		VENT
E	3/4"	SCH 80 PIPE STUB		REAGENT INLET
F	3/4"	SCH 80 PIPE STUB		ACID INLET
G	3"	150# ANSI R.F. FLANGE		OVERFLOW
H	3"	150# ANSI R.F. FLANGE		DECANT
J	2"	150# ANSI R.F. FLANGE		DISCHARGE
K	3"	150# ANSI R.F. FLANGE		BUBBLER ASSEMBLY

NOTES AND DATA

1. CODE CONST. / STAMPED	API 620/NO
2. OPERATING PRESS (PSIG) / TEMP (°F)	ATMOS/180
3. DESIGN PRESS. (PSIG) / TEMP (°F)	15/250
4. S.V. SETTING / HYDRO TEST PRESS.	VENTED/[illegible]% TEST PER API 620
5. CORROSION ALLOWANCE	1/16
6. STRESS RELIEVE / RADIOGRAPH	NO/NO
7. MATERIALS / THICKNESS	
SHELL	AS REQUIRED/ 3/8
HEADS	AS REQUIRED/ 3/8
PIPE	SCH 80
FLANGES	150# R.F.
COUPLINGS	3000 #
BOLTS	
NUTS	
GASKETS	
8. WELDING SPECS.	AWS AND API 620
9. WELD FINISH	WIRE BRUSH
10. SANDBLAST	NO
11. PASSIVATE	NO
12. PREPARE FOR LINING	NO
13. PAINT	NO
INSIDE	
OUTSIDE	
14. WEIGHT - NET / FLOODED	2,700/13,200
15. SPEC. NO.	

Rev	Drawn	Check	Appr	PE Appr	Date	Description
A	BRO					RELEASED FOR INFORMATION

ATI

OUTLINE
TYPICAL WASTE BATCH TANK (1100 GAL)

Scale	Drawing No.	Rev
3/4" = 1' 0"	S-M5-79	A

FIGURE 4-1

within the stator and cavities are formed which progress toward the discharge end of the pump.

b. Design Features of Each Pump

(1) A single rotating element delivers predictable, uniform, continuous flow.

(2) Discharge is non-pulsating and accurately repeatable.

(3) Capacity is proportional to speed.

(4) Discharge volume is unaffected by varying suction head.

(5) Internals and rotor are constructed of either 316L stainless steel, Alloy 20, or other alloy.

(6) Rounded and smooth transitions prevent material build-up.

(7) Pump disassembles in minutes for fast, easy cleaning, using common tools.

(8) The drive is completely isolated from pump case.

(9) A mechanical seal is provided to positively ensure that there is no contaminant leakage.

4.2.3 Evaporator Feed Pumps

a. Function

Two Evaporator Feed Pumps are provided to take waste from the waste recirculation lines and meter it into the Evaporator.

This service requires a precision positive displacement pump which is unaffected in performance by abrasion or variations in solids content. For this service the type pump selected is a progressive cavity, positive displacement pump, in which the rotor turns within the stator and cavities are formed which progress toward the discharge end of the pump. In order to vary the processing rate capabilities of the system, the Evaporator Feed Pumps are provided with variable speed drives.

b. Design Features of Each Pump

(1) A single rotating element delivers predictable, uniform, continuous flow.

(2) Discharge is non-pulsating and accurately repeatable.

(3) Capacity is proportional to speed.

(4) Discharge volume is unaffected by varying suction head.

(5) The pump is supplied with a D.C. variable speed drive for precise flow rate control.

(6) Internals and rotor are constructed of either 316 S.S., Alloy 20, or other alloy.

(7) The pump disassembles in minutes for fast, easy cleaning using common tools.

(8) Transitions are rounded and smooth to prevent material build-up.

(9) The drive is completely isolated from pump case.

(10) A mechanical seal is provided to positively ensure that there is no contaminant leakage.

4.3 Bitumen Storage and Feed Subsystem

The Bitumen Storage and Feed Subsystem is provided to maintain an operating inventory of molten bitumen and to meter it at the proper rate to the Evaporator as required for solidifying waste.

4.3.1 Bitumen Storage Tank

a. Function

The Bitumen Storage Tank (or Tanks, if required) is provided to ensure an adequate storage of bitumen for processing.

b. Design Features

(1) The capacity is 8000 gallons. This allows the unloading of 5000 gallon tank trucks or cars when the Bitumen Storage Tank is 40% full.

(2) The tank can be placed indoors or outdoors.

(3) The tank is fabricated of carbon steel.

(4) Three steam coils are provided in the tank to maintain temperature at 280°F to assure a liquid state for the bitumen.

(5) The tank is vented to prevent pressure build-up.

(6) The tank is designed to API 650.

(7) Thermocouples are provided to ensure proper temperature control.

(8) A ladder and quick opening manhole are provided.

(9) The tank is fully insulated to minimize heat loss.

(10) A fill line with strainer is provided for filling. The strainer prevents foreign material from entering the tank. Differential pressure across the strainer must be checked periodically during filling.

4.3.2 Bitumen Metering Pump

a. Function

The Bitumen Metering Pump is a variable speed pump provided to precisely meter molten bitumen to the Evaporator for the solidification of waste. The flow rate of bitumen is automatically maintained in correct proportion to the waste feed rate to the Evaporator by automatic control of the speed of the Bitumen Metering Pump drive. The Bitumen Metering Pump is capable of metering small quantities of viscous bitumen at varying process rates. It is a progressive cavity, positive displacement pump, in which the rotor turns within the stator, forming cavities which progress toward the discharge end of the pump.

b. Design Features

(1) A single rotating element delivers predictable, uniform, continuous flow.

(2) Discharge is non-pulsating and accurately repeatable.

(3) Capacity is proportional to speed.

(4) Discharge volume is unaffected by varying suction head.

(5) Cast iron casing, tool steel internals, chrome plated hardened steel rotor, and rubber stator are the materials of construction.

(6) Pump is provided with a D.C. variable speed drive for precise flow rate control.

(7) A strainer is provided in the suction line to prevent small clumps of bitumen from reaching the pump.

(8) The pump disassembles in minutes for fast, easy cleaning using common tools.

4.4 Volume Reduction and Bituminization Subsystem

The Volume Reduction and Bituminization Subsystem receives the prepared waste, evaporates the water from the waste, mixes the waste solids with molten bitumen, charges the waste/bitumen mixture into containers, and caps the filled containers.

4.4.1 Luwa Thin-Film Evaporator

a. Function

The Luwa Thin-Film Evaporator receives the prepared waste from the Waste Feed Subsystem, evaporates the water from the waste, mixes the remaining solids with molten bitumen, and discharges the waste/bitumen mixture into waste containers.

b. Design Features

(1) The Evaporator parts in contact with waste, bitumen and vapor can be constructed of 316 S.S., Hastelloy, Incoloy, Monel, nickel, titanium or other corrosion resistant alloys.

(2) The tangential feed introduction in the direction of the rotor rotation assures clean, uniform distribution of waste and bitumen into the distribution ring.

(3) The feed distribution ring is an integral part of the rotor. The waste and bitumen entering the two feed nozzles are taken up by the distribution ring and are evenly distributed around the perimeter of the thermal wall. Water vapor traveling upward is kept separated from the feed, minimizing the entrainment of liquid particles.

(4) The entrainment separator sits above the feed inlets and the vapor-generating thermal section as an integral part of the Luwa Evaporator, and consists of rotating baffle plates of highly efficient design. The design of this separator is such that liquid particles entrained in the vapors are impinged on the baffle plates, and through centrifugal force are pulled toward the conical shell of the rotating separator where they are forced back into the waste stream. The vapors leave the top of the entrainment separator essentially free of particles. The decontamination factor is typically 10^4 to 10^5.

(5) The required small and uniform clearance between the rotor blade tip and the Evaporator wall demands a concentric Evaporator assembly. The interlocking flange designs of the individual Evaporator sections provide an accurate, concentric seating of each Evaporator section. This also assures properly aligned reassembly of top cover and bottom bearing after inspection or maintenance.

(6) Only one double mechanical seal is needed in the Luwa Evaporator. It is of attractive simplicity and reliability. Carbon rings run on stationary stellite surfaced stainless steel rings to provide the seal surface.

(7) The "floating type" graphite bottom bushing is located in the process space, eliminating the need for a mechanical seal at the "hot end". This simple pin and bushing allows an axial rotor expansion different from the axial shell expansion. This lower bushing is accessible and can be serviced easily from the bottom without removing the rotor.

(8) The Luwa Evaporator is delivered after a stringent test run under vacuum in Luwa's shop, completely assembled with rotor in place.

(9) Inspection is generally done with rotor in place, and only unusual, infrequent circumstances would necessitate pulling the rotor. For this, a simple hoist is all that is needed to remove the rotor. For inspection of the top cover assembly containing the main roller bearing and the double mechanical seal, the rotor can remain in the Evaporator while the top cover is pulled off, completely assembled for inspection at a more convenient place.

(10) The Evaporator drive, mechanical seal, and roller bearing are separated from the process section by a shield wall.

(11) The process surface in the thermal section is machined for complete roundness and uniform rotor clearance throughout. The design lends itself well for thorough cleaning of all process surfaces by simply flushing with bitumen and water.

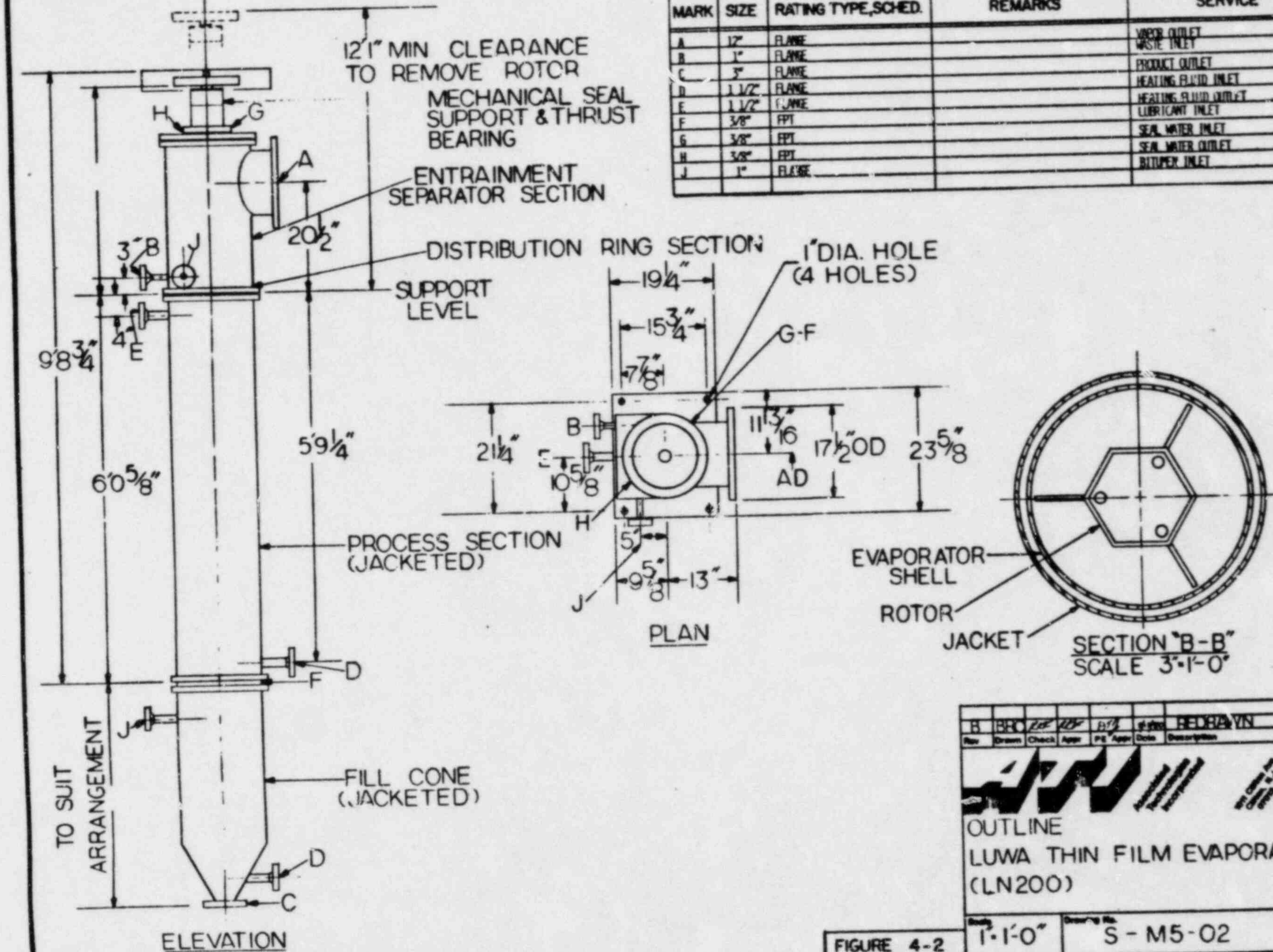
(12) A small flow of air is pulled into the bottom outlet of the Evaporator to provide sufficient upward velocity across the face of the outlet to prevent vapors from leaving the Evaporator through the bottom outlet. The vapors are forced to exit through the vapor outlet of the Evaporator and enter the Condenser. This air flow is provided by the Exhaust Fan.

(13) The jacketed bottom discharge cone is designed with sufficient volume to receive the waste/ bitumen mixture while the bottom discharge valve is closed for waste container indexing.

Figure 4-2 is an outline drawing of a Luwa Thin-Film Evaporator Model LN-0200. Figure 4-3 is a photograph of a Model LN-0350.

NOZZLE SCHEDULE

MARK	SIZE	RATING TYPE, SCHED.	REMARKS	SERVICE
A	12"	FLANGE		VAPOR OUTLET
B	1"	FLANGE		WASTE INLET
C	3"	FLANGE		PRODUCT OUTLET
D	1 1/2"	FLANGE		HEATING FLUID INLET
E	1 1/2"	FLANGE		HEATING FLUID OUTLET
F	3/8"	FPT		LUBRICANT INLET
G	3/8"	FPT		SEAL WATER INLET
H	3/8"	FPT		SEAL WATER OUTLET
J	1"	FLANGE		BITUMEN INLET



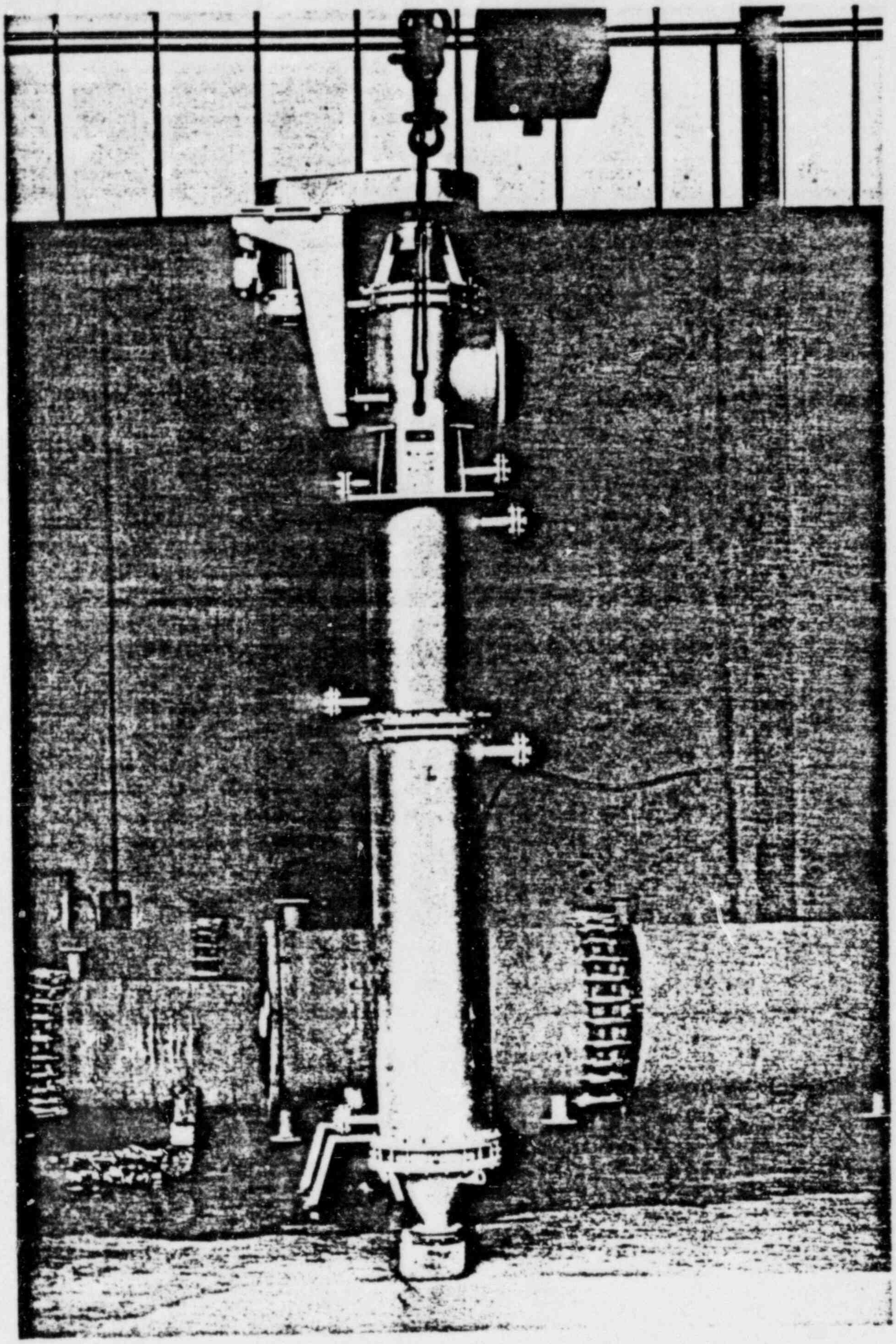


FIG. 4-3 LUWA THIN-FILM EVAPORATOR MODEL LN-0350

4.4.2 Turntable

a. Function

When 55-gallon drums are selected for use, ATI's 8-position Turntable can be utilized for positioning the drums under the Evaporator for filling. When the level in the drum being filled reaches a predetermined level, the Evaporator outlet valve is automatically closed, a Drip Tray is automatically placed under the valve, and the drive mechanism of the Turntable is activated to index the drum. This places the next drum in position for fill. This operation of changing to the next drum position is completely automated. When a drum has travelled a complete circuit around the turntable, it has cooled sufficiently to allow product shrinkage and is in position for final filling. Upon high level the drum is again removed from below the Evaporator and is rotated to the next position. The filled drum is then capped by the Cap Crimper which is located above the Turntable.

b. Design Features

(1) The Turntable is designed to accept the load of eight full containers and the Cap Crimper.

(2) The turntable is supported by eight rollers fixed in a frame.

(3) The Turntable is driven by a motor located outside the shield wall for easy access. The motor drives a right angle speed reducer. A shaft mounted on ball bearings penetrates the shield wall and is connected to the speed reducer with a flexible coupling. The penetration coupling is connected to a sliding spline shaft with two universal joints. The chain sprocket which drives the Turntable is connected to the spline shaft through a right angle gear drive.

(4) A hand crank is provided which is connected to the drive shaft via a chain and sprocket outside the shield wall which enables manual turning of the Turntable in emergency conditions.

(5) The Turntable frame is covered by stainless steel trays with guide rails and stops to make sure the drums are placed in the correct position.

(6) Redundant limit switches are provided to ensure that the Turntable stops at the correct position.

4.4.3 Drip Tray and Swing Arm

a. Function

A Drip Tray is automatically placed under the Evaporator waste discharge valve by the Swing Arm when waste containers are being indexed, to catch any dripping of bitumen/waste mixture that may occur from the closed valve. This mechanism can also be used to take samples of the bitumen/waste mixture. Soiled trays are discarded by placing them in waste containers.

b. Design Features

(1) The Swing Arm design incorporates a stainless steel ring for supporting the Drip Trays. A remotely operated mechanical arm is used to pick up a tray from a stack of trays and place it into the support ring. This same mechanical arm is used to place the soiled tray in an empty waste container waiting to be filled.

(2) The Swing Arm is rotated by two flexible cables which extend through the shield wall to a remote pneumatic actuator.

(3) An adjustable stop assures proper positioning of the Drip Tray under the Evaporator discharge valve.

The Swing Arm can be seen in Figure 2-3 of Section 2.

4.4.4 Additional Equipment Items

a. Ventilation Hood

The purpose of the Ventilation Hood is to capture any off-gas that may leave the surface of the bituminized waste and also to act as a splash shield to prevent contamination of the outside of the waste drum.

The hood extends from the Evaporator discharge valve outlet to the top of the waste drum, enclosing the stream of bituminized waste as it falls from the outlet into the drum. Air is pulled from the room into the bottom of the hood, entering through the small gap between the bottom of the hood and the top rim of the drum. This flow of air is maintained at 175 SCFM to yield sufficient air velocities for capturing and transporting any off-gas that may be present.

A viewing window is included in the side of the hood to permit visual observation of the waste flow.

b. Evaporator Waste Discharge Valve

This valve is a jacketed, full port, pneumatically actuated ball valve. It is automatically closed when the level in the waste container reaches a predetermined point. The process wetted parts are 316 S.S. Heating fluid is circulated through the valve jacket to maintain the bitumen/waste mixture in a molten state.

c. Secondary Level Detector

This detector is used as a backup to the primary level detector to detect high level of bitumen/waste mixture in the waste container. It consists of a steam or hot air probe that is inserted by remote actuation into the top of the container. Steam or hot air is bled through the probe at a small rate. Should the level of product reach the probe, the back pressure produced in the steam or hot air line is sensed, providing a signal for automatic response. Figure 4-4 shows the Secondary Level Detector at the Barsebeck installation.

d. Cap Crimper

The Cap Crimper is used to remotely crimp container caps to seal the filled waste containers. Two designs are available for use, one designed by SGN and the other by an American manufacturer. With both designs, the Crimper is lowered by gravity to the crimping position. An air cylinder actuates the crimping head and crimps the cap with moveable jaws. The jaws are retracted and the crimping head is raised. The American design provides a seal that has been proven to meet DOT standards. The American design can also be used to pick up the caps, position them on the containers, and lift capped containers of up to 1000 pounds. Figure 4-5 shows the Cap Crimper at the Barsebeck installation.

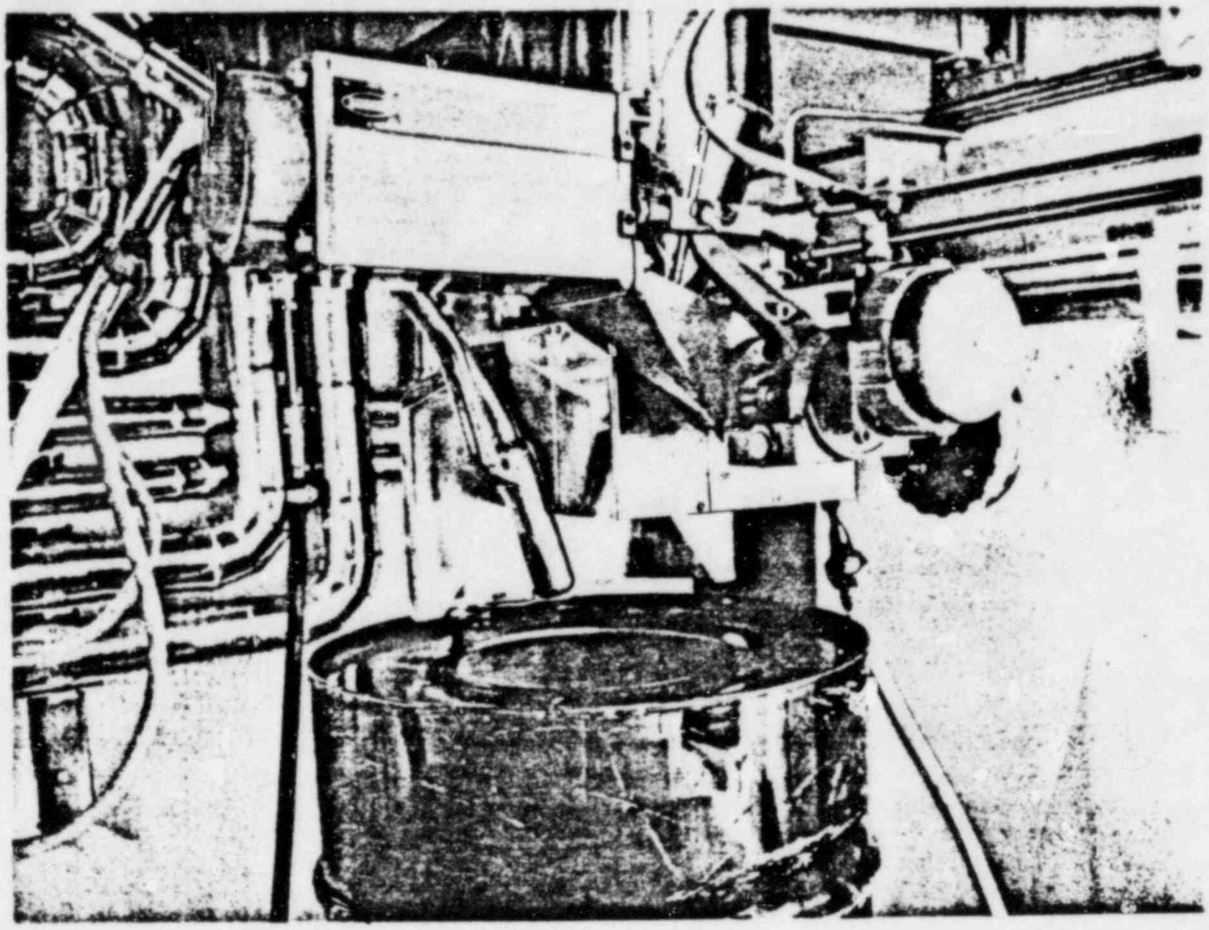


FIG. 4-4 SECONDARY LEVEL DETECTOR, BARSEBECK NUCLEAR POWER STATION

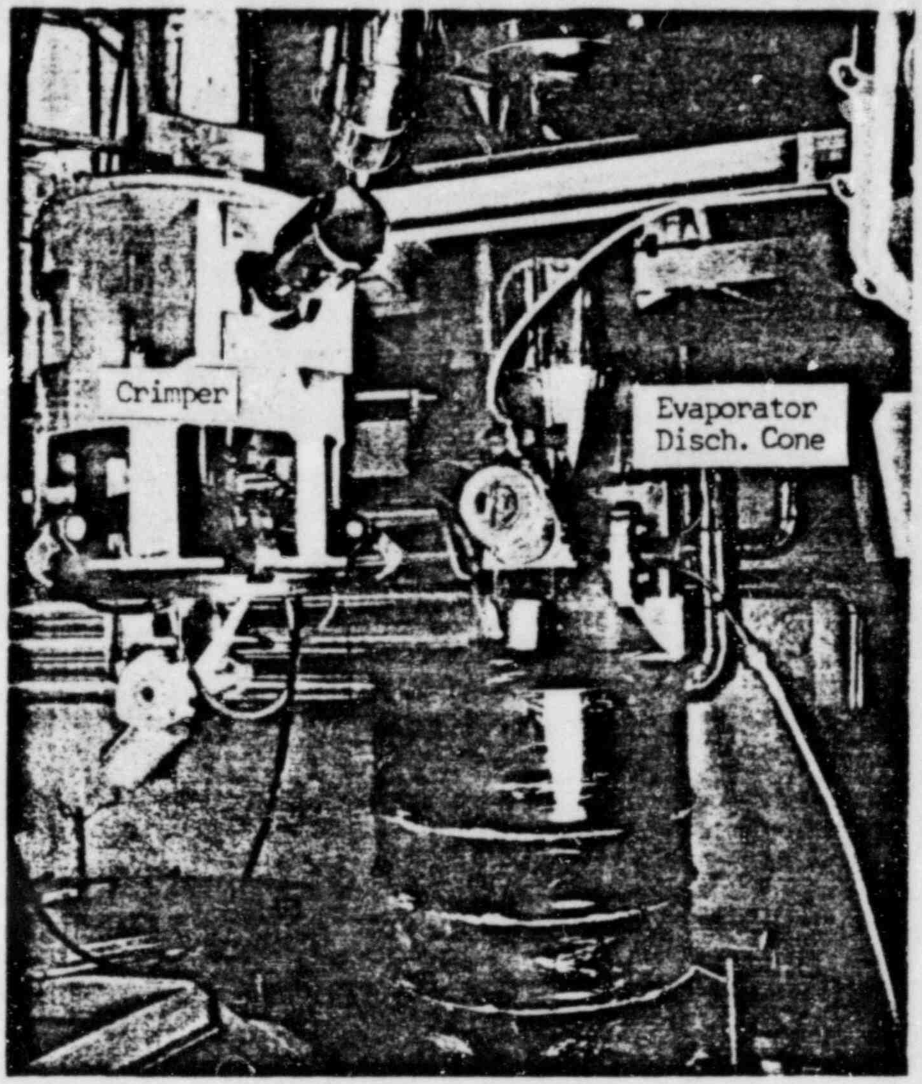


FIG. 4-5 CAP CRIMPER, SGN DESIGN, BARSEBECK NUCLEAR POWER STATION

4.5 Distillate Subsystem

The function of the Distillate Subsystem is to condense, treat and discharge the distillate produced by the Evaporator.

4.5.1 Condenser

a. Function

The vapor produced in the Evaporator is pulled into the Condenser by the Exhaust Fan. The vapor flowing through the tubes of the Condenser is cooled and condensed by the cooling water flowing through the shell. The condensed vapors (distillate) and the noncondensable gases (including air) enter a chamber which allows the distillate to drain to the Distillate Collection Tank and the noncondensables to exit to the Organics Filter, HEPA Filter and Exhaust Fan.

b. Design Features

(1) Standard shell and tube heat exchanger, with 316 S.S. tubes and tubesheets, carbon steel shell.

(2) Pressure drop on the vapor side is limited to 1" water column by the design of the tubes.

(3) Design is single pass countercurrent.

(4) The Condenser can be of horizontal, sloped design or vertical design. In either case, it is self-draining.

(5) The tube bundle is removable.

(6) The design includes impingement baffles opposite the shell inlet nozzle to prevent impingement of the incoming flow on the tube bundle.

(7) The Condenser is an outside packed floating head exchanger which compensates for expansion differences between the shell and the tubes.

(8) The Condenser is designed to the ASME Pressure Vessel Code, ASME Section VIII.

(9) Mixing of shell or tube side fluids is prevented through gasketed joints.

(10) Outleakage of radioactivity is precluded since the cooling water is at a higher pressure than the vapor and condensate.

4.5.2 Distillate Collection Tank

a. Function

The Distillate Collection Tank is provided to collect, monitor and store distillate before transfer through the Distillate Oil Filters to the plant's liquid waste system.

b. Design Features

(1) The tank is skid mounted complete with piping and valves.

(2) The tank and internals are constructed of [illegible] stainless steel for corrosion protection.

(3) The tank is designed and constructed in accordance with API 650.

(4) The tank design includes a manhole for inspection and maintenance.

(5) A flanged connection is provided for a level monitor.

(6) The tank interior is smooth and rounded to eliminate pockets where activity could accumulate.

(7) The tank is equipped with an internal nozzle for flushing with water. A drainage path and vent are provided to allow complete drainage of the tank.

(8) A caustic solution inlet is provided for pH adjustment of acidic distillate.

4.5.3 Distillate Transfer Pumps

a. Function

The two Distillate Transfer Pumps transfer the distillate from the Distillate Collection Tank through the Distillate Oil Filters to the plant's liquid waste system.

b. Design Features

(1) The pumps are low volume centrifugal pumps.

(2) Casing, internals, and impeller are constructed of 316 S.S.

(3) Stuffing box is complete with mechanical seals.

(4) Pump and motor are mounted on a common base.

(5) The pump internals can be flushed with water.

4.5.4 Distillate Oil Filters

a. Function

A small amount of light oils are carried over from the Evaporator with the distillate. Three Distillate Oil Filters arranged in series are provided to remove these oils from the distillate. The filters contain activated charcoal. When saturated, the charcoal is sluiced to a Waste Batch Tank and is bituminized in the Evaporator.

b. Design Features

(1) Each vessel includes internal distribution and and collection headers to distribute the distillate evenly over the filter bed and collect the distillate in the bottom of the vessel.

(2) A charcoal fill connection is provided on each vessel for charging a new bed of charcoal.

(3) The three filters are skid mounted complete with piping and valves.

(4) The filter vessels are constructed of 316 S.S.

(5) The vessels are designed and constructed in accordance with the ASME Section VIII Code for Unfired Pressure Vessels.

(6) The interior of each vessel is rounded and smooth to eliminate pockets where activity could accumulate.

(7) The filters are designed with remotely operated valves so that personnel exposure is minimized.

(8) The system is designed so that the first two filters reduce the effluent oil content to acceptable levels. The third filter acts as a polishing filter and a backup for the other two. The first two filters are valved so that either can be placed upstream of the other. In this way, the filter with the newest carbon can be placed downstream of the other for maximum cleaning efficiency.

4.5.5 Distillate Cooler

a. Function

The Distillate Cooler is an optional equipment item used to cool the distillate when it is to be returned to a Waste Batch Tank for diluting resin slurries. Since degradation of resins can occur at temperatures above 140°F, the distillate temperature is lowered through the Cooler below this temperature before the distillate is returned to the Waste Batch Tank. The distillate flows through the tubes while the cooling water flows through the shell of the cooler.

b. Design Features

(1) The Cooler is a standard four pass, shell and tube heat exchanger.

(2) The tube bundle is removable.

(3) The heat exchanger tubes and tube sheets are constructed of 316 S.S. The shell is carbon steel.

(4) Hubs are enlarged under connections for unrestricted flow.

(5) Transverse baffles direct flow through the shell.

(6) Roller-expanded tubes assure permanently tight, leakproof fit.

(7) The Cooler is designed to the ASME Pressure Vessel Code, ASME Section VIII.

(8) Mixing of shell and tube side fluids is prevented through gasketed joints.

4.6 Heating Fluid Subsystem

The ATI System utilizes a high temperature heating fluid instead of high pressure steam to evaporate the waste water in the Luwa Thin-Film Evaporator. Use of a heating fluid allows sufficient temperature to evaporate water without high pressure. The heating fluid is circulated from an electric resistance heat exchanger through the Evaporator jackets, fill cone and discharge valve and recirculated back to the heat exchanger by a centrifugal pump. Use of a heating fluid provides precise control of process temperature over the entire length of the Evaporator. The differential between the inlet and outlet temperature is only 10 degrees F. The heating fluid system is inherently a safe design. It is the same type of system used to preheat fuel oil on start-up of oil fired boilers. Figure 4-6 shows a typical Heating Fluid Subsystem.

4.6.1 Pump and Heater

a. Function

The heating fluid is heated to process temperatures by the Heater and recirculated through the Evaporator jackets by the Pump.

b. Design Features

(1) The Heater consists of flanged, electric steel-sheathed immersion heating elements assembled into an all-welded steel chamber with 2" insulation. The heating elements are of low watt density design to prevent spot heating.

(2) A 3-mode electronic temperature controller provides precise, automatic control of heating fluid temperature.

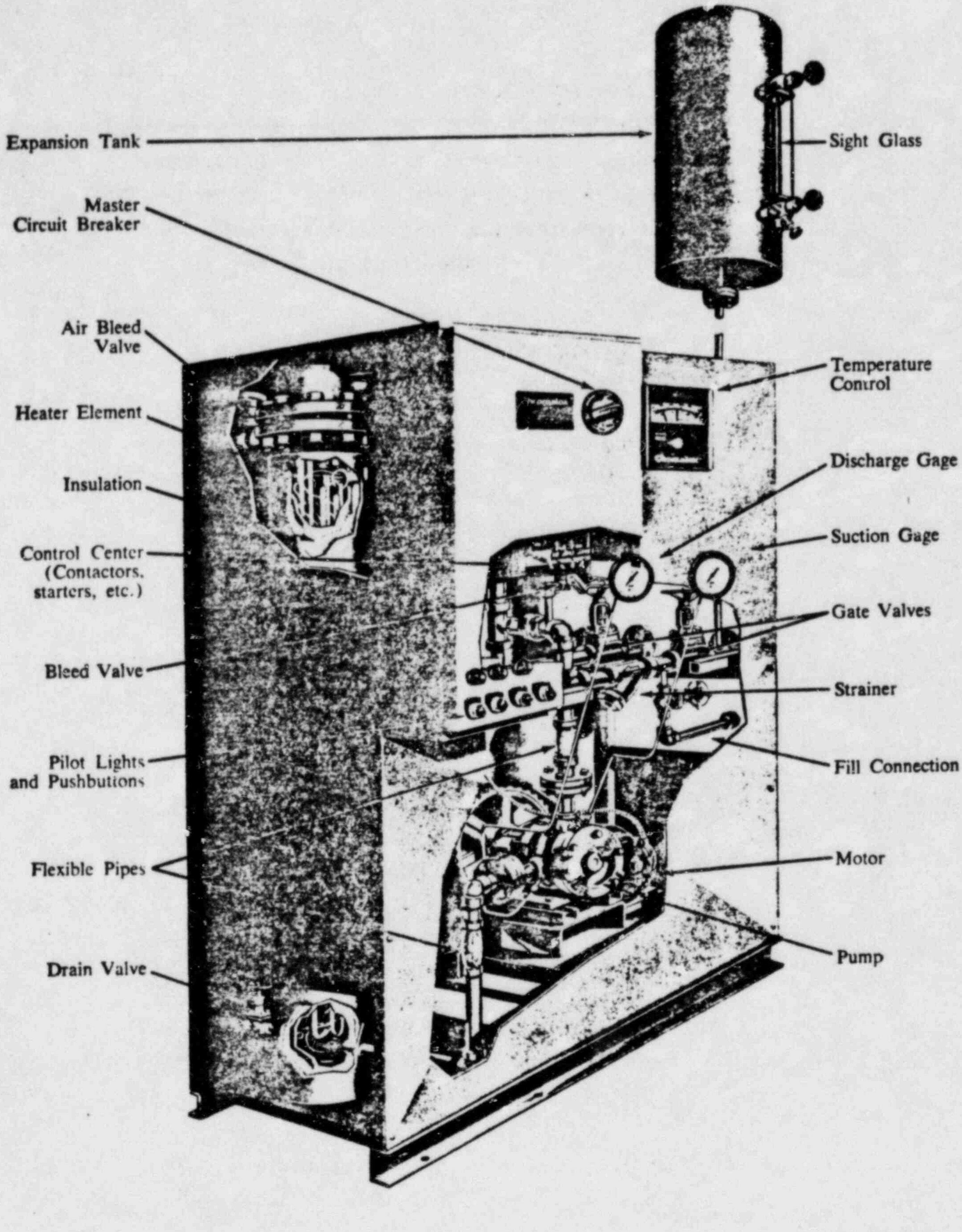


FIG. 4-6 HEATING FLUID SUBSYSTEM

(3) Electrical equipment is pre-wired in a NEMA rated enclosure. A complete electric system is provided, including master circuit breaker, motor starter, magnetic contactors, selector switches, push buttons, pilot lights, control relays, fuses, and control circuit transformer.

(4) Electrical interlock prevents operation of Heater without Pump.

(5) Redundant high temperature interlocks eliminate the possibility of overheating the Evaporator.

(6) Internal piping provided, including drain valves, bleed valves, interface gate valves, fill line, pump suction and discharge pressure gauges, and strainer. A bypass relief valve allows continuous flow through the Pump and Heater should flow to the Evaporator be shut off.

(7) All wiring in accordance with specifications of National Electric Code and Underwriters' Laboratories, Inc.

(8) Thermostats are fail-safe design.

(9) Pressure switches limit operating pressure.

(10) The Pump is a high temperature, cast iron pump with a water-cooled mechanical seal.

4.6.2 Expansion Tank

a. Function

The Expansion Tank accommodates the change in fluid volume due to expansion when the temperature is raised from room temperature to operating temperature.

b. Design Features

(1) The tank is elevated to keep the circulating system filled with heating fluid.

(2) A nitrogen blanket prevents oxidation of the heating fluid and increases fluid life.

(3) A sight glass permits visual check of heating fluid level.

(4) Float switches shut down the system in the event of low fluid level in the Expansion Tank.

(5) Tank is all-welded steel construction, tested at 150 psig.

(6) Filling vent provided.

4.6.3 Drain Tank and Filling Pump

a. Function

The Drain Tank is provided so that the Heating Fluid Subsystem can be drained for maintenance. The Filling Pump is provided to refill the subsystem with heating fluid.

b. Design Features

(1) The Drain Tank capacity is 200 gallons. Construction is all-welded steel. Design is per API 650.

(2) The Filling Pump is a gear pump.

4.7 Auxiliary Subsystems

Several small subsystems are provided as required to support the operation of the ATI System.

4.7.1 Ventilation Subsystem

a. Function

The Ventilation Subsystem serves two functions -- it pulls a small volume of air into the bottom of the Evaporator, preventing vapors from leaving through the bottom outlet; and it pulls air into the Ventilation Hood, capturing off-gas or fumes that may escape from the surface of the bituminized waste as it flows into the waste container. The air that is pulled into the Evaporator is pulled to the Condenser, where it is separated, along with other non-condensables, from the condensed vapor. These non-condensables then merge with the exhaust from the Ventilation Hood and are cleaned by the Organics Filter and HEPA Filter before entering the Exhaust Fan. The cleaned gas is then discharged to the plant ventilation system.

b. Design Features

(1) Approximately 175 SCFM of air is pulled into the Ventilation Hood. This volume provides sufficient air velocities to capture and transport any off-gas or fumes that may be present and prevent them from entering the room.

(2) Approximately 10 SCFM of air is pulled into the discharge pipe of the Evaporator. This

volume provides sufficient air velocities at the bottom outlet to ensure upflow of vapors.

(3) The flow of air into the Ventilation Hood and the flow of air into the Evaporator are balanced by means of adjustable dampers in the two connecting ducts. Once the desired flows have been obtained, the dampers are bolted into place.

4.7.2 Steam Subsystem

a. Function

In some facilities, steam is not available for use in the radwaste system. In these cases, an auxiliary Steam Subsystem is provided to produce the steam required for heating the Bitumen Storage Tank and for operating the Secondary Level Detector used to detect high level in the waste container.

b. Design Features

(1) The Steam Subsystem consists of an electrode boiler and condensate return system.

(2) The electrode boiler is a pressure vessel with three electrodes immersed in water. Electricity conducted through the water between the electrodes generates the steam directly.

(3) The condensate from the loads is collected in a tank and pumped back into the boiler.

(4) The condensate pump is regulated by boiler water level.

(5) A pressure relief valve is provided to prevent overpressurization.

(6) A complete control package is provided for automatic control of the Steam Subsystem.

4.7.3 Cooling Water Subsystem

a. Function

In some facilities, sufficient cooling water may not be available for the radwaste system. In these cases, a commercial air-cooled water chiller can be supplied to provide cooling water for the Condenser (and the Cooler, if provided).

b. Design Features

(1) The chiller is a two-part system with the compressor and condenser located outside the building and the evaporator/heat exchanger located in the area of the ATI System.

(2) A closed loop water/glycol system is provided, complete with tank and recirculating pump. This system recirculates a glycol solution through the chiller heat exchanger and then through the Condenser (and Cooler, if provided).

(3) A complete control package is provided for automatic control of the Cooling Water Subsystem.

4.8 Waste Container Handling Equipment

The equipment selected to position empty waste containers under the Evaporator and to transfer filled containers depends upon the type of container used -- 55 gallon drums or liners of 50 ft^3 or larger capacity.

4.8.1 Equipment to Handle 55-Gallon Drums

a. Turntable

For a description of ATI's 8-drum Turntable, see Section 4.4.2.

b. Cap Crimper

For a description of the Cap Crimper, see Section 4.4.4.d.

c. Drum Lifter

When drums have been filled, they are lifted from the Turntable by a Drum Lifter which is attached to the hoist hook of a crane. Two types of Drum Lifter can be used, as described below.

(1) Bradley Automatic Drum Lifter Style #434-02-01. This lifter is a non-powered tong that is attached to a crane hook and lowered over the drum to be lifted. When it is lowered against the drum, an automatic latch is disengaged, allowing the tongs to close against the drum when raised by the crane hoist. Two V-pads attached to the ends of the tong are squeezed against the sides of the drum by the weight of the tongs and drum.

The capacity of this Automatic Drum Lifter is 1000 pounds. Material of construction is ASTM A36 carbon steel.

When the drum has been transferred to its desired location, it is lowered to the floor. When the weight of the drum is supported by the floor, a further lowering of the lifter against the top of the drum engages the automatic latch, locking the tongs into the open position, allowing the lifter to be raised away from the drum. See Figure 4-7.

(2) Bradley Motorized 4-Jaw Drum Lifter Style #S325-23-1. This lifter is attached to a crane hook and lowered over the drum to be lifted. A 1/4 H.P., 1750 RPM motor, operated from the crane control console, positions four spring-loaded jaws against the drum under the top rim. The drum is then lifted by the crane, transferred to the desired location, and lowered to the floor. The jaws are opened from the crane control console, allowing the lifter to be raised away from the drum. See Figure 4-8.

The capacity of the lifter is 1000 pounds. Limit switches prevent the hoist from being raised or lowered if the jaws are not correctly opened or closed.

One advantage of this lifter is that drums can be arranged with it so that they are touching each other, making maximum use of storage space. No room is required between drums for the lifter to operate. To accomplish this drum arrangement, it must be possible to rotate the drum so that the four jaws of the Drum Lifter are located in the quadrants where the drums are not touching. This

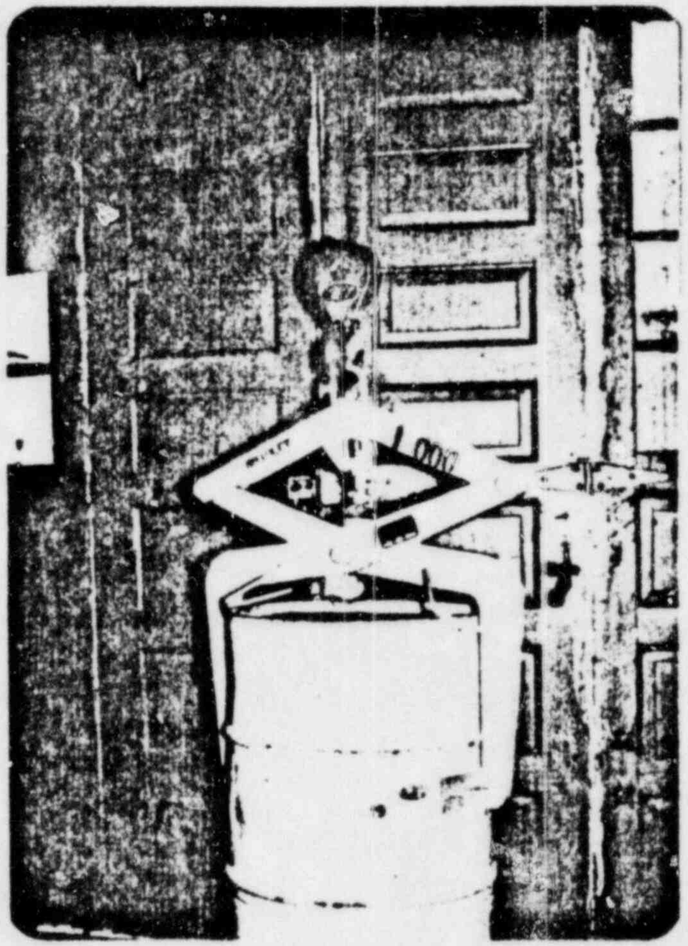


FIG. 4-7 AUTOMATIC DRUM LIFTER

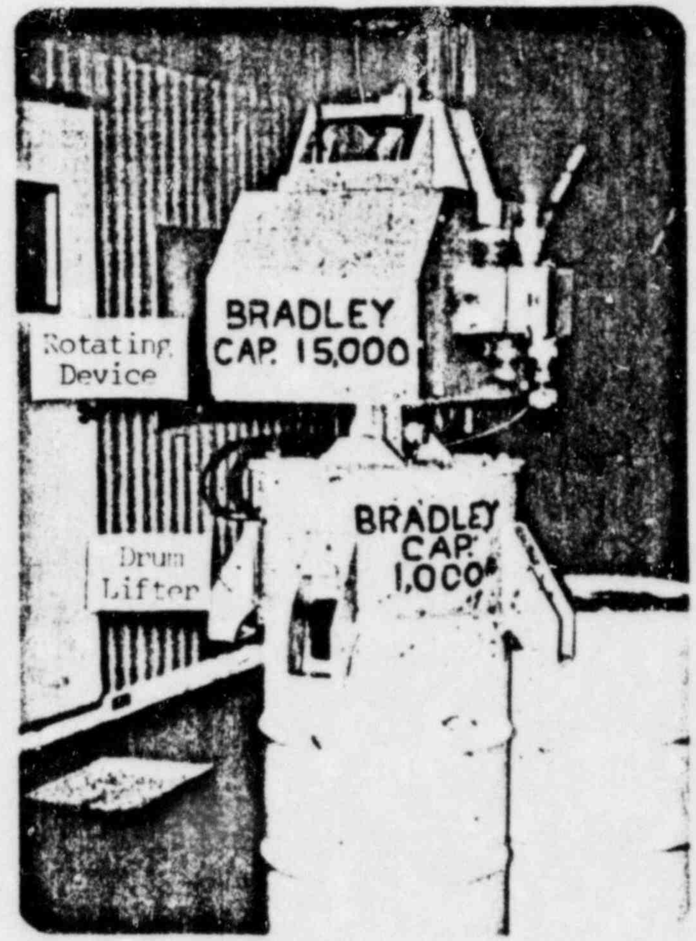


FIG. 4-8 MOTORIZED 4-JAW DRUM LIFTER

rotation can be accomplished by using a Bradley Power Rotating Hook. This is a crane attachment which incorporates a 3/4 H.P., 1200 RPM motor and can rotate its hook 320 degrees. It is controlled from the crane control panel.

d. Bradley Automatic Drum Up-Ender Grab Style #434-12-1

This crane attachment is used to up-end a drum from a horizontal to a vertical position. The grab is lowered over the end of the drum. When the grab has contacted the drum, further lowering disengages an automatic latch. This allows the tongs to close and grip the drum. The hoist is raised and moved forward at the same time, righting the drum to the vertical position. The grab is lowered until the automatic latch engages, which holds the tongs in an open position. The grab is then lifted from the drum.

e. Bridge Crane

The Bridge Crane is used, with the attachments described above, to lift, transfer, up-end, lower, and position waste containers. The design of the Crane is in accordance with the Crane Manufacturers Association of America (CMAA) Specification #70 and American National Standards Institute (ANSI) B30.2. Equipment included is as follows:

(1) Crane bridge and end trucks, with spring bumpers; footwalks per OSHA standards.

(2) Hoist and trolley, with spring bumpers, detachable nesting guides to prevent drum swinging.

(3) Seven drives: main hoist, trolley (2), bridge (2), hoist inching, hook rotation.

All drives five-speed except hoist inching and hook rotation. AC motor brakes.

(4) Festooned cable system.

(5) Bridge and trolley track sweeps and rail stops.

(6) Crane controls, including interlock to prevent release of container unless hoist cable is completely slack, interlock to prevent high speed movement unless hook is in upper position, overload limit with reset and alarm, interlock to prevent raising container unless grab is in fully engaged position, limit switch to prevent collision of container with a shield wall.

(7) Lighting on crane, 500 watt incandescent lights mounted on trolley.

(8) CCTV monitoring equipment.

(9) Control console located in control room.

f. Conveyor or Monorail

Depending upon the plant layout, a conveyor or monorail may be appropriate for drum transfer instead of or in addition to the Bridge Crane. The design of the conveyor or monorail would depend on plant layout.

4.8.2 Equipment to Handle 50 ft^3 and Larger Liners

a. Transfer Cart

The Transfer Cart is provided to transfer empty liners to the fill point below the Evaporator and to transfer filled liners away from this position. The cart design is tailored to meet specific plant requirements, but typical features may include the following:

(1) The cart is driven by a 1 H.P. motor and travels on standard ASCE cart rails.

(2) Liners sit directly on the cart. Should it be desired to use 55-gallon drums also, the drums are supported by a platform that sits on the cart. This platform raises the drums to the level of the Evaporator discharge.

(3) Turntable surface is 316 S.S., structural members and cart body are carbon steel.

(4) Festooned cable supplies power to the cart.

(5) The cart platform is provided with guide rails and stops to ensure the correct positioning of drums and liners.

(6) Limit switches are provided to ensure that the cart stops at the correct position.

(7) Limit switches are provided to ensure that the cart is not moved unless the Secondary Level Detector is in the up position, the Drip Tray is positioned under the Evaporator, and the valve on the bottom of the Evaporator is closed.

b. Liner Grab

This crane attachment is used to grab liners, providing a means for lifting, transferring, and positioning them. The Liner Grab can be either mechanical or electric powered and is similar in design to the Drum Lifter described in 4.8.1.c., but of higher capacity. The specifics of the design are tailored to meet the design of the liner used.

c. Bridge Crane

The Bridge Crane is used to lift, transfer, lower, and position liners. The design is similar to that described in 4.8.1.e.

d. Monorail

Depending upon the plant layout, a monorail may be appropriate for liner transfer instead of or in addition to the Bridge Crane.

4.9 Radiation Monitoring and Decontamination

ATI can provide, as options, equipment for radiation monitoring and decontamination of filled waste containers.

4.9.1 Radiation Monitoring

The design of the monitoring equipment will depend upon specific plant requirements. One design is as follows:

After a waste container has been filled and allowed to cool, it is moved with the Bridge Crane and container grab to the Monitoring Station. Here the container is rotated by a small turntable and swiped from top to bottom by a swiping arm. The swipe is removed by a remote manipulator and placed into a swipe transfer drawer. From here the swipe is taken to the laboratory or the nearest monitoring station to determine the activity of the swipe and, thereby, the need for container decontamination. The container is also monitored for contact dose rate by an activity monitor.

4.9.2 Decontamination

The philosophy utilized in the design of the ATI System is to prevent contamination of the waste container exterior during filling. The Ventilation Hood is designed to act as a splash shield to prevent splashing of material onto the sides of the container during filling. The Turntable drive is designed to provide smooth starting and stopping to prevent sloshing of bituminized product in the filled containers.

When large liners are used, an apron is placed around the fill port to prevent contamination of the liner exterior. This apron is then placed by remote manipulation into the next liner to be filled.

Experience at Barsebeck and Saclay (Section 12) has shown that contamination of container exteriors can be prevented through proper system design.

In those cases in which decontamination equipment is requested, ATI can provide a complete system to clean the containers. A system for mechanical removal of dried material or a system for steam cleaning can be provided.

4.10 Power Supply

The following categories of electrical power are required for operation of the ATI System:

4.10.1 Three Phase, 60 HZ

Three phase 60 HZ power is required for operation of integral horsepower motors. This can be at any of a number of standard voltages; i.e., 240V, 480V, 575V, dependent on what is standard for the particular facility. The motors are individually supplied from combination motor starter units in a motor control center which may either be furnished by ATI or others.

4.10.2 Single Phase, 60 HZ

a. Single phase 60 HZ power is required for operation of fractional horsepower motors. This is at 120 volts. The motors are individually fed from a circuit breaker panel located either in the motor control center or the operator's control panel.

b. Single phase 60 HZ 120V power is also required for operation of instrumentation equipment and control circuits within the system. This power may be furnished either from the facility's instrumentation power system or from additional circuit breakers in the panel used to supply fractional horsepower motors.

4.10.3 125 Volt D.C.

125 volt D.C. power is required to operate the annunciator inputs. This power is furnished either from the facility's 125V D.C. annunciator supply system or from transformer/ rectifier circuits within the annunciator system.

4.11 Valves and Piping

The design, fabrication, material selection, installation, inspection and testing of all piping, valves, and associated appurtenances comply with ANSI B31.1 Power Piping Code.

The system piping can be divided generically into three classes according to the type of fluid being transferred -- radioactive liquids, non-radioactive liquids or gases, and slightly radioactive low pressure gases.

4.11.1 Piping for Radioactive Liquids

a. Description of Liquids

Process streams included in this class are:

(1) Concentrates

(2) Resin Slurries

(3) Filter Sludges

(4) Diatomaceous Earth Slurries

(5) Ash Slurries

(6) Chemical Drains

(7) Decontamination Solutions

(8) Filter Backwash

(9) Activated Carbon Slurries

(10) Distillate

(11) Bituminized Product

In addition to being radioactive, these streams may contain high concentrations of solids, may exhibit wide variations of pH, and may have crystallization potentials at relatively high temperatures. These streams may be corrosive and abrasive and may have a high potential for plugging.

b. Valve and Piping Design

The piping design complies with ANSI/ANS 55.1 and includes the following features:

(1) Fluids with high concentrations of solids are kept moving at high velocity.

(2) In upset conditions that would stop fluid movement, the system is interlocked to automatically flush the lines with water.

(3) The alloy materials selected for use in the system are appropriate for the fluids specified and take into consideration a corrosion allowance.

(4) Bends of at least five pipe diameter radii or long radius elbows are used.

(5) All connections are welded except where connections are made to equipment which may require periodic maintenance. Equipment connections are flanged.

(6) All valves in contact with radioactive fluids are full port valves, bolted bonnet, packless, tight shut-off with replaceable UHMW polyethylene liners.

(7) Control valves are pneumatic diaphragm actuated type with fail safe design.

(8) Piping systems are designed to minimize pockets and for ease of decontamination, maintenance and replacement.

(9) Piping and valves are heat traced where crystallization potential exists.

4.11.2 Piping for Non-Radioactive Fluids

a. Description of Fluids

Process streams included in this class are :

(1) Bitumen

(2) Heating Fluid

(3) Reagents

(4) Compressed Air

(5) Steam

(6) Condensate

(7) Demineralized Water

(8) Raw Water

b. Piping Design

The philosophy utilized in the design and fabrication of valves and piping for non-radioactive fluids conforms to the appropriate codes and standards and utilizes standard engineering practice for the particular fluid handled.

4.11.3 Piping for Slightly Radioactive Low Pressure Gases

a. Description of Gases

Gases included in this class are:

(1) Off gas exhausted from the Ventilation Hood

(2) Non-condensable gases exhausted from the Condenser

b. Piping Design

The piping or ducting is welded to prevent gas leakage. Valves are packless.

4.12 Heat Tracing and Insulation

4.12.1 Heat Tracing

In those portions of the system where it is necessary to maintain the fluid temperature above the plant ambient temperature, heat tracing is used. The involved areas are: bitumen feed line, Waste Batch Tanks, and waste recirculation and feed lines.

The heat tracing material used is self-limiting electrical heating wire. As ' temperature rises, the resistance of the element increases until thermal equilibrium is reached. This material cannot overheat.

The temperature in the bitumen feed line and in the Waste Batch Tanks must be controlled more accurately than is possible with self-limiting electrical heating wire alone. For these services, temperature controllers are used to modulate the voltage applied to the tracing.

4.12.2 Insulation

To reduce the process heat requirements and also reduce the load on the plant HVAC system, many of the process components are insulated.

All heat traced items are insulated, plus the Bitumen Storage Tank, Luwa Evaporator, Evaporator vapor outlet pipe, and heating fluid piping.

The recommended insulation R value for the heating fluid piping is 3.0 hr ft^2 ^oF/BTU, which could be provided by 1½-inch thick molded fiberglas insulation.

The recommended insulation R value for the waste recirculation and feed lines and the bitumen lines is 2.3 hr ft^2 ^oF/BTU, which could be provided by 1-inch thick molded fiberglas insulation.

The recommended R values above are based upon general economic insulation thicknesses. These values can be increased or decreased to meet specific plant conditions.

4.13 Scope of Supply

The scope of equipment supplied by ATI can be divided into two categories -- primary and secondary.

4.13.1 Primary Scope of Supply

The primary scope is that equipment which is always to be supplied by ATI in every system. Included are the following equipment items:

- Luwa Evaporator
- Heating Fluid Subsystem
- Condenser
- Distillate Collection Tank
- Distillate Transfer Pumps
- Distillate Oil Filters
- Organics Filter
- HEPA Filter
- Exhaust Fan
- Bitumen Storage Tank
- Bitumen Metering Pump
- Ventilation Hood
- Evaporator Feed Pumps
- Drip Tray and Swing Arm
- Control Panel

Instrumentation & Control Devices
Chemical Pretreatment Subsystem
Evaporator Bottom Bearing Lubricant Container

4.13.2 Secondary Scope of Supply

The secondary scope is that equipment which is plant specific and which may be supplied by ATI's Client if desired. Included are the following equipment items:

Containers
Container Turntable
Container Transfer Cart
Cap Crimper
Decontamination Equipment
Remote Manipulators
Bridge Crane
Power Rotating Hook
Drum Grapple
Drum Upender
Jib Crane
Waste Batch Tanks
Waste Batch Tank Agitators
Grinder
Waste Recirculation Pumps
Waste Oil Feed Pump
Heating Fluid
Piping and Accessories
Hand Valves
Insulation
Heat Tracing
Distillate Cooler
Wiring
Motor Control Centers
Special Tools
Radiation Monitoring Equipment
Closed Circuit Television
Steam Boiler
Instrumentation and Control Devices Associated with Secondary Scope of Supply
Cooling Water Subsystem

5. INSTRUMENTATION AND CONTROL

This section describes the instruments and controls utilized in the ATI System.

5.1 System Function

The instrumentation and control system is designed to accomplish the following functions:

- Safety
- Precise control of the quality of the product
- Complete record of the operations

5.1.1 Safety

Each parameter of the system which could, when outside of design limits, create a hazard to the operating personnel, the plant environment or to any plant equipment, is monitored to prevent such an occurrence. On those parameters where automatic tripping is practical and a gradual change of value is anticipated, an alarm is sounded as the design limit is approached, giving the operator an opportunity to make corrections before automatic shutdown takes place.

5.1.2 Precise Control of the Quality of the Product

The suitability for processing of the material in the Waste Batch Tank is assured by taking samples and performing laboratory analysis. The system flow rates are also determined from this analysis. Closed loop control of the Evaporator heating fluid temperature assures that the temperature for complete evaporation is maintained. Closed loop control of the speed of the Evaporator Feed Pump and the Bitumen Metering Pump assures that the proper flow rates are maintained.

5.1.3 Complete Record of Operations

The flow rates of materials into the Evaporator and all critical temperatures in the system are continuously recorded. This information, along with the lab reports for the samples taken from the Waste Batch Tank, provides a complete record of exactly what is in each waste container.

5.2 Analog Control, Indication and Recording

Analog control, indication and recording within the system all take place at the operator's panel. Electronic equipment is utilized for maximum reliability and flexibility. Figure 5-1 is the Process and Instrumentation Diagram for the ATI System.

5.2.1 Waste Feed Subsystem

The level in each Waste Batch Tank is measured by a differential bubbler system. This level is displayed on the panel front. An ultrasonic level detector is utilized as a secondary, or backup, detector.

The density of the recirculating waste stream is measured and displayed on the control panel. This measurement is a basic parameter used in determining the correct feed rate to the Evaporator.

A Microprocessor Based Programmable Controller is used to adjust the set points of the waste feed rate controller and the bitumen ratio controller. Extreme care is used in the design of the system to prevent operator error in establishing the set points for the waste feed rate controller and the bitumen ratio controller. The process parameters for the waste to be handled are entered into the programmable controller. The controller checks to see that the values are within those expected for the type of waste being processed. If they are, the programmable controller then calculates the correct set points, checks to see that they are within the values expected for the type of waste being processed, and, if so, feeds them directly to the controllers. If the parameters entered or the set point values calculated are not within the range of acceptable values preprogrammed into the programmable controller, the controller gives an error message and will not proceed until the error has been corrected. The calculations programmed into the programmable controller are those described in The Process Control Program, Section 3.4.

The output of the waste feed rate controller determines the speed of the Evaporator Feed Pump. The loop is closed by measuring the actual flow rate and feeding this signal back to the waste feed rate controller. The flow rate signal is recorded to provide a permanent record of the contents of the waste container.

5.2.2 Bitumen Subsystem

The Bitumen Storage Tank temperature is monitored at three different levels. The temperature of the bitumen in the transfer line is also monitored. Each of these temperatures may be read on an indicator at the control panel. The temperature of the bitumen in the Bitumen Storage Tank is controlled by two temperature regulators which control the steam to three steam coils inside the tank. The steam pressure to these temperature regulators is controlled by a pressure reducing valve.

The level of bitumen in the Bitumen Storage Tank is monitored and indicated on the control panel.

The set point for bitumen flow control is generated as a ratio to the flow of waste material to the Evaporator. This ratio will vary depending upon the makeup of the waste feed material and is determined by the programmable controller as described above in Section 5.2.1. The set point of the bitumen ratio controller is adjusted by the programmable controller. The ratio controller then maintains the desired ratio of bitumen flow to waste flow by adjusting the set point of the bitumen flow controller, which controls the speed of the Bitumen Metering Pump. The actual flow rate of bitumen to the Evaporator is measured and this signal is fed back to the bitumen flow controller. The flow rate of bitumen is recorded to provide a permanent record of the contents of the waste container.

5.2.3 Evaporator

The Evaporator motor current is measured and displayed on the control panel. The level of the waste in the waste container is measured also and displayed on the control panel. The temperature of the vapors and of the bituminized product discharged from the Evaporator are measured and indicated on the control panel. The bituminized product temperature is also recorded.

5.2.4 Heating Fluid Subsystem

The temperature of the heating fluid discharging from the Heater is measured and recorded. The flow rate of heating fluid is measured and indicated on the control panel. These measurements allow monitoring of the trends of any changes which may occur in the heating system.

5.2.5 Distillate Subsystem

The temperature of the exhaust gas from the Condenser is measured and indicated on the control panel to monitor the performance of the Condenser. The temperature of the liquid in the Distillate Collection Tank is also measured and indicated on the control panel. The level in this tank is monitored and recorded to provide a record of the amount of liquid collected.

Figure 5-2 shows one of the instrument panels for the bituminization system at Barsebeck Nuclear Power Station, Sweden.

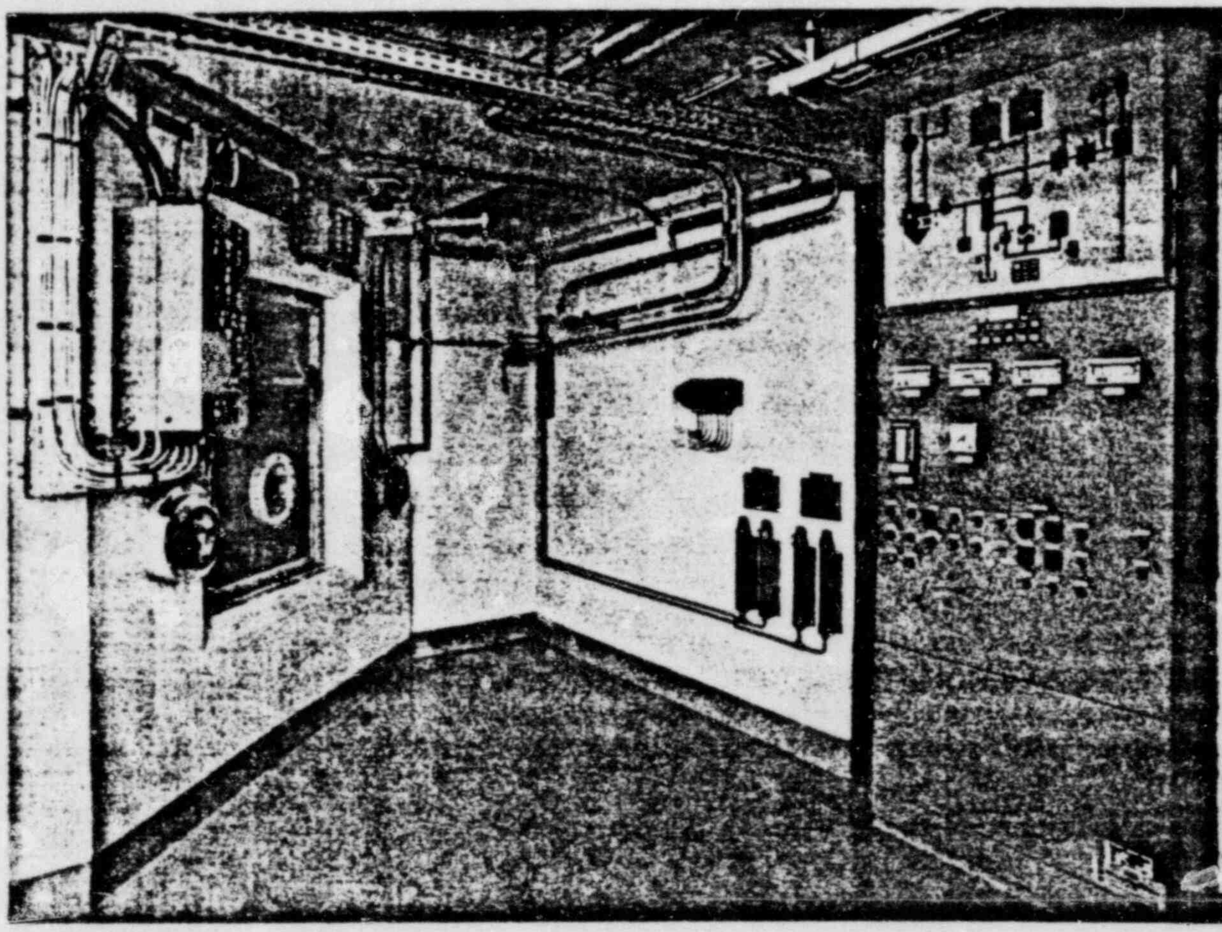


FIG. 5-2 FILLING CELL VIEW WINDOW AND ONE INSTRUMENT PANEL, BARSEBECK NUCLEAR POWER STATION

5.3 Automatic Sequential Control

There are four automatic sequences designed into the ATI control system. These sequences are provided in order to assure correct start-up, shutdown, drum indexing, and flushing of piping. These sequences are described below.

5.3.1 Start-Up

After the operator has set the proper flow rates for the system, selected those pumps which he wishes to operate, and has started the Evaporator, he presses the "Feed Start" button. This initiates the following sequence: the Bitumen Metering Pump starts; the bitumen blocking valve opens; the waste feed valve opens; and the Evaporator Feed Pump starts.

5.3.2 Shut-Down

When a signal requiring stopping Evaporator feed is received by the system, the following sequence is initiated: the waste feed valve closes; the feed flushing valve opens; this valve remains open for a period of time sufficient to flush out the waste feed line; then the flushing valve closes and the feed and bitumen pumps stop. This provides for complete flushing of the waste material from the pumps and piping.

5.3.3 Drum Indexing

When the level of waste in the container reaches the high level set point, the following sequence is initiated. The Evaporator discharge valve closes and a time period is initiated. This period allows partial filling of the Evaporator discharge cone. If the discharge valve is not opened before the completion of the time period, the shut-down sequence described above is initated. This sequence allows indexing of the drum turntable without shutdown of Evaporator feed.

If the indexing switch is in the automatic position, the following sequence is initiated upon closing of the Evaporator discharge valve. The secondary level detector retracts, the drip tray moves under the Evaporator discharge, the turntable advances, the drip tray retracts, the secondary level detector moves into the drum and the Evaporator discharge valve opens. The sequence stops and an alarm is sounded after all drums have been filled.

5.3.4 Flushing

When a signal requiring closing of the Waste Batch Tank discharge valve or stopping the Waste Recirculation Pump is received by the system, the following sequence is initiated: the tank discharge valve closes; the waste system flushing valve opens; this valve remains open for a period of time sufficient to flush out the waste recirculation line; then the flushing valve closes and the Waste Recirculation Pump stops. This provides for complete flushing of the waste material from the pumps and piping.

5.4 Interlock List

A Microprocessor Based Programmable Controller is used to carry out all interlocking control. It also is used for all trip limits which are based on analog signals. This system provides the most efficient and functional package available for this application.

The list below is an outline of the basic interlocks required for operation, safety and equipment protection in the system. These interlocking requirements are the minimum for each system. Additional interlocks may be added for operating convenience or to meet specific client requirements.

5.5 Failure Analysis

The outline below lists those equipment, process and operator failures which can affect the operation of the equipment, the quality of the product or the safety of the operator. Each class of failure is evaluated as to consequence, means of detection, and manual or automatic responses which prevent damage to equipment, hazard to the operator, or production of unsatisfactory product. Failure modes are assumed and presented without consideration of the high equipment reliability designed into the ATI System.

A "defense in depth" design philosophy is used in each protection system whose failure could potentially result in a local release of radioactive meterial. High equipment reliability and an effective manintenance program, combined with the "defense in depth" design, are judged to preclude the necessity for multiple failure consideration.

Note that if the operator deliberately operates the system outside the requirements of the Process Control Program, the system will respond as though the control device had failed, providing protection for the system, the operator and the product.

6. SYSTEM EQUIPMENT LAYOUT

This section describes the arrangement of the equipment included in the ATI System and the floor space required.

6.1 Layout Considerations

With any equipment, the best arrangement is based on many considerations, some of which are discussed below.

a. Floor space and building volume requirements should be minimized in order to minimize building and HVAC equipment costs.

b. Good shielding arrangements should be provided to minimize radiation exposure to workers during normal operations and equipment maintenance.

c. Piping lengths between Waste Batch Tanks, Waste Recirculation Pumps, Evaporator Feed Pumps and the Luwa Evaporator should be minimized. The primary consideration should be to minimize length of piping containing radioactive slurries, then piping containing concentrates and other radioactive fluids, and lastly piping containing non-radioactive materials.

d. Adequate space should be provided for maintenance accessibility, equipment installation and removal for pumps, drives, heat exchanger tube bundles, etc.

e. The equipment should be arranged to facilitate the material handling scheme, including the storage of empty drums or liners; the transfer of empties to the filling area; the removal of filled drums and liners to swipe, decontamination, and capping stations; transfer of filled waste drums or liners to waste storage areas; and transfer from storage areas to transportation shields for shipment.

6.2 Space Requirements

Space requirements vary depending on waste container size selected and the material handling equipment available. But the basic ATI System requires about 1,400 sq. ft. of floor area. Because of its minimal space requirements, the ATI System can be backfitted into almost all power plants.

6.3 Recommended Equipment Arrangement

If a new radioactive waste treatment building is being considered, the best arrangement would be the basic arrangement shown in Figure 6-1. The following comments are pertinent to the arrangement shown:

a. The area required for the basic ATI System equipment is 1,400 sq. ft. The arrangement provides a convenient and efficient arrangement for the ATI equipment.

b. A waste storage area is provided in which drums can be stacked six high. Storage capability for empty drums is also provided in this area.

c. The height shown for the building is not the minimum possible. If a hatch were provided directly above the Luwa Evaporator for pulling the rotor out through the roof when required for inspection or maintenance, the minimum height requirement would be approximately 22 feet from floor to ceiling for the Evaporator shown, the Model LN-0350. The height required depends upon the model to be used.

d. The system control panel is located in the process area. The crane control panels and control consoles could also be located in the same area. This arrangement is convenient because the operator who is monitoring the waste system control panel can be performing material handling operations at the same time. The system control panel, crane control panels and/or crane control consoles could be located or combined with other radioactive waste treatment system controls in a central control area if desired.

e. The decontamination and swipe station is located adjacent to the waste storage area. The waste storage area is located as close to the truck bay and building access as possible for convenience and efficiency during truck loading.

f. Labyrinth entrances are shown for personnel access into each equipment cell. This is probably the safest method of shielding between equipment and lower radiation zones. Most large equipment is located so that it can be removed through the roof of the upper or second level. Equipment can be easily removed through a normal sized hatch.

g. In order to minimize piping lengths ATI recommends that a pipe chase be included below the floor of the second or upper level. Equipment has been arranged as much as possible to minimize piping length. For example, the Waste Recirculation Pumps are located adjacent to the Waste Batch Tanks; the Evaporator Feed Pumps are located between the Waste Recirculation Pumps and the Luwa Evaporator; and the Distillate Tank, Pumps and Filters are all located adjacent to each other.

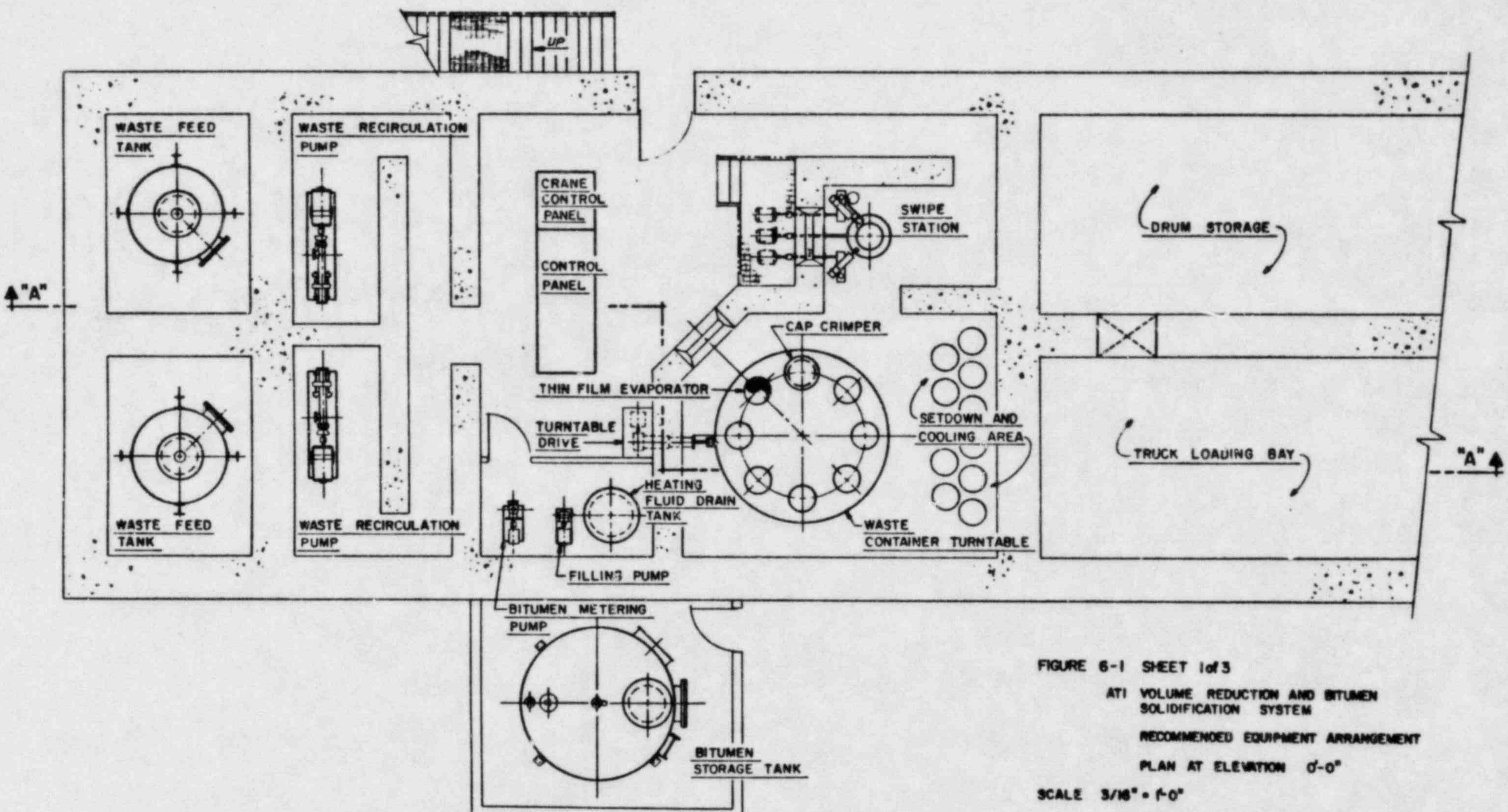


FIGURE 6-1 SHEET 1 of 3

ATI VOLUME REDUCTION AND BITUMEN SOLIDIFICATION SYSTEM

RECOMMENDED EQUIPMENT ARRANGEMENT

PLAN AT ELEVATION 0'-0"

SCALE 3/16" = 1'-0"

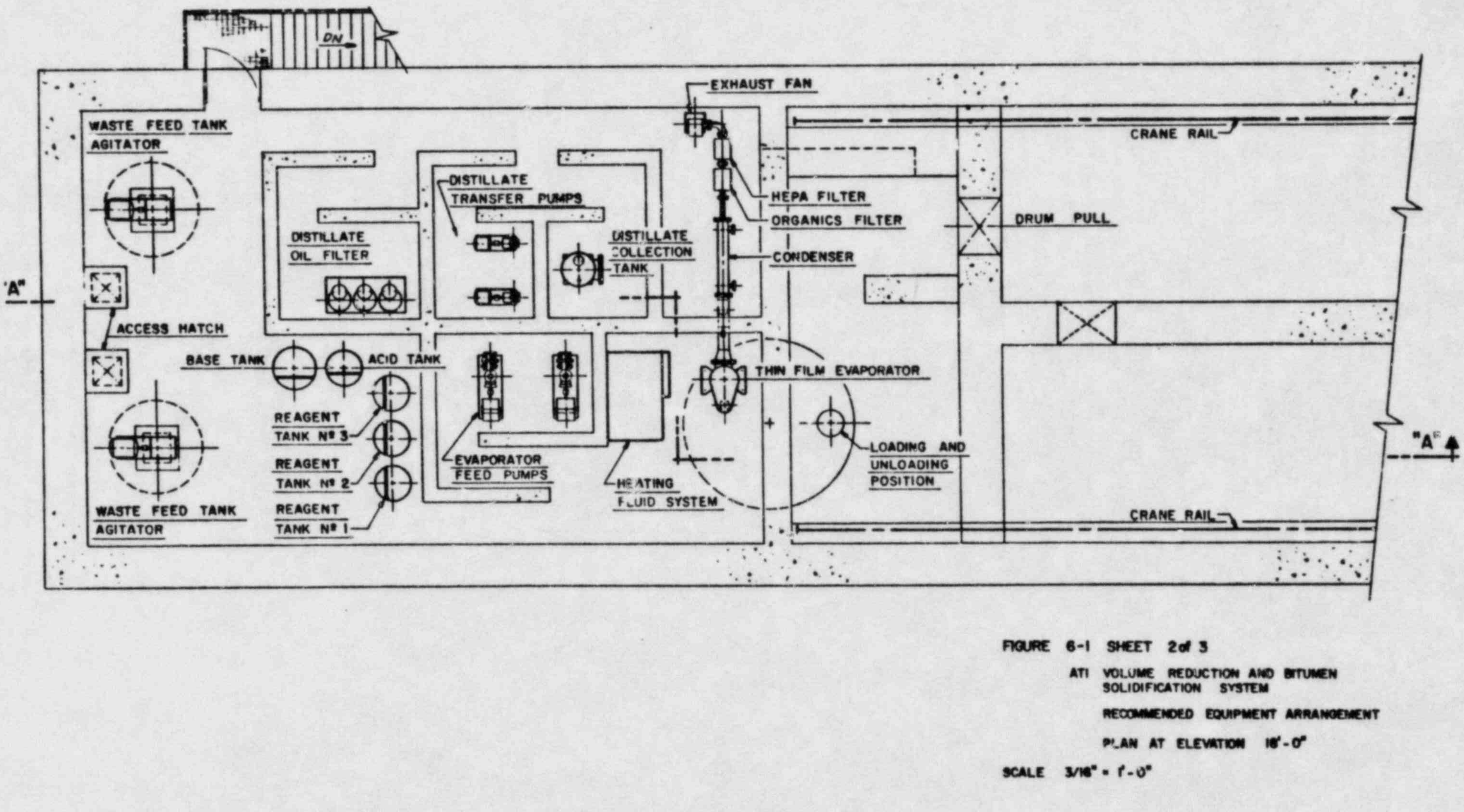


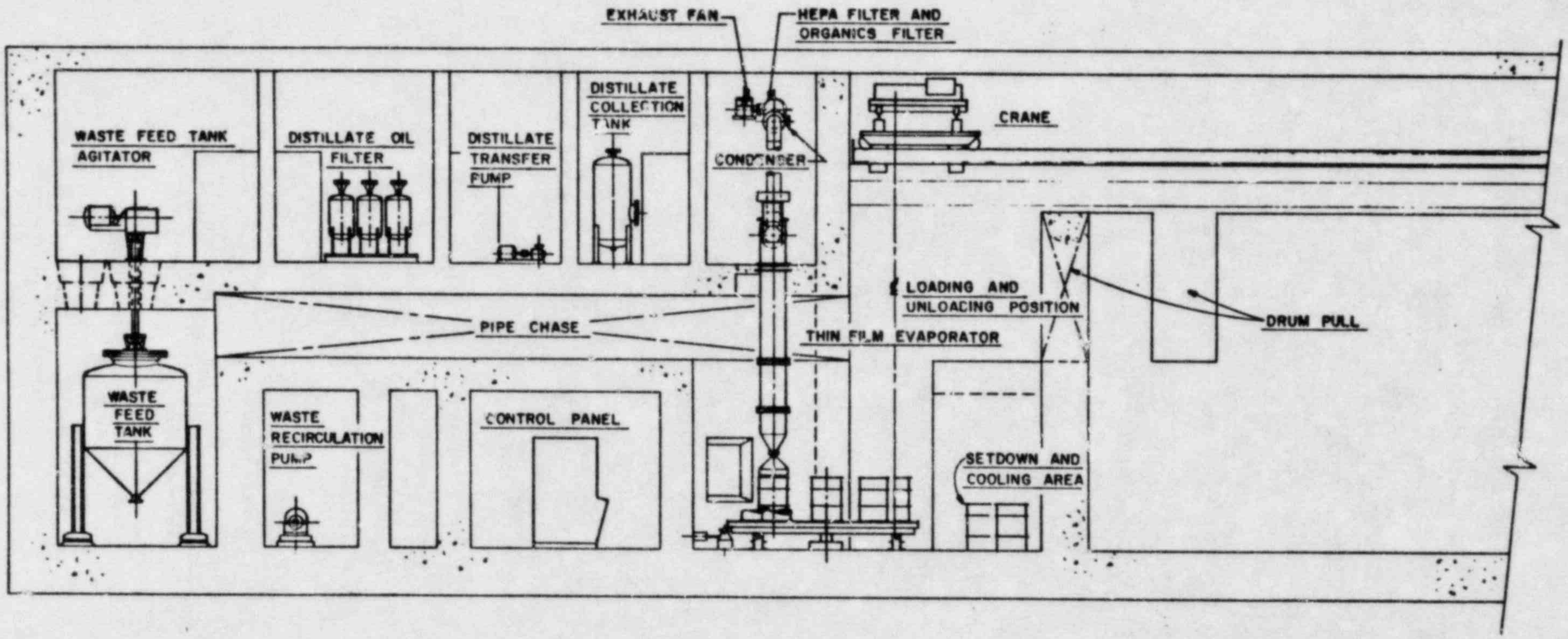
FIGURE 6-1 SHEET 2 of 3

ATI VOLUME REDUCTION AND BITUMEN SOLIDIFICATION SYSTEM

RECOMMENDED EQUIPMENT ARRANGEMENT

PLAN AT ELEVATION 16'-0"

SCALE 3/16" = 1'-0"



SECTION "A-A"

FIGURE 6-1 SHEET 3 of 3

ATI VOLUME REDUCTION AND BITUMEN SOLIDIFICATION SYSTEM

RECOMMENDED EQUIPMENT ARRANGEMENT

SECTION "A-A"

SCALE 3/16" = 1'-0"

6.4 Container Storage Area Required

Sufficient storage area should be provided for the solidified waste containers to allow for shipping delays and burial site handling delays. The storage area should be capable of accommodating a minimum of 30 days of normal operation waste input to the system. Where possible, the storage area should be sized to accommodate six months of normal operation waste input.

The actual size of the storage area is plant specific and depends upon the types and volumes of waste generated. The volume reduction factors shown in Table 6-1 should be used when determining solidified product volumes for various waste types when processed in the ATI System.

Table 6-1

VOLUME REDUCTION FACTORS

Waste Type	Description	Bituminized Product Concentration	Vol. Reduction[1] Factor
Spent Resin	dewatered bead or powder, with 40 to 50 wt % dry solids	45 wt % solids, 55 wt % bitumen	1.25 to 1.75, depending upon % dry solids in feed
Boric Acid Concentrates	12 wt % boric acid	45/55	4.75
Sodium Sulfate Concentrates	a) 15 wt % sodium sulfate	45/55	3.5
	b) 22 wt % sodium sulfate	45/55	2.25

1) Volume Reduction Factor is defined as the volume of raw waste as received by the ATI System divided by the volume of bituminized product discharged from the ATI System.

As an example of storage area requirement calculations, assume a plant has a yearly waste production of 20,000 ft^3 of 12% boric acid and 10,000 ft^3 of dewatered resins. The solidified product resulting from six months' production of this waste will be 2105 ft^3 of bituminized sodium borates (at a VRF of 4.75) and 3333 ft^3 of bituminized resins (at a VRF of 1.5). If each solidified waste container is filled to 90% of its total volume, this volume of waste will require 786 fifty-five gallon drums, or 121 fifty ft^3 liners, or thirty-six 170 ft^3 liners.

Fifty-five gallon drums can be stacked in pyramid arrays with the bottom layer a square composed of 6 drums by 6 drums. The next layer is 5 drums by 5 drums, the next 4 by 4, and so on. The top, or sixth, layer is one drum. This pyramid stack will contain 91 drums and will require 121 ft^2 of floor space and 17 ft of headroom. To store 786 drums as required to have the desired storage area of six months of raw waste production will require 9 of these pyramid stacks, for a total floor space requirement of 1089 ft^2.

50 ft^3 liners (4 ft diameter x 4 ft height) cannot be stacked. To store 121 of these as required to have the desired 6 months' storage area will require 1936 ft^2 of floor space, assuming the liners are arranged in a square of 11 liners by 11 liners.

170 ft^3 liners (6 ft diameter x 6 ft height) cannot be stacked. To store 36 of these as required to have the desired 6 months' storage area will require 1296 ft^2 of floor space, assuming the liners are arranged in a square of 6 liners by 6 liners.

6.5 Maintenance Accessibility

The optimum system layout separates high and low maintenance items and takes into consideration their relative effects on maintenance personnel. Higher maintenance items, such as rotating equipment, which come into contact with radioactive fluids must be easily accessible and must be isolated from other radioactive higher maintenance equipment and from non-radioactive components. ATI has selected equipment with consideration for component maintenance requirements, maintenance frequency, time required to perform maintenance, ease of performing the maintenance, and the exposure the maintenance personnel may receive as a result of performing the maintenance.

6.5.1 Luwa Evaporator

The Luwa Evaporator components which require scheduled maintenance are separated from the low-maintenance and "hot" portion of the Evaporator by shielding. The Evaporator drive, seal, and support and thrust bearing are separated from the process section by a shield wall. This design minimizes personnel exposure. After 10,000 operating hours at Barsebeck Nuclear Power Station in Sweden there have been no failures of equipment which caused operators to enter the hot cell for maintenance. The internal bottom bearing is accessible and can be replaced easily from the bottom without removing the rotor.

6.5.2 Condenser

The Condenser is located in a low activity, easily accessible area. Adequate space should be provided for complete removal of the tube bundle.

6.5.3 Heating Fluid Subsystem

The Heating Fluid Subsystem is located in a low activity maintenance area. The Heating Fluid Pump, pump drive, piping, heating element, relief valve, and instruments are easily accessible within the enclosure. The Heating Fluid Subsystem should be located within a room with adequate head room to pull the heating element vertically out of the vessel. The Heating Fluid Drain Tank and Filling Pump should be located below the heating element vessel in order to allow the fluid to drain by gravity.

6.5.4 Waste Batch Tanks

The Waste Batch Tanks should be located in a "hot" cell isolated from maintenance components. The drive for each tank agitator should be separated from the tank through a shield floor and located in a low activity maintenance area. Infrequently, the agitator must be pulled from the tank. Provisions must be made to allow for agitator removal by either locating the tank and agitator in a building with enough height to allow the removal, or by providing an access door in the ceiling above the agitator drive, or by providing an agitator which can be disassembled in stages.

6.5.5 Waste Pumps

The Waste Pumps must transfer high concentrations of solids. As all rotating equipment requires occasional maintenance, the pumps must be located in an area where accessibility is good, but isolated to minimize radiation exposure to the maintenance personnel. The pumps ATI has selected for the service of radioactive wastes are quick disassembly pumps which allow the maximum amount of maintenance in the minimum amount of time.

6.5.6 Distillate Subsystem

The Distillate Collection Tank, Distillate Pumps, and Distillate Oil Filters should be separated from each other by shield walls. Though the activity in the distillate is low, precautions should be taken to isolate the equipment with the highest dose rate (the Distillate Collection Tank) from the components with the greatest maintenance requirement (the pumps and filters). Adequate room in each cell to provide maintenance is required.

6.5.7 Turntable

The waste container Turntable which is in a high radioactivity area should be isolated by a shield wall from the Turntable motor. The motor should be easily accessible.

6.5.8 Non-Radioactive Components

All components which do not come in contact with radioactive waste should be located away from high activity components. Standard engineering practice for providing maintenance accessibility should be exercised for these components.

6.5.9 Preventive Maintenance Program

A preventive maintenance program should be developed to plan and coordinate maintenance activities in order to minimize radiation exposure and interference with system operation.

7. RADIATION EXPOSURE CONTROL

This section outlines the design features incorporated into the ATI System for the purpose of controlling and minimizing exposure of personnel to radiation.

7.1 System Flushing and Decontamination

The ATI System is designed so that all tanks, pumps, valves, piping and other components can be flushed prior to inspection or maintenance.

7.1.1 Waste Feed Subsystem

The Waste Batch Tanks are equipped with spray nozzles for flushing to remove residual contamination. A drainage path is provided in each tank for completely draining the tank.

The Waste Recirculation Pumps and the recirculation lines are automatically flushed with flush water after a termination signal is initiated at the operator's control panel. ("Flush water" may be demineralized water, condensate, recycled water from radwaste evaporators, or other suitable, clean water.) This timed flush will effectively flush all solids in the pump and recirculation line through the piping and back to the Waste Batch Tank. The branch lines from the recirculation lines to the Evaporator Feed Pumps and the Evaporator Feed Pumps themselves are flushed in a similar manner.

7.1.2 Luwa Evaporator

The Luwa Evaporator is decontaminated in the following steps. When waste feed is to be terminated the operator initiates shut down of the Evaporator Feed Pump. This causes a flush valve to automatically open, to feed flush water instead of waste to the Evaporator. Since the Evaporator is a plug flow machine, there is no back mixing and residence time distribution is very narrow. All solids that enter the Evaporator are removed in less than 1 minute. Flushing with flush water and bitumen effectively removes all solids from the Evaporator. After 10 minutes of flushing, the flush water flow is terminated. Bitumen feed is then terminated and the Evaporator drive is shut off. The Luwa Evaporator is a self-draining machine and will completely drain of bitumen except for a very fine film on the wall surface. Experience at Barsebeck Nuclear Power Station indicates that with this 10 minute decontamination of the Evaporator, radiation levels have been reduced from as high as 150 mrem per hour to 5 mrem per hour contact. This indicates the effectiveness of the decontamination operation.

7.1.3 Distillate Subsystem

The Distillate Collection Tank is equipped with a spray nozzle for flushing. Also included is a drainage path for completely draining the tank.

The Distillate Oil Filters are designed for remote sluicing of spent charcoal to the Waste Batch Tanks. The filter vessels can be thoroughly flushed and drained.

7.1.4 Waste Containers

Experience with the ATI/SGN System has shown that external contamination of filled waste containers is minimal and has not posed any problems in container handling. If desired, however, waste containers can be decontaminated by a remote mechanical method or by steam cleaning. ATI can supply equipment to perform this decontamination.

7.2 ALARA Design

This section discusses the ATI approach to meeting the intent of Regulatory Guide 8.8. The ATI System is designed to maintain radiation exposure as far below the regulatory limits as is reasonably achievable.

7.2.1 ATI/Client Interface

Because the ATI System interfaces with other plant systems, ATI's contracted services include working with the Utility/Operator to assure that overall station objectives for ALARA are met by the design. The system supplied by ATI achieves minimal operational exposure through extensive automation and carefully planned operating procedures which have been established during actual operation in nuclear facilities. ATI provides the necessary instructions for plant personnel to adequately support the objectives of the Utility/Operator's overall Radiation Protection Program.

7.2.2 Equipment Layout and Design Considerations

The following features are incorporated into the ATI System design:

a. The equipment layout reduces personnel exposure by segmenting the components so that non-radioactive components and frequently used instruments and controls are not in the same area as radioactive components. Equipment such as pumps and motors, which require routine maintenance, are isolated from other radioactive components.

b. The simplicity of the overall system design reduces the need for complex operations, assures long-term reliability, and minimizes the need for access to areas of highest radiation.

c. The Thin Film Evaporator has a minimum of moving parts, contains only a small volume of waste product at any one time, and is self-draining to minimize contaminant build-up.

d. All components are designed for reliable operation over the 40-year design life of a nuclear facility.

e. All components in contact with the radioactive process stream are designed to minimize crud build-up in pockets or at elbows and tees.

f. Radiation shielding is provided to isolate radioactive components and reduce exposure during normal operation and maintenance.

g. Airborne contaminants are controlled by the Vent Hood located over the waste container. The drumming area is the only part of the system open to the atmosphere.

The simple design, highly automated operation, and high quality components of the system achieve ALARA objectives. Typically, European nuclear power plant waste systems using the process have occupational exposures of less than one (1) manrem/yr.

7.2.3 Equipment ALARA Features

a. Luwa Evaporator

(1) The Evaporator drive, seal, and support and thrust bearing are separated from the process section by a shield wall.

(2) The process surface in the thermal section is machined for complete roundness and uniform rotor clearance throughout. The design lends itself well to thorough cleaning of all process surfaces by simply flushing with bitumen and flush water. This flushing is only required before maintenance is performed in the filling cell.

b. Condenser

(1) Mixing of shell and tube side fluids is prevented through gasketed joints.

(2) Outleakage of radioactivity is prevented since the cooling water is at a higher pressure than the vapors and condensate.

c. Waste Batch Tanks and Agitators

(1) Each tank has a cone bottom to ensure positive drain on flushing.

(2) All tank nozzles and connections are self-draining.

(3) Each tank is equipped with a spray nozzle for internal flushing.

(4) A water flush connection is provided to back-flush the outlet.

d. Waste Recirculation Pumps

(1) All angles are rounded or curved to ensure there are no points where radioactivity can accumulate.

(2) The drive of each pump is completely isolated from the pump case.

(3) Decontamination is accomplished by flushing the pump, while it is running, with flush water.

(4) Mechanical seals are provided and are equipped with seal water connections to positively ensure there is no contaminant leakage.

e. Evaporator Feed Pumps

(1) The drive of each pump is completely isolated from the pump case.

(2) Decontamination is accomplished by flushing the pump, while it is running, with flush water.

(3) Mechanical seals are provided and are equipped with seal water connections to positively ensure there is no contaminant leakage.

f. Distillate Collection Tank

(1) The tank interior is smooth and rounded to eliminate pockets where activity could accumulate.

(2) The tank is equipped with an internal nozzle for flushing with flush water. A drainage path and vent are provided to allow complete drainage of the tank.

g. Distillate Transfer Pumps

(1) Mechanical seals are provided and are equipped with seal water connections to positively ensure there is no contaminant leakage.

(2) The system is designed so that the pump internals can be flushed with flush water.

h. Distillate Oil Filters

(1) The interior of each vessel is rounded and smooth to eliminate pockets where activity could accumulate.

(2) The vessels are designed so that their interiors can be flushed. A drainage path and vent are provided to allow complete drainage of the vessels.

(3) The filters are designed with remotely operated valves so that personnel exposure is minimized.

i. Cooler

(1) Mixing of shell and tube side fluids is prevented through gasketed joints.

(2) Outleakage of radioactivity is prevented since the cooling water is at a higher pressure than the distillate.

8. FIRE PROTECTION PROGRAM

NRC Regulatory Guide 1.120 recommends that a nuclear power plant fire protection program should:

- Prevent fires from starting.
- Detect fires quickly, suppressing those fires that occur, putting them out quickly, and limiting their damage.
- Provide for a system designed so that a fire that starts in spite of the fire prevention program and burns for a considerable time in spite of fire protection activities will not prevent essential plant safety functions from being performed.

This section discusses the conformance of the ATI System with these objectives.

8.1 Fire Prevention

The ATI System is designed so that the temperature of any combustible is strictly controlled to ensure that combustion does not occur.

There are basically three combustibles in the process: the heating fluid, the bitumen, and the bituminized product. The fire prevention measures surrounding these three materials are discussed in this section.

8.1.1 Bitumen

a. Temperature Stability

The bitumen utilized in the ATI Process is a straight distilled, viscosity graded asphalt cement designated

AC-20. Its open cup flash point varies with the supplier, but a number of suppliers can guarantee a flash point greater than 600°F. The user of an ATI System should specify a minimum flash point of 600°F when purchasing bitumen for use in the system. The spontaneous ignition point can be specified to exceed 800°F.

b. NFPA Rating

Bitumen is not included as a flammable or combustible liquid in NFPA 30 "Flammable and Combustible Liquids Code". It is categorized as follows in NFPA 49 "Hazardous Chemicals Data".

- Offers no health hazard beyond that of ordinary combustible material.
- Must be preheated before ignition can occur.
- Is normally stable even under fire exposure conditions and is not reactive with water.

Thus the NFPA considers bitumen to present no notable health hazard, no reactivity hazard and only a slight flammability hazard.

c. Storage Temperature

The temperature of the bitumen in the Bitumen Storage Tank is controlled and maintained bewteen 275 and 285°F by two temperature regulators which control steam to three internal steam coils. The steam pressure to these regulators is controlled by a pressure reducing valve which limits the steam pressure to 50 psig (298°F) so that even if a temperature regulator fails, the maximum temperature the bitumen is exposed to is 298°F. In addition, the bitumen temperature in the tank is measured at three different levels and displayed on the operator's control panel.

d. Transfer Temperature

The temperature of the bitumen in the transfer line to the Evaporator is controlled and maintained between 275 and 285°F by a temperature controller which regulates the voltage applied to electrical heat tracing. This special tracing is self-limiting, i.e., its electrical resistance increases with temperature. This occurs independently at each point along the length of the tracing. With this type of tracing, it is impossible to overheat, even should the temperature controller fail, for as the temperature increases, the resistance increases so that thermal equilibrium is maintained. The even, low watt density of the tracing provides low sheath temperatures and prevents hot spots. This tracing is used in oil refineries, chemical and petrochemical processing areas, and is approved by Factory Mutual for use in hazardous areas. Should the bitumen temperature rise above 285°F, an alarm is sounded.

e. Process Temperature

The temperature of the bitumen in the Evaporator is controlled and maintained between 315 and 325°F. A temperature monitor measures and records the temperature of the bitumen or bituminized product as it is discharged from the Evaporator. Should the temperature exceed 325°F, an alarm is automatically sounded. Should the temperature exceed 340°F, an interlock initiates an automatic shut down sequence which includes shutting off the heating elements of the Heating Fluid Subsystem. The temperature of the heating fluid is controlled and maintained between 450 and 465°F. This temperature is required to provide adequate temperature difference between the heating fluid and the waste. This temperature difference is the driving force for heat transfer into the waste, which is required for water evaporation. The bitumen or bituminized product temperature is raised to 315-325°F as it passes through the Evaporator. The temperature of the bitumen or bituminized product is limited to this range during normal operation by the heat transfer coefficient of the Evaporator and the residence time of the product in the Evaporator (less than one minute).

Should the temperature of the heating fluid exceed 465°F, an alarm is automatically sounded. Should the temperature exceed 470°F, an interlock initiates an automatic shut down sequence which includes shutting off the heating elements. A redundant temperature monitor and high temperature interlock provide assurance of high temperature protection.

When the Evaporator discharge valve is closed for drum indexing, a timer is actuated. Should the valve remain closed for a period exceeding the timer set point, an interlock initiates an automatic shut down sequence. This prevents the overheating of bitumen or bituminized product in the discharge cone. Should the discharge valve fail closed or plug, the product level rises into the process zone of the Evaporator, producing a high current draw to the Evaporator drive. A high current interlock initiates a shut down sequence. This prevents the overheating of bitumen or product under stagnant conditions.

f. Margin of Safety

The initiation of a fire requires as a minimum an oxidizable material, oxygen, and an ignition source or heat. Eliminating any one of the requirements will prevent fires from igniting. Bitumen is an oxidizable material and oxygen is present in the Bitumen Storage Tank and within the Evaporator. The key, therefore, is to prevent the bitumen from reaching the temperatures required to sustain combustion even if an ignition source were present.

With the controls and interlocks discussed above, the maximum possible bitumen temperature at any point in the system is 340°F. This is a very safe 260°F below its minimum flash point of 600°F and 460°F below its minimum spontaneous ignition point of 800°F.

Table 8-1 summarizes the characteristics and process temperatures of bitumen.

Table 8-1

SAFETY CHARACTERISTICS OF BITUMEN

(AC-20 Viscosity Graded Asphalt Cement)

Open Cup Flash Point:	>600°F (buyer specified)
Spontaneous Ignition Point:	>800°F (buyer specified)
Softening Point:	140°F
Minimum Pumping Temperature:	250°F
Storage Temperature:	275 to 285°F
Transfer Temperature:	275 to 285°F
Temperature in Evaporator:	315 to 325°F normal, 340°F maximum

8.1.2 Bituminized Product

a. Temperature Stability

The bituminized product is a matrix of solid waste and bitumen. The addition of typical power plant waste solids to bitumen yields a product with a temperature stability that is equal to or greater than that of the bitumen alone.

b. Process Temperature

The temperature of the product is controlled so as not to exceed 340°F as described in Section 8.1.1.e above.

c. Margin of Safety

The maximum possible product temperature at any point in the system is 340°F. This is a very safe 260°F below its minimum flash point of 600°F and 460°F below its minimum spontaneous ignition point of 800°F.

d. Fire Spread from Another Source

The physical layouts recommended for the treatment and handling of radioactive wastes isolate the product to control personnel exposure. As an added benefit, this isolates the product from combustibles. Bituminized waste is present in only two locations: the processing cell and the product storage area.

Within the processing cell the only combustibles present are in the bitumen feed lines and the heating fluid system, both of which are sufficiently protected to prevent fires. Despite the fire prevention methods, should a fire spread to the product in the product container, a container lid could be used to cap a container and smother the fire. The processing cell is completely isolated and the fire would not be able to spread to other areas in the plant.

Combustible materials should not be present in a product storage area, therefore the probability of a fire spreading to the product is small. The product is stored in capped containers, thereby significantly reducing the chances of spreading a fire even if a fire somehow initiated in the product storage area. A capped container is a fire prevention method in itself. According to calculations performed by ATI, a 55-gallon capped drum of product can sustain approximately 20 minutes of 1470°F fire surrounding the container before the product will reach its minimum flash point of 600°F and 25 minutes before the product will expand to the point of rupturing the drum. Actual tests performed independently verify these results.[6]

e. Ventilation

Ventilation is required to ensure the removal of any combustible volatiles that may be released from the bituminized product as it is discharged from the Evaporator into waste containers. The Ventilation Hood extends from the Evaporator discharge to the waste container fill port, surrounding the bituminized product stream and capturing any volatiles. These volatiles are filtered and exhausted into the plant ventilation system.

The filling cell and the filled container storage area must be ventilated. A negative pressure of 15mm wc and an air renewal rate of 10 changes per hour are recommended to ensure positive removal of any volatiles.

8.1.3. Heating Fluid

a. Temperature Stability

There are a number of heating fluids on the market which exhibit favorable characteristics for use in the ATI System. One of these is Dow Corning Silicone Fluid Type 710, a phenylmethyl polysiloxane silicone fluid. It exhibits low volatility, high resistance to oxidation, high open cup flash point and high radiation resistance. It is an electrical insulator so that, in the unlikely event that a heating element arcs, the silicone oil suppresses and suffocates any potential fire. The temperature characteristics of Dow Corning Fluid 710 are as follows:

Flash Point, Open cup: 575°F

Thermal Decomposition Initiation Point: 700°F

Spontaneous Ignition Point: 910°F

b. NFPA Rating

NFPA 321 "Basic Classification of Flammable and Combustible Liguids" classifies the heating fluid as a combustible liquid Class III B (liquids having flash points at or above 200°F), their most stable class of combustible liquids.

c. Process Temperature

The temperature of the heating fluid is controlled and interlocked so as not to exceed 470°F. Should the temperature of the fluid exceed 465°F, an alarm is automatically sounded. Should the temperature exceed 470°F, an interlock initiates an automatic shutdown sequence which includes shutting off the heating elements. A redundant temperature monitor and high temperature interlock provide assurance of high temperature protection. The steel-sheathed heating elements of the Heating Fluid Subsystem are of low watt density design to prevent hot spots. These elements are typically used for preheating oil for oil fired boilers. An interlock prevents operation of the heating elements unless the Recirculation Pump is running. A bypass relief valve allows continuous flow of heating fluid through the Pump and Heater should flow to the Evaporator be shut off. Thermostats are all of fail safe design. Pressure switches limit operating pressure. Float switches provide low and high level protection in the heating fluid Expansion Tank.

d. Nitrogen Blanket

The Heating Fluid Subsystem is inerted by maintaining a nitrogen blanket on the Expansion Tank. The primary purpose of inerting the system is to increase the life of the heating fluid by eliminating oxygen and to prevent volatility of the heating fluid. The exclusion of oxygen also provides the added benefit of fire prevention.

e. Margin of Safety

With the controls and interlocks discussed above, the maximum possible heating fluid temperature at any point in the system is 470°F, a safe 105°F below its flash point and 440°F below its spontaneous ignition point.

A fire is prevented by keeping the temperature below its flash point, by preventing an ignition source within the system and by inerting the system, keeping oxygen out of the closed system. Two of the three parameters required to initiate or sustain combustion are not present. The absence of either is adequate fire prevention.

8.1.4 Other Combustibles

Two other combustibles are present in the ATI System in very small quantities: Reagent #1 and the lubricant for the Evaporator bottom bearing.

a. Reagent #1

Reagent #1 is a surfactant which, in its pure form, is a soft, waxy solid with a melting point of 86^{O}F. It has a flash point of 200^{O}F and is classified as a Class III B combustible liquid per NFPA 321. It is diluted in water to a non-combustible 25% solution in Reagent Tank #1, a 100 gallon tank, prior to use in the process.

Reagent #1 can be purchased in its pure form or in solution form. If purchased in its pure form it should be stored in a ventilated room, isolated from ignition sources and other combustibles. The container lids should be kept on all stored containers prior to use.

b. Evaporator Bottom Bearing Lubricant

The bottom bearing of the Luwa Evaporator is continuously lubricated while the Evaporator is operating to increase the bearing life and thus decrease potential maintenance. The recommended lubricant is a petroleum base long chain alkane series hydrocarbon lubricant with a flash point of 485^{O}F and a boiling point of over 700^{O}F. It is a common readily available lubricating oil which should be handled with the same precautions as other lubricants in the plant. It is metered to the bottom bearing from a small vented vessel (5 to 10 gallons) located near the Evaporator.

8.2 Fire Suppression

The ATI System is designed so as to prevent fires from starting through the proper selection of high temperature fluids and binder and through the careful design of instrumentation and control protection devices. Though the probability of a fire initiating is extremely low, adequate methods of detecting fires quickly and suppressing those fires that occur to limit their damage must be provided. The plant fire protection program must include proper detection devices and suppression systems in these areas:

- The processing cell.
- The bitumen storage area.
- The bituminized product handling area.
- The Heating Fluid Subsystem area.

8.2.1 The Processing Cell

Included in the processing cell are the Luwa Evaporator, containers of the bituminized waste, and heating fluid piping. The processing cell during normal conditions is isolated from plant personnel and monitored through observation windows and closed circuit TV. ATI advises that the cell include strategically located smoke detectors to warn an operator and automatically initiate a safe automatic system shutdown. The suppression system should deluge the cell. A CO_2 system in compliance with NFPA 12 is the recommended suppression system.

The fire protection program for the low level radioactive waste area must be integrated with the total plant fire protection system which mandates an automatic water spray fixed fire suppression system with spray nozzles located in each room. ATI does not recommend the use of a water spray system as the primary suppression system in the three areas where bitumen or the bituminized product are present. Water is an adequate and appropriate fire suppressant for bitumen fires — water will quickly put a fire out and prevent the spreading of a fire. However, there are post-fire suppression ramifications with water spray systems for bitumen applications, as follows:

a. Water spray systems necessitate the installation of floor drains. The problem of where to drain slightly radioactive water is therefore created.

b. Bitumen and the bituminized product are thermoplastic fluids. The water spray system will quickly cool the bitumen, causing it to solidify and plug the floor drains.

c. The plugging of the floor drains will create a flooding in the area. The area would then have to be leak-proof to prevent radioactive water from seeping into other areas, and methods of cleaning up the area would have to be developed.

d. A storage tank for liquid wastes would have to be designed to accommodate a fire water deluge.

e. Equipment could be damaged as a result of the water spray and subsequent flooding.

All of the above problems could be eliminated with an adequately designed automatic CO_2 fire suppression system for the areas using or storing bitumen and the bituminized product.

8.2.2 Bitumen Storage Area

The fire suppression system recommended for the bitumen storage area is dependent upon whether storage is inside or outside the building.

If the Bitumen Storage Tank is placed inside the building, an automatic suppression system should be provided, preferrably a CO_2 suppression system as discussed in 8.2.1. The Bitumen Storage Tank should be isolated from the rest of the radwaste system with diked retaining capacity equal to the storage capacity. A fixed nozzle water sprinkler system is not recommended due to the potential hazard of overflowing the retaining capacity and plugging the drain. Ventilation should be adequate for fume removal to the atmosphere.

If the Bitumen Storage Tank is located outside the building with a retaining wall sufficient in volume to sustain a tank rupture, the fire suppression system could consist of the normal plant raw water fire loop with a hydrant in close proximity to the tank. It is not required that special fire protection equipment be utilized.

The Bitumen Storage Tank is designed and fabricated per API-650. Though bitumen is not classified as a flammable or combustible liquid, ATI recommends that the installation, ventilation, and foundation design for the Bitumen Storage Tank comply with NFPA-30 requirements for Class III B combustible liquids.

8.2.3 Bituminized Product Handling Area

In the bituminized product storage area, the waste/bitumen mixture has cooled to atmospheric conditions. The probability of a fire in this area is extremely remote. It is recommended that smoke detectors and automatic CO_2 suppression systems be strategically placed to smother any fire in the area should an outside source of fire ignite the product. Also see Section 8.1.2. d.

8.2.4 Heating Fluid Subsystem Area

The Heating Fluid Subsystem area does not contain bitumen or bituminized product. Therefore, a water sprinkler system is acceptable in this area. ATI recommends that the sprinkler system for this area be integrated into the total plant automatic spray system.

8.3 Protection of Plant Safety Functions

Pursuant to Branch Technical Position 9.5-1, any applicant who intends to use the ATI System must submit for approval by the NRC a plant fire hazard analysis. This analysis must demonstrate that safety related systems are not affected by fires that are initiated by or spread to the ATI System.

ATI recommends that the combustibles associated with the system be located within the facility outside the realm of possible influence upon safety related systems in the event that a sustained fire develops despite the fire prevention methods and fire suppression systems adopted.

The utility applicant should take into consideration that the ATI System includes basic engineering practices, complies with all applicable codes for handling combustible fluids, provides safety interlocks to prevent high temperatures and to reach a safe shutdown mode, includes proper ventilation, and recommends conventional fire suppression equipment.

This system has been in use for solidifying research, military, and power plant wastes around the world for many years. Fires have been non-existent.

8.4 Safety Interlocks

The ATI System is well instrumented and interlocked to prevent fire initiation, to eliminate the spread of a fire should one originate from an outside source, to prevent release of radioactivity to the environment above allowable levels, to prevent system upset conditions from producing an unacceptable product, and to protect equipment from possible damage. Redundant instruments and interlocks are provided for control points which, when exceeded, could become a hazard. Prior to interlock action, annunciation warns the operator that the parameters are approaching the limit set points. Safety interlocks are provided to initiate a safe shut down or safe response to ensure the following:

a. Prevent heating fluid from exceeding a set temperature.

b. Prevent bituminized product from reaching a high temperature.

c. Prevent heating fluid from reaching a low flow, low temperature, or low level.

d. Prevent bituminized product from over-flowing container.

e. Prevent low mechanical seal water supply pressure.

f. Prevent feed of waste to the Evaporator without bitumen feed.

g. Prevent high vapor temperature. This interlock isolates the Evaporator and Condenser, closing the feed, discharge and vent valves, in the event of high vapor temperature.

h. Prevent high and low temperatures in the Bitumen Storage Tank and bitumen feed line.

i. Prevent pumps from pumping at too low a suction pressure.

j. Ensure flow of air from Condenser and container fill area.

k. Guarantee automatic flushing with water for decontamination after shut down.

l. Prevent high levels in tanks.

m. Ensure proper ratio of bitumen and waste.

n. Prevent a high concentration in resin slurry.

o. Prevent low bituminized product temperature.

In addition to the above safety interlocks, the system is well instrumented with indicators and recorders on the control panel to inform the operator of process conditions and annunciators to warn the operator of any potential upset condition.

9. CODES, STANDARDS AND REGULATIONS

The following Codes, Standards and Regulations are followed, where applicable, in the design, fabrication and inspection of the ATI System. The following list is based upon typical requirements. Owner specifications may contain requirements other than those listed below which are evaluated on a case-by-case basis. ATI uses good engineering judgement and practice in following the applicable sections of these Codes, Standards and Regulations to the extent practicable.

9.1 Federal Regulations

10 CFR 20	Standards for Protection Against Radiation
10 CFR 50, Appendices A, B & I	Licensing of Production and Utilization Facilities
10 CFR 51	Licensing and Regulatory Policy and Procedures for Environmental Protection
10 CFR 71	Packaging of Radioactive Material for Transport and Transportation of Radioactive Material under Certain Conditions
49 CFR 173-178	Department of Transportation, Hazardous Materials

9.2 U.S. Nuclear Regulatory Commission Regulatory Guides and Branch Technical Positions

USNRC RG-1.143	Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants

USNRC RG-8.8	Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations Will Be as Low as Is Reasonably Achievable
USNRC RG-1.120	Fire Protection Guidelines for Nuclear Power Plants
USNRC BTP ETSB 11-1	Design Guidance for Radioactive Waste Management Systems Installed in Light-Water-Cooled Nuclear Power Reactor Plants
USNRC BTP ETSB 11-3	Design Guidance for Solid Radioactive Waste Management Systems Installed in Light-Water-Cooled Nuclear Power Reactor Plants

9.3 Industrial Standards

The American National Standards Institute (ANSI) B16.5-1973	Steel Pipe Flanges and Flanged Fittings
ANSI B16.11	Forged Steel Fittings, Socket Welded and Threaded
ANSI B16.25	Buttwelding Ends
ANSI B31.1	Power Piping
ANSI N45.2.2	Packaging, Shipping, Receiving, Storage and Handling of Items for Nuclear Power Plants
ANSI Y32.14	Graphic Symbols for Logic Diagrams
ANSI B30.2	Cranes
ANSI/American Nuclear Society (ANS) 55.1-1979	Solid Radioactive Waste Processing System for Light Water Reactor Plants
ANSI/ANS 55.6-1979	Liquid Radioactive Waste Processing System for Light Water Reactor Plants
American Society of Mechanical Engineers (ASME) Section II	Materials

ASME Section VIII, Division 1	Pressure Vessels
ASME Section IX	Welding and Brazing Qualifications
American Petroleum Institute (API) 620	Recommended Rules for Design and Construction of Large, Welded Low-Pressure Storage Tanks
API 650	Welded Steel Tanks for Oil Storage
National Electrical Code	Standards
Institute of Electrical and Electronic Engineers	Standards
National Electrical Manufacturers Association	Standards
Insulated Power Cable Engineers Association	Standards
American Institute of Steel Construction	Standards
American Society for Nondestructive Testing	Standards
American Society for Testing and Materials	Standards
Anti-Friction Bearing Manufacturers Association	Standards
Hydraulic Institute	Standards
Uniform Building Code	Standards

American Welding Society	Standards
Instrument Society of America	Standards and Practices for Instrumentation
American Gear Manufacturers Association	Standards
International Atomic Energy Agency, Safety Series No. 6	Regulations for the Safe Transport of Radioactive Material
Crane Manufacturers Association of America	Specification #70
National Fire Protection Association	Standards

10. QUALITY ASSURANCE PROGRAM

ATI has established a Quality Assurance Program for radioactive waste management systems which is documented in "The ATI Quality Assurance Manual for Radioactive Waste Management Systems."

The Quality Assurance Manual serves as the documentation of a Quality Assurance Program which has been established to conform with Nuclear Regulatory Commission Guide 1.143, "Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants" and the applicable portions of Appendix B to Title IV, Code of Federal Regulations, Part 50.

The following is a summary of the areas controlled by the Quality Assurance Program.

10.1 Organization

The organization of each radioactive waste management system project at ATI is established with specific emphasis on those factors which promote quality.

Each individual in the organization has specific responsibilities as they relate to quality assurance.

10.2 Design Control

All design work performed by ATI is done with care and precision to assure the utmost quality. Wherever possible, standard procedures are established and used. In all cases a thorough checking procedure is used to eliminate errors.

10.3 Procurement Document Control

All procurement activities at ATI are carried out in such a manner as to assure that all technical and quality requirements for purchased goods and services are fulfilled.

10.4 Instructions, Procedures and Drawings

In order to assure quality of work and to adequately document the results of the work, all activities relating to quality are conducted in accordance with written procedures and all results are documented in accordance with those same procedures.

10.5 Document Control

All documents relating to the quality of design, fabrication and erection of a radioactive waste management system project are diligently monitored to assure that each document is correctly executed, reviewed and maintained on file.

10.6 Control of Purchased Material, Equipment and Services

All material, equipment and services purchased by ATI for radioactive waste management system projects are subject to a system of controls which ensures that the quality is within the requirements of the project.

10.7 Identification and Control of Materials, Parts and Components

ATI's involvement with the identification and control of materials, parts and components is through vendors and subcontractors. ATI ensures that sufficient controls are used by its vendors and subcontractors through its procedures for control of purchased material, equipment and services.

10.8 Control of Special Processes

ATI's involvement with special processes is through vendors and subcontractors. ATI ensures that sufficient controls are used by its vendors and subcontractors through its procedures for control of purchased material, equipment and services.

10.9 Inspection

ATI's involvement with inspection other than source inspection, receiving inspection and project acceptance inspection is through vendors and subcontractors. ATI ensures that sufficient controls are used by its vendors and subcontractors through its procedures for control of purchased material, equipment and services.

Source inspection, receiving inspection and project acceptance inspection are performed and documented in accordance with established procedures.

10.10 Test Control

ATI's involvement with testing is through vendors and subcontractors. ATI ensures that sufficient controls are used by vendors and subcontractors through its procedures for the control of purchased material, equipment and services.

10.11 Control of Measuring and Test Equipment

ATI's involvement with measuring and test equipment is through vendors and subcontractors. ATI ensures that sufficient controls are used by its vendors and subcontractors through its procedures for the control of purchased material, equipment and services.

10.12 Handling, Storage and Shipping

ATI's involvement with handling, storage and shipping is through vendors and subcontractors. ATI ensures that sufficient controls are used by its vendors and subcontractors through its procedures for the control of purchased material, equipment and services.

10.13 Inspection and Test Status

ATI's involvement with documentation of inspection and test status is through vendors and subcontractors. ATI ensures that sufficient controls are used by its vendors and subcontractors through its procedures for the control of purchased material, equipment and services.

10.14 Nonconforming Items

ATI's involvement with nonconforming items except those discovered during ATI inspections or tests is through vendors and subcontractors. ATI ensures that sufficient controls are used by its vendors and subcontractors through its procedures for the control of purchased material, equipment and services. When nonconforming items are discovered during ATI inspection or tests, the nonconformances are detailed in the inspection or test report and the materials and/or equipment involved are entered into the vendor or subcontractor's system for disposition of nonconforming items.

10.15 Corrective Action

ATI's involvement with corrective action for nonconforming items except for those nonconforming items found during ATI inspection or tests is through vendors and sub-contractors. ATI ensures that sufficient controls are used by its vendors and sub-contractors through its procedures for the control of purchased material, equipment and services. Nonconformances revealed by ATI inspections and tests require reinspection or retest before the materials and/or equipment can be released for installation or use. When the nonconformance is revealed by a source inspection, the inspector may at his discretion delegate the reinspection to the relieving inspector at the job site.

10.16 Quality Assurance Records

Throughout "The ATI Quality Assurance Manual for Radioactive Waste Management Systems" the requirements for documentation of projects are described. These documents form the quality assurance record for the project. These documents are prepared, reviewed, approved, distributed, and used in accordance with the procedures outlined in the Quality Assurance Manual.

10.17 Audits

ATI conducts a program of quality assurance audits to ensure that the procedures required by its Quality Assurance Program are being followed and that, in the implementation of the procedures, the goal of ensuring quality is attained.

11. RADIOLOGICAL CONSEQUENCES

11.1 Introduction

This section provides an evaluation of the radiological impact of the ATI System and its waste product during in-plant operations and during transportation and disposal. Both normal and accident situations are considered. This analysis shows that the ATI System will not increase the radiological impact over that of non-volume reduction systems and that the benefits due to volume reduction can be significant in fewer shipments and lower exposures. Furthermore, the quality of the solidified product in terms of no free liquid, low leach rate and demonstrated product integrity further tends to reduce doses when compared to less effective binders.

11.2 In Plant

11.2.1 Introduction

The radiological impact of the ATI System during in-plant operations is evaluated in this section for normal operation and accident conditions.

11.2.2 Normal Operations

Equipment design features, layout and system design considerations for controlling radiation exposure are discussed in Section 7 of this report. The system process is such that liquids from the ATI System are returned to the plant liquid radwaste system and gaseous wastes are processed and controlled by the in-plant gaseous radwaste system. Thus the liquid and gaseous wastes are not increased over those already evaluated in plant specific Safety Analysis Reports.

The portion of gaseous waste which is processed through the ATI System may be evaluated as follows. Table 11-1 presents a comparison of observed decontamination factors for the Luwa Evaporator with those proposed in NUREG 0017. Since these DF's compare favorably, it is concluded that the ATI System does not add to the plant effluent over that already evaluated.

Table 11-1

DECONTAMINATION FACTORS

Luwa vs. NUREG 0017

Isotope	Decontamination Factor

11.2.3 Accidents

Routine operation failures leading to release of radioactive material are reviewed in Section 5.5 of this report. If failures beyond those proposed in Section 5.5 occur, the in-plant liquid and gaseous radwaste protection systems would function to preclude uncontrolled releases to the environment. Local in-plant exposures would increase, of course, but no more than exposures already evaluated due to in-plant accidents in plant specific Safety Analysis Reports.

In-plant fire protection is presented in Section 8 of this report, which outlines the prevention and suppression systems. An analysis has been performed by ATI which assumes a bare 55 gallon drum 90% full of bituminized product being subjected to 1470°F (which would only occur during the unlikely event of fire initiation and subsequent failure of the fire protection system). The results of this analysis are that it would take approximately 20 minutes for the product to reach 600°F, its minimum flash point. The calculations also show a 25 minute time period required to rupture the drum, thus providing a release path to the environment. These times are of such magnitude that operator action is readily assumed, especially in consideration of the unlikelihood of sustaining a 1470°F environment.

11.2.4 Conclusion

Since the ATI System does not add significantly to plant releases, is designed with careful attention to ALARA, and is protected against in-plant accidents, it is concluded that the system does not add to the radiological impact of the plant.

11.3 Transportation

Radiation doses may be received during the transportation phase of solid waste disposal as a result of exposures along the route or due to postulated accidents. This section will evaluate the ATI System by making comparisons to the results found in WASH 1238.

11.3.1 Waste Characteristics

Table 11-2 presents a comparison of the number of volume reduced drums resulting from using the ATI System to the number of drums resulting from the WASH 1238 assumptions. This Table and the following analysis is a comparison only and not to be taken as actual operating results.

The WASH 1238 data reflects an assumed volume increase of 4 for a cement system (7.2 ft^3 product/1.8 ft^3 waste input). Section 6.4 of this report presents a volume reduction factor of 1.25 to 1.75 for spent resin and much higher values for the boric acid and sodium sulfate concentrates example. For purposes of comparison, a volume reduction factor of 1.5 is chosen. This results in an overall reduction in the number of drums produced by a factor of approximately 6 and an increase in curies per drum by a factor of 6.

11.3.2 Packaging

The volume reduction process increases the concentration of radioactivity in the drum and thus increases the shielding requirements. It is assumed that additional shielding is provided in order to offset the increased activity concentration, yielding equivalent exposure rates for volume reduced and non-volume reduced packages.

Table 11-2

SOLID WASTE FROM 1100 MWe BWR

	Volume (ft^3/yr)	Radio activity (Ci/ft^3)	No. of Drums ATI[1]	No. of Drums WASH[2] 1238	Ci/Drum ATI[1]	Ci/Drum WASH[2] 1238
Cleanup Sludge	120	13	11	67	140	23.3
Condensate Sludge	2100	0.14	194	1166	1.5	0.25
Waste Sludge	920	0.01	85	511	0.12	0.02
Waste Bead Resin	60	0.01	6	34	0.12	0.02
Cond. Bead Resin	600	0.06	56	334	0.06	0.01
Totals	3800 ft^3/yr		352	2112		

1) Assumes a volume reduction factor of 1.5 and concentration of waste in product in a 45/55 ratio waste/bitumen.

2) Assumes concentration of waste in product in a 1.8/5.4 ratio per WASH 1238.

11.3.3 Transportation Conditions

Assumptions presented in WASH 1238 are that trucks carry 40-50 drums per truckload and rail cars carry 200-250 drums per car. Therefore, 8 truck shipments or 2 rail shipments might be expected, using the ATI system. (In reality, the number of drums per shipment and the number of shipments per year depend upon activity level and shielding requirements, but these numbers are used here for the purpose of comparison.) The average distance of 500 miles and average transit time of 3 days by truck and 7 days by rail presented in WASH 1238 remain unchanged.

11.3.4 Radiation Exposure from Normal Transportation Activities

Although an increase in radioactivity due to volume reduction is expected for the ATI System, a corresponding increase in shielding provided is also expected. Therefore, no change in the WASH 1238 exposure rates is expected. Those assumptions are: 50 to 60 mrem/hr at the surface of the truck or rail car; 25 mrem/hr at 3 feet from the surface of the vehicle; 10 mrem/hr at 6 feet from the surface of the vehicle; and 0.2 mrem/hr in the truck cab.

Table 11-3 presents a comparison of doses estimated using exactly the same assumptions as WASH 1238 except that the values are reduced by 1/6 due to 1/6 the number of shipments being made. It should be noted that the number of people exposed changes in the case of general public onlookers since this is a trip dependent number, while the people along the route remain constant in number and are exposed to either more or fewer trips. In the case of transport workers, two drivers and two garagemen are exposed in either case for trucks, but brakemen are different along the route for each trip and taken as 10 per trip.

There is a temptation to reason that the increased concentration in activity is not offset by the increased shielding provided. This reasoning exactly cancels the dose reduction

Table 11-3

ESTIMATED DOSES FROM TRANSPORTATION
UNDER NORMAL CONDITIONS PER REACTOR YEAR

	TRUCK				RAIL			
	Man-Rem		No. People		Man-Rem		No. People	
	ATI	WASH 1238	ATI	WASH 1238	ATI	WASH 1238	ATI	WASH 1238
Transport Workers	0.17	1	4	4	0.0083	0.05	20	100
General Public Onlookers	0.1	0.6	80	500	0.017	0.1	20	100
People Along the Route	0.067	0.4	1.5×10^5	1.5×10^5	0.017	0.1	1.5×10^5	1.5×10^5
Totals	0.337	2.0			0.0423	0.25		

from fewer trips and results in exactly the same exposure as that presented in WASH 1238. However, it should be pointed out that an increase in concentration of radioactivity must still be shielded such that the limits of 49CFR are met (e.g., 200 mrem maximum) at the vehicle surface, which is only a factor of 4 larger than WASH 1238 assumptions. Since shielding calculations are conservative in general and are based on worst case concentrations, it is appropriate to maintain the assumptions presented above and conclude an overall dose reduction due to fewer drums being shipped.

11.3.5 Transportation Accidents

Transportation accidents are shown in WASH 1238 to have very similar probabilities per vehicle mile for truck or rail. Table 11-4 presents a comparison of total probability per reactor year for the ATI System and the WASH 1238 assumptions. The probability in each Accident Severity Category for the ATI System is less than that for the non-volume reduction system by a factor of 6.

Table 11-5 shows a comparison of estimated curies released from various proposed accidents. In each case, the ATI System results in an increase in available curies released by a factor of 6 due to concentration.

The net result of accident comparison is then that the accident probability is reduced by the same factor that the potential curie release is increased.

With respect to fire hazards, ATI has calculated the effect of temperature at 1470°F on a 3 by 5 array of drums in a commercially available cask without external thermal shielding. The results are that for the drums initially at 70°F and instantly subjected to an external 1470°F

Table 11-4

TRANSPORTATION ACCIDENT PROBABILITY

Accident Severity Category	Probability per Vehicle mile per yr	Total Probability per Year	
		ATI[1)]	WASH 1238[2)]
Minor	2×10^{-6}	8×10^{-3}	4.6×10^{-2}
Moderate	3×10^{-7}	1.2×10^{-3}	6.9×10^{-3}
Severe	8×10^{-9}	3.2×10^{-5}	1.8×10^{-4}
Extra Severe	2×10^{-11}	8×10^{-8}	4.6×10^{-7}
Extreme	1×10^{-13}	4×10^{-10}	2.3×10^{-9}

1) 8 truck trips per year x 500 miles each trip = 4000 miles

2) 46 truck trips per year x 500 miles each trip = 2.3×10^{4} miles

Table 11-5

ESTIMATED RELEASES FROM ACCIDENTS

Activity in curies that Become Airborne

Accident

Type Package	Lid loose one drum		Contents of one drum spilled out		25 drums broken open severe impact	
	ATI	WASH 1238	ATI	WASH 1238	ATI	WASH 1238
Type A Package	$6x10^{-7}$	10^{-7}	$6x10^{-6}$	10^{-6}	$6x10^{-3}$	10^{-3}
Type B Package	$6x10^{-6}$	10^{-6}	$6x10^{-6}$	10^{-6}	1.5	0.25

environment, it would take approximately 45 minutes for the bituminized product to reach a temperature of 600°F, which is its minimum flash point (see Section 8.1.2). It would take 60 minutes for the product to expand to the point of rupture of the drums. Of course, the thermal insulation would greatly increase these times.

Risk due to accidents which result in the cask or drum being immersed in water are shown to be acceptable due to a favorable leach rate compared to IAEA standards as described in Section 3.7 of this report.

11.3.6 Conclusions

Comparisons with existing analyses in WASH 1238 result in observing that the ATI System has either the same or reduced radiological impact when compared with non-volume reduction systems.

11.4 Disposal

For an analysis of the radiological impact of disposal, the reader is referred to the "Environmental Impact Statement for Near Surface Disposal of Radioactive Waste," an NRC Document written by the Division of Waste Management in the Office of Nuclear Material Safety and Safeguards. This document is scheduled for publication in April, 1981 as a support document for 10CFR61.

11.5 Radiological Analysis Conclusions

The preceding analysis shows that the benefits of reduced product volume made possible by using the ATI System exceed or, at least, offset the potential risks due to higher waste concentrations. These benefits are enhanced by providing additional in-plant shielding, transportation shielding and procedures in plant, during transportation and at disposal which complement the advantages of volume reduction.

12. OPERATING EXPERIENCE

The ATI System, as proposed for use in U.S. power plants and as submitted for NRC approval, is a system currently being used successfully for the proposed application throughout the world. Wastes that have been successfully volume reduced and bituminized include power plant wastes (both BWR & PWR), research wastes, and military wastes.

Table 12-1 is a summary of the facilities worldwide utilizing the system offered by ATI/SGN. Each of these facilities is described more fully in the following sections.

TABLE 12-1 SYSTEM REFERENCE LIST

Facility	Operator	Type of Facility	Waste Type	Luwa Evaporator Model No.	Bitumen System Startup Date	Drums of Solidified Waste
Barsebeck Nuclear Power Station	Sydkraft	Two 590 MWe BWRs	bead resin, powdered resin, lab, decon, sodium sulfate	LN-0100	1975	2500 (as of 11/80)
Mihama Nuclear Power Station	Kansai Electric Power Co.	Three PWRs 320, 470, & 780 MWe	boric acid, laundry, decon, chemical	LN-0200	1978	230 (as of 6/79)
Tsuruga Nuclear Power Station	Japan Atomic Power Co.	340 MWe BWR	sodium sulfate, decon, chemical, laundry	LN-0200	1977	250 (as of 6/79)
Advanced Thermal Reactor, Tsuruga	Power Reactor and Nuclear Fuel Development Corp.	200 MWe LWCHWR	equip. and floor drains	LN-0200	1977	33 (as of 6/79)
Cadarache Nuclear Research Center	CEA	Research & Development	Various	LN-0050	1971	No Record
Saclay Nuclear Research Center	CEA	Research & Development	decon, EDTA, phosphates, nitrates, chlorides, ammonia, acids, bases	LN-0050	1975	1000 (as of 10/80)

TABLE 12-1 SYSTEM REFERENCE LIST

Facility	Operator	Type of Facility	Waste Type	Luwa Evaporator Model No.	Bitumen System Startup Date	Drums of Solidified Waste
Valduc Military Center	CEA	Military Weapons	sodium nitrate, diatomaceous earth	LN-0050	1971	2500 (as of 10/80)
Monts d'Arree Nuclear Power Station	Electricite de France	70 MWe GCHWR	sodium nitrate, phosphates	LN-0050	1980	300 (as of 10/80)

12.1 Barsebeck Nuclear Power Station[7]

12.1.1 Background

Barsebeck 1 and 2 are ASEA-ATOM boiling water reactors, each of 590 MWe, situated on the coast approximately 30 kilometers north of Malmo, Sweden. Unit 1 was in commercial operation on July 1, 1975 and Unit 2 was started two years later. The reactors are owned and operated by Sydkraft, a private power company supplying southern Sweden with electricity.

The delivery of a waste treatment plant by SGN included all mechanical and electrical equipment as well as erection and start-up.

At the time, mixing with cement was the method most widely used at nuclear power stations. Bitumen solidification had been practiced at nuclear centers but not at commercial nuclear power stations.

Better economy during storage and transport was important in choosing bitumen solidification rather than concrete solidification. The Thin Film Evaporator method was found suitable for treating concentrates, resins and filter sludges as well as mixtures of these. Barsebeck thus became the first power station to use bitumen solidification. The bituminization system supplied by SGN was started up in 1975.

12.1.2 Process Description

At Barsebeck, filter sludges and ion exchange resins are the principal wastes generated. The volume of concentrates is small because the condensate polishing system utilizes precoat filters instead of regenerable filter demineralizers.

A flow diagram of the installed system is presented in Figure 12-1. Wastes to be solidified are collected in two 1850 gallon stainless steel tanks equipped with turbine agitators and internal steam coils. The waste consists mainly of powdered ion exchange resin or bead resin. In the latter case the beads are ground to a powder by a wet grinder during transfer to one of the feed tanks.

The slurry is decanted to obtain a 15-20 wt % dry resin slurry and is chemically pretreated.

Bitumen is stored at 250°F in two 8000 gallon storage tanks. The bitumen used is Mexphalte 40/50, a straight distilled bitumen.

Slurry and bitumen are fed into the Luwa Evaporator Model LN-0100. Heat is provided by a heating fluid which is electrically heated to 450°F and circulated through the Evaporator jacket. The water in the waste is evaporated, condensed, cooled and filtered before entering the low level liquid waste treatment system.

The bitumen/solid waste mixture flows from the bottom of the Evaporator into 220 liter drums. Each drum is filled in two steps. After the first filling, the product is allowed to cool and shrink. The drum is then "topped off" by a second filling. The filling cell includes an eight-drum turntable. With this turntable, eight positions are available for filling, cooling, crimping of lids, monitoring surface dose rate, discharging filled drums and loading empty drums.

Normally the process is started by an experienced operator who knows the equipment in detail. Once the flow rates are

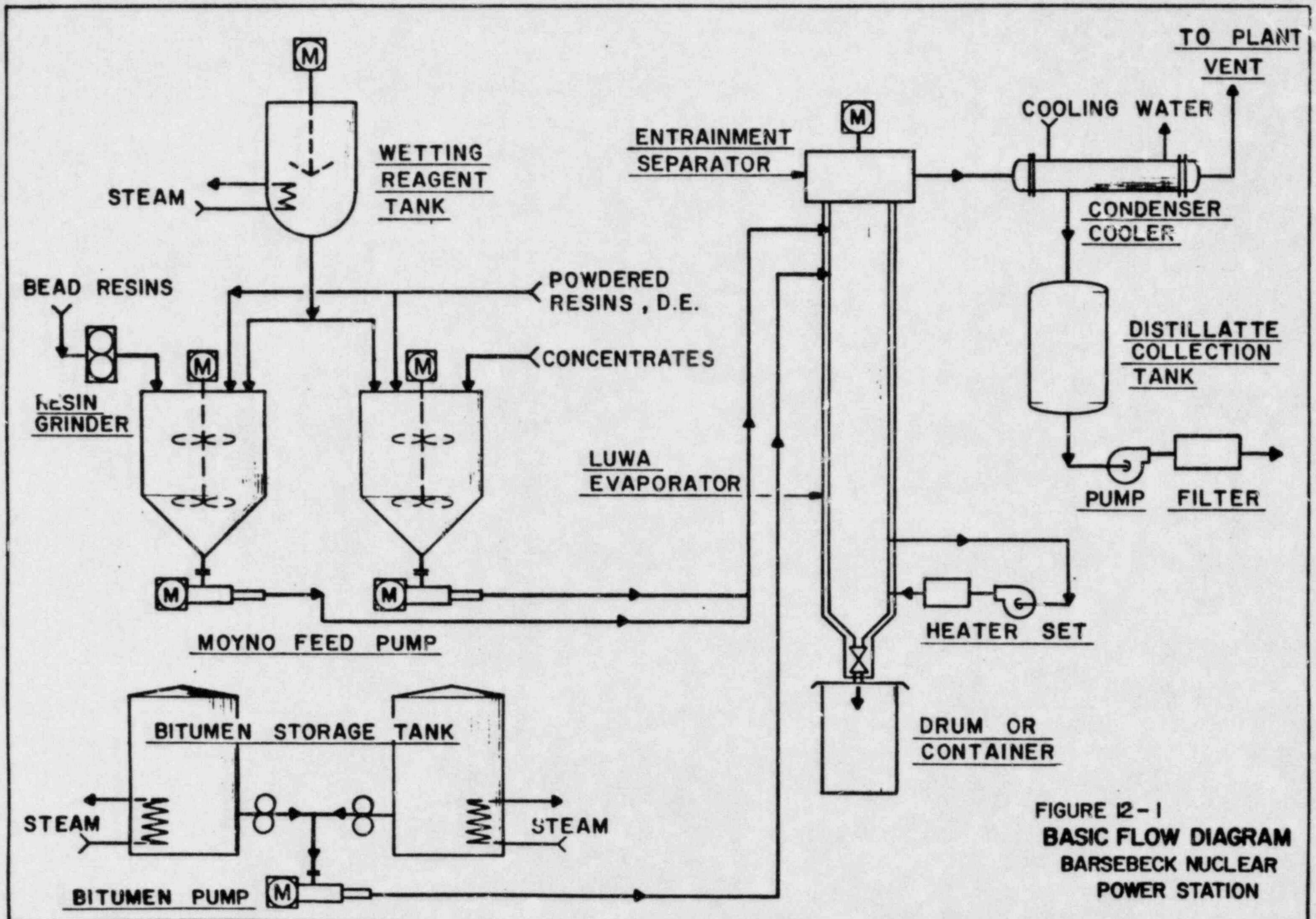


FIGURE 12-1
BASIC FLOW DIAGRAM
BARSEBECK NUCLEAR POWER STATION

established and the product flows well into the drum, the filling station is manned by shift personnel from the reactor. It is then normal that the process runs without interruption of product flow for approximately 100 hours or until the feed tank is emptied.

A representative sample of each batch of slurry is always taken from the feed tanks. Complete nuclide identification is made and the results, along with operating parameters from the solidification of each particular batch, are stored on punched tape. A computer program calculates drum activity content at any desired time. This procedure aids in drum handling and inventory, local storage and transport.

Figure 12-2 is the Process and Instrumentation Diagram for the Barsebeck bituminization system.

12.1.3 Operating Experience

a. Hours of Operation

There have now been five years of operating experience with the system. As of November, 1980, 2500 drums (220 liter) of bituminized waste had been produced and the system had been operated over 10,000 hours.

b. Evaporator Reliability

The Thin-Film Evaporator has proven to be quite reliable and easy to operate. There has been very little maintenance required during five years of operation. The bottom bearing of the Evaporator has been replaced once as a routine preventive measure, not because of wear.

c. Product Quality

Testing of the bituminized product has shown water content less than 0.5 wt %, swelling unnoticeable after three months of water immersion, flash point greater than 617°F. During the inactive test period in 1974, bituminized product containing resins and sodium sulfate showed no exothermic reaction below 932°F. Samples of product tested for leaching by the IAEA standard test procedure[1] exhibit leach rates of 2×10^{-6} cm/day (primarily Co 60) after three months. In one experiment, a 220 liter drum with two holes, each of one dm^2 area, placed in a small tank with 565 liters of fresh water leached a total of 10^{-5} of the drum activity after 135 days.

d. Decontamination

Decontamination of equipment, including the Evaporator, has been performed without problems. It has been found that operating with pure bitumen for a short period after each shut-down keeps the Evaporator clean enough from an operational point of view. The occupational exposures received during operation and maintenance have been very low (<1 manrem/yr). As long as drums are removed from the filling cell there are no limitations as to the time that can be spent in the cell.

e. System Improvements

A number of improvements have been made to the system since start-up as the result of experience gained during operation. Some of these changes were necessitated by the fact that the system was originally designed to treat a mixture of concentrates and resins, not resins only (deep bed demineralizers were originally planned in the condensate polishing systems). The improvements made are described below.

(1) The Moyno Pump feeding the slurry was subject to excessive wear. The reason for this was found to be unsatisfactory design of valves, flow-meter and pipes between the the pump and the Thin-Film Evaporator. Connecting pipes for drainage, sampling and recirculation to the tank acted as pockets where resins could accumulate and cause clogging. Due to insufficient instrumentation, no warning of clogging was given to the operator. The interruption of flow caused excessive abrasion of the pump stator. In addition, all valves near the pump were manual and placed in a narrow lead box. The physical position of the valves was such that the flow paths could not easily be seen by the operator.

The solution to these problems was the installation of three-way remotely operated valves at all pipe connections after the pump. All pockets were thereby eliminated and all valves needed during normal operation can now be controlled from the central panel.

All new systems proposed by ATI also incorporate the following additional features to prevent pump wear:

- Full port plug valves with smooth transitions to eliminate restrictions.
- Piping designed to prevent low spots.

- Automatic sampling by-pass to prevent temporary "dead-head" operation.
- Automatic flush of piping with flush water after pump shutdown.
- High pressure interlock for pump protection.

(2) Sampling of slurry in the feed tank was not possible with the installed equipment. Two methods to withdraw a sample from the recirculation pipe were tried without success, one using a compressible plastic bottle and rubber membrane to suck slurry, the other using a syringe connected to the recirculation pipe. Finally another method was adopted. A defined volume (75 ml with approximately 15 g of dry resins) of slurry can be trapped by operating two three-way valves in the recirculation pipe. The sample is flushed out into a shielded bottle. By measurement of the volume in the bottle, the dilution of the slurry is accounted for.

(3) The heating coil in the feed tank had to be replaced due to fretting corrosion. The steam enters and exits the tank at the top which caused water to condense in the bottom part of the coil. The opening time for the steam valve was increased and the coil was replaced.

(4) On one occasion, an operator attempted to actuate the Evaporator discharge valve before it was sufficiently heated. The valve was damaged and had to be replaced.

Interlocks were added to prevent actuation of the valve if not at the proper temperature.

(5) The wet grinder for bead resins suffered cracks in the corundum discs. It was difficult to adjust the distance properly between the two discs. A meter for the electrical current of the motor was installed next to the adjustment wheel of the grinder. Contact between the two discs gives a sharp increase in the electrical current of the motor, providing a signal for the operator.

Maintenance work has been rather limited, except for the improvements described above.

f. Fire Protection

The filling cell is equipped with a CO_2 extinguishing system. No fire has ever occurred during processing, transport or storage at Barsebeck.

12.2 Mihama Nuclear Power Station

12.2.1 Background

Mihama 1, 2 and 3 are PWRs of 320 MWe, 470 MWe and 780 MWe, respectively, located on the Tsuruga Peninsula of the island of Honshu, Japan. The reactors were placed into commercial operation in November 1970, July 1972 and December 1976 respectively, and are operated by Kansai Electric Power Company.

An SGN bituminization system was installed and placed into operation in July 1978. The bituminization system, which utilizes a Luwa Thin-Film Evaporator Model LN-0200, replaced a cement system that was originally selected for the Mihama Station. Two factors influenced this decision to change:

- Japan has a very high population density. Little space is available for the disposal of radioactive waste. Therefore, volume reduction is an essential part of waste management.

- The bitumen process is more appropriate for laundry wastes and decontamination agents than cement processes.

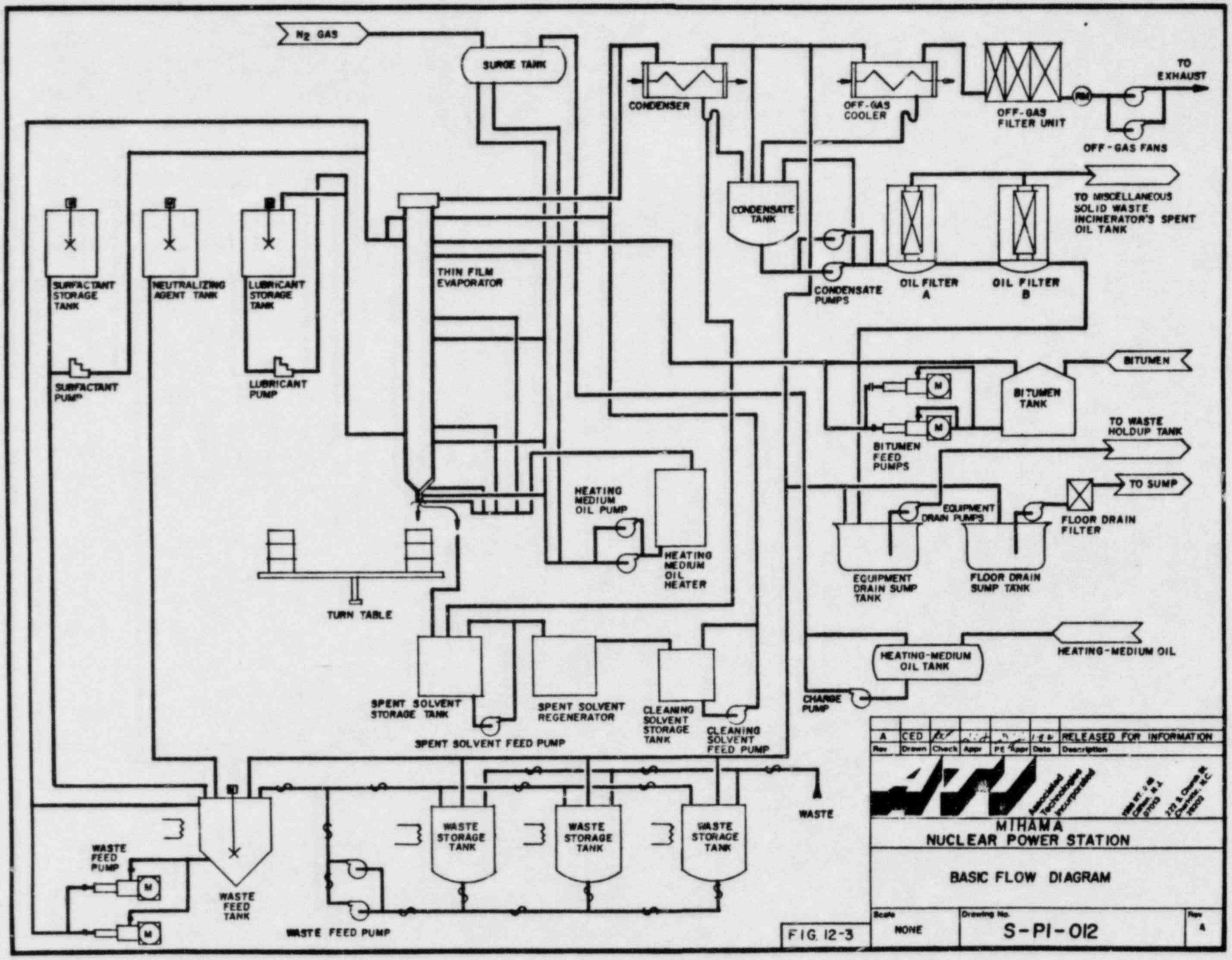
12.2.2 Process Description[8]

Liquid concentrates treated include boric acid, laundry wastes, decontamination agents and chemical wastes.

The flow sheet of the SGN process utilized at Mihama is shown in Figure 12-3. Concentrated liquid waste produced at the Mihama Power Station is stored in three waste storage tanks, each with a capacity of 8,000 gallons. Concentrated waste is stored as long as possible to lower radiation levels through radioactive decay. Then the waste is transferred to the waste feed tank, which has a capacity of 1850 gallons.

The liquid waste is kept at 167°F by an electric heat tracing system to prevent crystallization in the tanks and piping. The waste in the waste feed tank is analyzed to measure radionuclide content, solids content, pH and specific gravity. Caustic soda is added to adjust pH. The flow rate of bitumen is determined from a specified mixing ratio in the range of 40-50% dry solids, and the speed of the waste feed pump and Thin-Film Evaporator rotor are set.

The Evaporator is heated with a heating fluid maintained at 473°F. The mixture of solids and bitumen flows down through



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Associated Technologies Incorporated

MIHAMA NUCLEAR POWER STATION

BASIC FLOW DIAGRAM

Scale: NONE
Drawing No. S-PI-012
Rev A

FIG. 12-3

the Evaporator, exits at a temperature of approximately $320^{\circ}F$, and is charged into 200 liter drums. Essentially all the water in the waste feed is evaporated. The residual water in the product is less than 1 wt %.

Nine drums are set on a turntable. Whenever a drum is filled, the table turns two positions sequentially. The drums are filled twice to allow shrinkage of the product and to maximize waste loading in each drum.

The material handling equipment consists of a nine position turntable, sliding double door for empty drum introduction, an empty drum delivery conveyor, an empty drum positioner, a capper, a drum lid carrier and a drum lid stacker. Figure 12-4 shows the layout of the drum filling/handling room.

A programmable controller is used to sequentially operate the material handling equipment. In addition, closed circuit TV and lead glass windows are provided for monitoring the filling operation.

An infrared laser system is used to monitor the filling level. This is a noncontact type sensing device. The level is continuously indicated. Indication of product level in the drum prevents spills resulting from overfilling.

The turntable can be manually operated from outside the shield wall in the event of a drive failure. Drums are removed from the turntable by a crane. The filled drums are placed on a scale to measure their weight. Also, drums are remotely swiped to ensure that there is no radioactive contamination of the exterior surfaces. Finally, the dose rate on the surface of the drum is measured before transfer to storage.

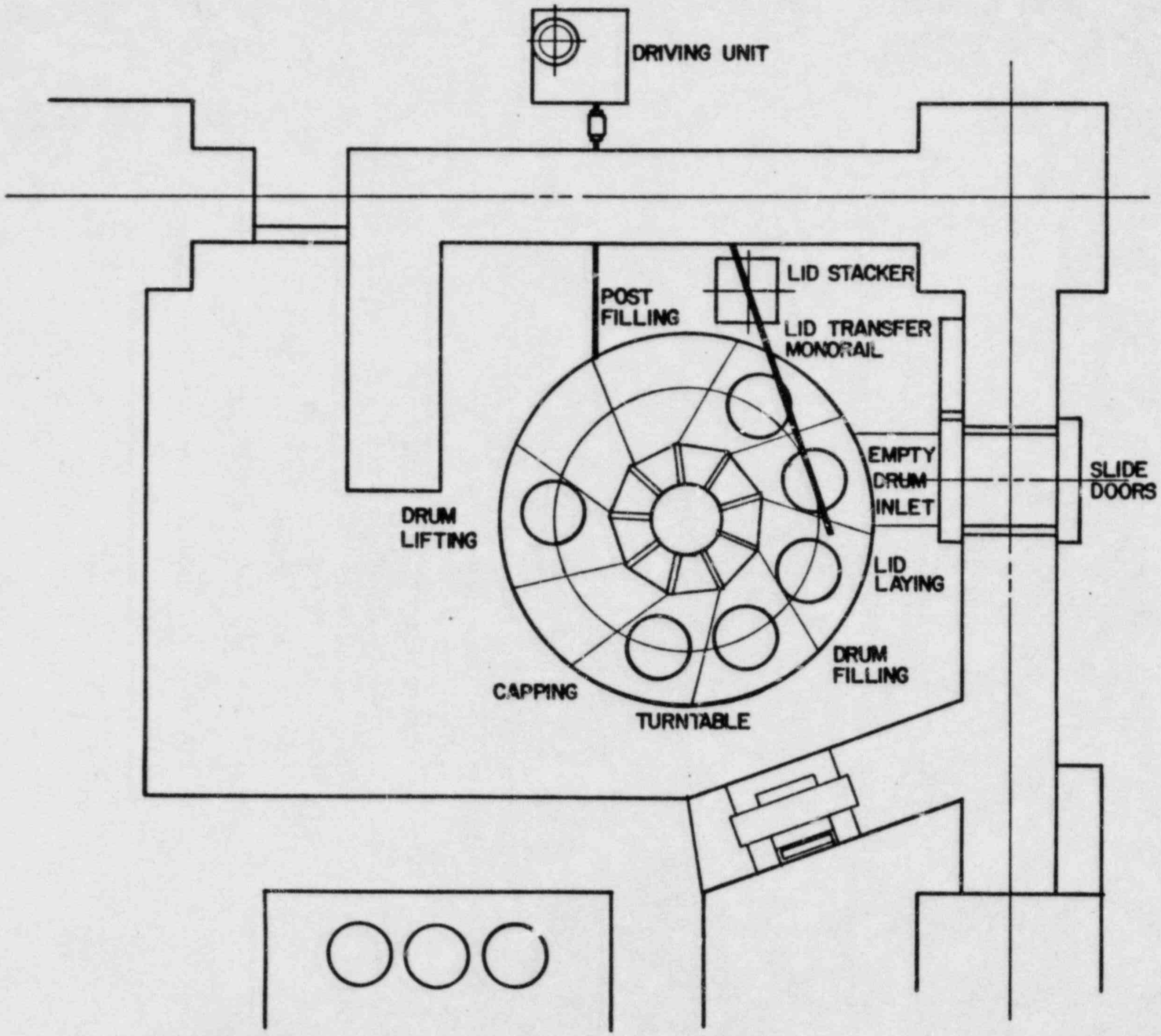

FIGURE 12-4 LAYOUT OF FILLING CELL, MIHAMA NUCLEAR POWER STATION

Bitumen is stored in a 4000 gallon outdoor storage tank maintained at 270°F by steam heating.

Water evaporated by the Luwa Thin-Film Evaporator is condensed in a condenser, collected in a distillate collection tank, and pumped through oil filters before being pumped to the auxiliary building of the power station. Vent gas from the condenser and waste feed tanks flows through the off-gas filter and is discharged to the plant ventilation system of the auxiliary building and processed there along with other exhaust gases from the plant.

The Evaporator bottom bearing lubricant and the heating fluid have flash points higher than their operating temperatures. A CO_2 fire protection system is provided in the heating fluid system room. A water sprinkler system is provided in the drum filling room and the drum storage room. Fire control dampers are installed in the HVAC ducts.

12.2.3 Operating Experience

As of June 1979, the bituminization system had produced 168 drums of simulated waste product (inactive) and 62 drums of actual waste product (active).

The bituminized product has a residual water content of less than 1.0 wt % and a solids content of approximately 45 wt %.

The waste material is easily solidified. The Thin-Film Evaporator is stable in operation and has an evaporative capacity of over 200 liters of water per hour.

The Decontamination Factor is approximately 2200 as measured for boron.

No fires have been reported.

12.3 Tsuruga Nuclear Power Station

12.3.1 Background

Tsuruga is a 340 MWe GE BWR that went into commercial operation in March 1970. Tsuruga is owned and operated by Japan Atomic Power Company and is located on the Tsuruga Peninsula, Honshu Island, Japan. The original solidification system was cement. However, in the mid-1970's it was decided that a bitumen system would offer significant volume reduction of the evaporator concentrates waste. An SGN bitumen system using a Luwa Thin-Film Evaporator Model LN-0200 was ordered, installed and placed into operation in 1977.

12.3.2 Process Description[9]

The system is used to volume reduce and bituminize the large volumes of sodium sulfate wastes that are produced in the regeneration of deep bed demineralizers. The system is also used to solidify decontamination agents, laboratory chemicals, and laundry wastes.

Evaporator concentrates and other wastes are fed to the Luwa Evaporator simultaneously with straight-distilled bitumen. The water is evaporated and the solids are mixed with bitumen. The bituminized product is discharged into 200 liter drums set on a turntable. The Evaporator is heated by a thermofluid which is recycled through a resistance heater. The bituminized product discharges at a temperature of approximately 320°F into the drums. The system is very similar to the system installed at Mihama as shown in Figure 12-3.

12.3.3 Operating Experience

As of June 1979, the bituminization system had produced 166 drums of simulated waste product (inactive) and 84 drums of actual waste product (active).

12.4 Advanced Thermal Reactor (ATR), Tsuruga

12.4.1 Background

The ATR at Tsuruga is a light water cooled, heavy water moderated 200 MWe reactor which went into commercial operation in March 1979. It is an experimental power plant owned and operated by the Power Reactor and Nuclear Fuel Development Corporation (PNC), located on the Tsuruga Peninsula, Honshu Island, Japan. The SGN bituminization system was placed into operation in 1977 and then placed on standby until the reactor went into commercial operation.

12.4.2 Process Description

The wastes are primarily liquids consisting of equipment and floor drains. The system, which includes a Luwa Model LN-0200 Evaporator, is quite similar to the systems installed at the Mihama and Tsuruga power plants (Sections 12.2 and 12.3).

12.4.3 Operating Experience

As of June 1979, the bituminization system had produced 33 drums of simulated waste product.

12.5 Cadarache Nuclear Research Center

12.5.1 Background

Cadarache is a large CEA nuclear research center located in the south of France, about 50 miles north of Marseilles.

The French CEA began bitumen research in 1961 in Marcoule, France. In 1971, a Luwa Evaporator Model LN-0050 was installed at Marcoule and placed into pilot plant operation. In 1976, all bituminization research and development operations of the CEA were consolidated at the Cadarache Nuclear Research Center. At that time, the Luwa Evaporator Model LN-0050 was moved from Marcoule to Cadarache and its pilot plant bituminization use was continued there.

The Solid Waste Division at Cadarache is responsible for continuing research and development of the bituminization process as it applies to fuel reprocessing, research and power reactor wastes.

12.5.2 System Description

The facility at Cadarache is a pilot plant with tanks, pumps, heat exchangers and other equipment designed for maximum flexibility. The facility has complete hot sampling and analysis equipment for obtaining and analyzing waste samples. Instrumentation is provided to closely monitor process parameters.

The Luwa Evaporator installation is shielded so that active testing of wastes can be accomplished.

The system has been used to develop process controls for various waste types.

12.5.3 Operating Experience

Many different types of waste have been successfully bituminized and tested at Cadarache. The results of some of these tests are discussed in Section 13.1.

12.5.4 Planned Studies

A new Luwa Evaporator Model LN-0050 has been ordered for Cadarache and is to be delivered in January 1981. The design of this unit will permit testing of various rotor designs and will be used for optimization studies. In anticipation of the receipt of this unit, the existing Luwa Evaporator Model LN-0050 was removed from Cadarache in 1980 and transferred to the Monts d'Arree Nuclear Power Plant in Brennilis, in the province of Finistere, France for use in bituminization of power plant wastes (see Section 12.8).

12.6 Saclay Nuclear Research Center

12.6.1 Background

Saclay Nuclear Research Center, located east of Paris, France and operated by the CEA, is one of the three major nuclear research centers in France (Marcoule and Cadarache are the other two). At Saclay, there is a central treatment facility, designed and supplied by SGN, to collect and treat all radioactive liquids and slurries generated at the center. Part of that treatment facility is a bituminization system which was installed in 1975 and which includes a Luwa Model LN-0050. The bituminization system is not presently used for research studies at Saclay. Rather, its function is to volume reduce and bituminize the center's wastes on a production basis.

12.6.2 Process Description

The treatment facility consists of collection, storage and preparation tanks, a liquid waste evaporator or concentrator and a Luwa Thin-Film Evaporator system for solidifying liquids, evaporator concentrates, and sludge. The characteristics of the wastes vary but included are decontamination solutions, EDTA, acids, bases, phosphates, nitrates and solutions with high concentrations of chlorides and ammonia.

The Luwa Evaporator is constructed of a special alloy to resist corrosion.

12.6.3 Operating Experience

As of October 1980, more than 1000 drums (220 liter) of solidified product had been produced. Maximum activity per drum has been 25 curies and normal contact dose rate has been approximately 10 rad per hour.

The Luwa Evaporator is decontaminated by stopping waste feed and feeding only bitumen for a few minutes. Contact dose rates have been as low as 20 mrem per hour after use of this decontamination procedure.

12.7 Valduc Military Center

12.7.1 Background

Valduc is a large French military center primarily involved in military weapons production. In 1971 an SGN bituminization system was installed to collect, treat and solidify the center's wastes. The system includes a Luwa Evaporator Model LN-0050.

12.7.2 Operating Experience

Since 1971 the system has produced more than 2500 drums of bituminized product containing primarily alpha emitters. The chemistry of some of the wastes is classified, but sodium nitrate solutions and diatomaceous earth slurries are processed in the system.

12.8 Monts d'Arree Nuclear Power Station

12.8.1 Background

Monts d'Arree Nuclear Power Station, located in Brennilis in the Province of Finistere, France, is a 70 MWe gas cooled, heavy water moderated reactor that has been in operation since July 1967. The reactor was originally used by the CEA for research purposes. When research studies had been completed, the unit was placed into commercial operation and added to the network of Electricite de France (EDF).

The liquid waste produced by the plant, containing primarily phosphates and sodium nitrate, was stored in drums. By 1980 approximately 600 drums of waste had accumulated. The SGN bituminization system at Cadarache (see Section 12.5) was transferred to Monts d'Arree to process the accumulated waste.

12.8.2 Operating Experience

By October 1980 approximately 300 drums of bituminized product had been produced.

13. RESEARCH AND DEVELOPMENT

The development of bituminization from its initial concept into successfully operating systems has required extensive research and development on the part of numerous government agencies and private organizations worldwide. It is not the intent of this section to discuss all bitumen R&D efforts ever undertaken. Such an exercise is beyond the scope of this Topical. Rather, the intent here is to summarize recent studies that have contributed to current state-of-the-art bituminization. Should the reader desire to study a broader scope than that included here, a bibliography at the end of this section lists additional publications on bitumen research and development.

13.1 CEA

The organization contributing most to the development of bituminization into a viable, operating reality has been the French CEA. The CEA began its bitumen research in 1961 in Marcoule, France and continues its R&D efforts today at the Cadarache Nuclear Research Center. The Solid Waste Division at Cadarache is dedicated to the continuing research and development of the bituminization process.

For twenty years, the CEA has been involved with the laboratory study, industrial adaptation and implementation of the bituminization of low and medium activity radwastes.

The choice of the processes implemented has always been influenced by the desire to minimize the risks of exposing personnel to radiation during waste-conditioning operations, to minimize the chemical risks linked with the bituminization operation, and to ensure lasting and safe confinement of radioactive wastes, at the same time reducing their volume and weight.

These results have been sought and achieved by adopting continuous processes using proven materials which permit:

- Conditioning of wastes remotely without manual intervention.
- A very short heating and residence time for the products.
- Precise control of temperatures.
- The production of homogeneous encapsulated products.

Recent development studies[10] (undertaken since 1971) have been concerned with:

- The conditioning of liquid or solid wastes coming from the CEA's research centers.
- The conditioning of liquid or solid wastes produced by light water nuclear power stations (BWR as well as PWR) to meet the needs of electric utilities.
- Direct bituminization, without preconcentration, of wastes with low solids content coming from nuclear power stations as well as from nuclear research centers. These studies have been accomplished in the pilot installation of the Cadarache Center which is equipped with a Luwa LN-0050 Thin-Film Evaporator.
- Safety studies concerning wastes solidified by bitumen, including:
    - Leaching of the radioactivity in water (demineralized water, ground water, and sea water).
    - Thermal stability by gravimetric and differential thermal analysis of the wastes during the conditioning operation and at storage.

- Biological resistance with respect to attack by microorganisms for wastes buried in the ground.

These recent studies[10] are discussed in the following subsections.

13.1.1 Bituminization of Wastes from Nuclear Research Centers

The waste types, equipment and operating results of the three bituminization systems at Cadarache, Saclay, and Valduc are discussed in Sections 12.5, 12.6 and 12.7.

13.1.2 Bituminization of Wastes from Light Water Reactors

a. Boiling Water Reactors

Studies performed at the Marcoule Nuclear Research Center for perfecting the bituminization of BWR wastes were instrumental in the conception, construction and startup of the Barsebeck installation in Sweden (see Section 12.1).

A Luwa Thin-Film Evaporator Model LN-0050 performed the encapsulation of the following wastes:

- evaporator concentrates (mainly sodium sulfate solutions at 200 g/1) coming from ion-exchangers
- ion exchange resins, whole bead and ground
- filtration sludges (diatomates, "solka floc", etc.)

These various wastes were treated after mixing together and separately.

As an example, the encapsulated products coming from the solidification of these wastes using Mexphalte 40/50 bitumen had the following volumes in relation to the weight of solid content:

(1) Na_2SO_4 concentrates: 190 liters of encapsulated product for 100 kg of dry solid content (40 to 45 wt %).

(2) Whole bead Amberlite IRN 77 and 78 ion exchange resins: 230 liters of encapsulated product for 100 kg of dry solid content (40 to 50 wt %).

(3) Clarcel DIC 3 diatomates: 370 liters of encapsulated product for 100 kg of dry solid content (25 to 33 wt %).

(4) Mixture, 50 vol % Na_2SO_4 concentrates (200 g/l) and 50 vol % IRN 77 and 78 resins: 220 liters of encapsulated product for 100 kg of dry solid content (40 to 45 wt %).

(5) Mixture, 33.3 vol % Na_2SO_4 concentrates @ 200 g/l

33.3 vol % IRN 77 and 78 resins

33.3 vol % Clarcel DIC 3 diatomates:

225 liters of encapsulated product for 100 kg of dry solid content (36 to 40 wt %)

b. Pressurized Water Reactors

Studies performed at the Cadarache Nuclear Research Center for perfecting the bituminization of PWR wastes were used in the design and construction of the bituminization facility at Mihama Nuclear Power Station (see Section 12.2).

A Luwa Thin-Film Evaporator Model LN-0050 performed the encapsulation of the following evaporator concentrates:

- Concentrates at 200 g/l and 300 g/l of boric acid, neutralized with NaOH.

- Concentrates at 132 g/l of boric acid, 10 g/l of potassium chromate, 10 g/l of metallic oxides (iron, nickel, chrome, manganese, cobalt), 0.9 g/l of sodium chloride, neutralized with NaOH.

As an indication, solidified borate concentrates encapsulated in Mexphalte 40/50 bitumen had the following volume in relation to the weight of dry solid content: 190 liters of encapsulated product for 100 kg of dry solid content (40 to 50 wt %).

13.1.3 Direct Bituminization Without Preconcentration

Several active effluents have been solidified by direct bituminization in the Luwa Model LN-0050 pilot installation at the Cadarache Center:

- Spent effluents from the 310 MWe PWR located at Chooz, France, operated by the French-Belgian Society of Nuclear Energy of the Ardennes (SENA), containing 2.02 g/l of salts including 320 mg/l of boron, pH=9.2.

- Normal effluents coming from the Saclay Center, containing 2 g/l of salts, predominantly sodium phosphate, nitrate, chloride and sulfate, pH=6.6.

- Suspensions of saturated Amberlite resins extracted from the treatment unit of the decladding pools at La Hague Fuel Reprocessing Center, containing 10 g/l of a mixture of IRA 400 and IR 120 resins, pH=7.8.

a. Decontamination Factors of the Pilot Installation

When the waste is very dilute, a high percentage of the waste feed is evaporated in the Luwa Evaporator. This high evaporation ratio results in high vapor velocities, which in turn yield lower decontamination factors than for normal waste concentrations. Typical decontamination factors for the direct bituminization of the dilute wastes listed above are indicated in Table 13-1. Also shown for reference purposes are DFs for normal waste concentrations (greater than 10 wt % solids).

Table 13-1

DECONTAMINATION FACTORS
DIRECT BITUMINIZATION

Direct Bituminization	Bituminization, Normal Waste Concentration

b. Characteristics of the Distillate from Direct Bituminization

(1) Before treatment

Conductivity: 3 to 5 x 10^{-5} mho/cm

pH: 8.3 to 9.4 for the effluent solutions
7.4 to 8.2 for the resins

Organic content: 6 to 50 mg/l

(2) After treatment

pH: 6.8 to 7.5

Organic content: 1.5 to 4 mg/l

c. Characteristics of the Encapsulated Products

The encapsulated products of the direct bituminization of the wastes listed above had the following characteristics:

Actual Density:	1.38 to 1.57 for the effluent solutions
	1.23 for the resins
Water Content:	0 to 0.7 wt %
Bitumen Content:	50 to 60 wt %
Softening Point:	73 to 78°C

13.1.4 Safety Studies

a. Leaching

All the wastes solidified by bitumen during process studies and then produced on an industrial scale are tested in accordance with the leaching standards of the International Atomic Energy Agency.[1]

Leaching experiments in ordinary water on 150 to 200 l sludge blocks solidified by bitumen have been carried out at the Marcoule Center. After 1,800 days the fraction leached a/A was 8×10^{-4} and the leach rate was 2.5×15^{-6} cm/day in ordinary water, taking into account decay.

Laboratory leaching tests have also been carried out at the Cadarache Center. For all the wastes of the

Center (evaporation concentrates, various effluents, resins, chemical sludges), the average leach rates (expressed in cm/day) in demineralized water, of the encapsulated products, are as follows:

Cs 137: 10^{-5} to 10^{-8}

Sr 90: 10^{-5} to 10^{-7}

Ru 106: 10^{-5} to 10^{-6}

Co 60: 10^{-5} to 10^{-6}

Total gamma activity: 10^{-5} to 10^{-7}

Alpha emitters (Pu 238, Pu 239, Am 241, etc.): 10^{-5} to 10^{-7}

[redacted] These pretreatments decrease the leach rates of the target nuclides by a factor of from 5 to 100. With these pretreatments, leach rates are at the low end of the ranges listed above.

Leach tests have shown that straight distilled bitumen provides a higher leach resistance than blown bitumen.

See Section 3.7 for a more detailed discussion of leach test results.

b. Thermal Stability

At Cadarache, a gravimetric and differential thermal analysis has been made on most waste types which are likely to be solidified in bitumen.

This analysis makes it possible to detect abrupt exothermic reactions which may initiate fires. The test is intended to indicate the spontaneous combustion temperatures of the various wastes and to ascertain the thermal stability of the encapsulated products at various storage temperatures for a given period.

c. Radiation Resistance

Tests performed by the CEA have shown that the radiation resistance of blown bitumen is higher than that of straight-distilled bitumen. To prevent product degradation, the total irradiation level of the bituminized product should be limited to 10^8 rad for straight-distilled bitumen and 10^9 rad for blown bitumen. To assure operation within these limits, the specific activity of the product is limited to 1 curie/liter when using straight-distilled bitumen and 10 curies/liter when using blown bitumen.

d. Biological Resistance with Respect to Micro-organisms

Experiments involving the burial of laboratory samples of bituminized evaporator concentrates were conducted over 31 months starting in 1973. Samples were buried at a depth of 0.50 m in two different soils: some of the samples in a naturally drained grassland, the other ones in a marshy area, constantly damp and flooding for 5 months of the year. After 31 months of burial, microbiological examinations carried out on the buried samples could detect no action on the samples by the micro-organisms in these two types of soils (total bacteria, pseudomonas, denitrifying and sulfito-reductive bacteria).

In 1973, a study performed on bituminized concentrates in aerobic and anaerobic media revealed no special proliferation of germs on the surface of samples placed in pillars of sand where an intense bacterial culture had been developed.

13.2 Japan Atomic Energy Research Institute

The Japan Atomic Energy Research Institute, EBARA Inc., Kansai Electric Power Company, Power Reactor and Nuclear Fuel Development Corporation, and Japan Atomic Power Company have done considerable research, development and testing of active and inactive bituminized power reactor wastes. Almost half of the Japanese reactors are using, or plan to use, bitumen for solidification of radioactive wastes. The work has included process development associated with solidification of boric acid, incinerator ash, spent ion exchange resins, concentrated laundry wastes, chemical wastes, decontamination wastes, and concentrated regeneration wastes (sodium sulfate).

A number of different tests have been performed to determine physical properties of bituminized wastes. Some of these have included residual water content, penetrability, density, flash point, ignition temperature, and solid content in the product. Other tests[9] have included simulated pressure tests to determine if any deformation of drums containing waste occurred when subjected to 700 kg/cm^2 pressure. 200 liter drums withstood free-fall tests from heights of 4 and 6 feet onto a concrete slab. The packages retained their integrity after being subjected to these tests.

Extensive testing in Japan has confirmed that bituminization products and the bituminization process provide the most reliable and repeatable characteristics for volume reduction and waste disposal.

13.3 Atomic Energy of Canada, Limited (AECL), Chalk River, Canada

AECL began a research program in the mid-1970's to determine the best method of reducing the volume of CANDU reactor wastes. After an initial study, the decision was made to pursue research and development in bitumen.

AECL procured a Luwa Thin-Film Evaporator Model LN-0050 for testing and process development. To date, considerable work has been completed concerning bituminization of reverse osmosis concentrates and other radwaste solutions. The Luwa

Evaporator was chosen because of its versatility and competitive cost. Considerable work has been done on the unit to determine throughput rates, process temperatures and volume reduction factors. A number of different types of waste have been processed through the Luwa, including decontamination wastes and inorganic solutions.

Decontamination factors have exceeded 10^4 and have been insensitive to feed rate.

Tests have shown that the Luwa Evaporator can produce a high solids content waste product without operational difficulties. The results of such tests prompted AECL to procure two Luwa Model LN-0100 Evaporators to use at CANDU reactors. These units were ordered in late 1979 and delivered in October, 1980.

13.4 Brookhaven National Laboratory

The Nuclear Waste Management Research Group of the Brookhaven National Laboratory, Upton, New York, performed a study for the NRC of various radwastes solidified with cement and bitumen. Their findings were reported in two progress reports published in May 1978[2] and November 1978[4]. The highlights of these two reports, as they concern bituminized radwastes, are outlined below.

13.4.1 Progress Report No. 7[2]

The flash point and flame point of Pioneer 221 bitumen (Witco Chemical) were determined using the Cleveland Open Cup method. The bitumen had a flash point of $610 \pm 2^{\circ}F$ and a flame point of $668 \pm 4^{\circ}F$. Flash and flame points of three bituminized samples containing (1) water, (2) BWR chemical regenerative waste (sodium sulfate), and (3) boric acid waste were also determined. These samples were produced by a twin-screw vented extruder. The water sample contained approximately 0.5% water, 99.5% bitumen. The BWR chemical regenerative waste sample contained approximately 50 wt %

bitumen and 50 wt % solids (primarily Na_2SO_4). The boric acid waste sample contained approximately 50% bitumen and 50% solids (primarily neutralized boric acid). The samples containing water and sodium sulfate showed a small increase in the flash point (15-20°F) over that of the pure bitumen, but no effect in the flame point was noted. Flash point and flame point measurements could not be made on the boric acid waste sample due to foaming of the sample during heating.

Leach tests were performed on bituminized samples containing 17.5 to 44.3% sodium sulfate. The samples exhibited a tendency to swell, crack and break up during leach testing in distilled water and groundwater, due to the formation of sodium sulfate decahydrate. This degradation process exposed the salt to the leachant, so that after 7 to 14 days essentially all of the salt had been leached from the samples. (See Section 3.7 for a discussion of the pretreatments developed by the CEA to eliminate this degradation process and yield a highly leach resistance bituminized product.)

13.4.2 Progress Report No. 9[4]

Bituminized samples of neutralized boric acid were produced in a twin-screw vented extruder. These bituminized samples, which contained 30 to 36.1 wt % neutralized boric acid, were immersed in distilled water and groundwater. The leachant was sampled, analyzed for boron content, and replaced at 24-hour intervals. After 114 days of leach testing, the average leach rate, expressed as (cumulative fraction of boric acid released) x V/S ÷ time, was 1.47×10^{-3} cm/day, where V and S were the volume and surface area of the sample in cm^3 and cm^2, respectively. Leach rates in distilled water and groundwater were similar. (These leach rates are quite similar to those determined in studies performed by the CEA.[3] See Section 3.7 for a discussion of the CEA study and an analysis of what these leach rates mean in terms of actual leaching from production-sized samples.)

13.5 Bibliography of Additional Bitumen Research and Development

- Kenchington, J.M. et al., "An Evaluation of Liquid Radioactive Waste Treatment Systems for CANDU-PWH Reactors," Nuclear System Department, Ontario Hydro, Toronto, Canada, contributed by the Nuclear Engineering Division of the ASME for presentation at the Joint ASME/IEEE/ASCE Power Generation Conference, Dallas, Texas, September 10-14, 1978.

- Meier, G. and Bahr, W., "The Incorporation of Radioactive Wastes into Bitumen, Part I, The Bituminization Plant for Radioactive Evaporator Concentrates at the Karlsruhe Nuclear Research Center," KFK-2104, April 1975.

- Hild, W. et al., "The Homogeneous Incorporation of Eurochemic Medium Level Waste and High Enriched Waste Concentrate into Bitumen, A Review of the Development Work," September 1970

- Rodier, J. et al., "Coating of Evaporator Concentrates with Bitumen, Progress Report No.1," CEA-R-3632, 1968.

- Tabardel-Brian, R. et al., "Irradiation Testing of Bitumen and Bitumen Coated Products," CEA-R-3730, 1969.

- Rodier, J. et al., "Pilot Installation for Coating High Activity Concentrates with Bitumen," CEA-R-3734, 1969.

- Dejonghe, P. et al., "Insolubilization of Radioactive Concentrates for Embedding in Asphalt," EURAEC No. 695, 1964.

- Van de Voorde, N. and Dejonghe, P., "Insolubilization of Radioactive Concentrates for Embedding with Bitumen, Practices in the Treatment of Low and Intermediate Level Radioactive Wastes," Proc. Symp., IAEA, Vienna, 1965.

- Rodier, J. and Schneidhaeur, J., "Conditioning of Radioactive Wastes with Bitumen," CEA No. 1992, 1961.

- Rodier, J., Lefillatre, G., Estournel, R., "The Prospects of Bitumen as Coating Material for Radioactive Waste," Symposium on the Solidification and Long Term Storage of Highly Radioactive Wastes, Richland, Washington, February 14-18, 1966.

- Fernandez, N., "Bitumen Coated Products of the Sludge of Radioactive Effluent Treatment, Industrial Realization," Energie Nucleaire, 11,(6), 357, 1969.

- Rom, A.M., "Development of the Waste-Asphalt Process on a Semiworks Scale: Design and Installation of Evaporator Equipment in Building 4505," ORNL-TM-1637, 1966.

- Godbee, H.W. et al., "Laboratory Development of a Process for Incorporation of Radioactive Waste Solutions and Slurries in Emulsified Asphalt," ORNL-4003, 1967.

- Godbee, H.W. et al., "Development of a Process for Incorporation of Radioactive Waste Solutions and Slurries in Emulsified Asphalt," presented at American Chemical Society Meeting at Atlantic City, N.J., September 11, 1968.

- Goode, J.H. and Flanary, J.R., "Fixation of Intermediate - Level Radioactive Waste Concentrates in Asphalt, Hot-Cell Evaluation," ORNL-4059, 1968.

- Kluger, W. et al., "Fixing of Radioactive Residues in Bitumen," Karlsruhe Nuclear Research Center, Report KFK 1037, August 1969.

- Freese, H.L. and Gregory, W.T., "Volume Reduction of Liquid Radioactive Wastes using Mechanically Agitated Thin-Film Evaporators," Luwa Corporation, prepared for 85th National Meeting of American Institute of Chemical Engineers, Philadelphia, Pa., June 4-8, 1978.

- Oyen, L.C. and Tucker, R.F., Jr., "Low Level Waste Volume Reduction: Mechanical Systems," Sargent and Lundy Engineers, presented at the Waste Management 1980 Symposium, sponsored by the University of Arizona and U.S.D.O.E., Tucson, Arizona, March 10-13, 1980.

- Bourns, W.T. et al., "Development of Techniques for Radwaste Systems in CANDU Power Stations," Atomic Energy of Canada Research Company, Atomic Energy of Canada Limited, Chalk River Nuclear Laboratories, Chalk River, Ontario.

- Bonnevie-Svendsen, M. et al., "Studies on the Incorporation of Spent Ion Exchange Resins from Nuclear Power Plants into Bitumen and Cement," Joint Nordic Research Program, Paper IAEA - SM - 207/78, presented at the International Symposium on the Management of Radioactive Wastes from the Nuclear Fuel Cycle, Vienna, Austria, March 22-26, 1976.

- Sousselier, Y. et al., "Conditioning of Wastes from Power Reactors," CEA/SGN/GAAA, ANS Winter Meeting, San Francisco, California, November 11-16, 1973.

- Marillier, J.C., "Incorporation of Radioactive Wastes Into Bitumen," S.G.N., February 1970.

- Rodier, J. et al., "Solidification of Radioactive Sludge with Bitumen, Practices in the Treatment of Low and Intermediate Level Radioactive Wastes," IAEA, Vienna, 713, 1966.

- "Insolubilization of Chemical Precipitation Sludges with Bitumen," Installation of the Center of Plutonium Production at Marcoule, IAEA Technical Reports Series No. 82, 1968.

- Lefillatre, G. et al., "Utilization of a Thin Film Evaporator for Coating Radioactive Concentrates with Bitumen," CEA-R-3742.

- Hild, W. et al., "Bituminization of Radioactive Wastes at the Karlsruhe Nuclear Research Center - Experience from Plant Operation and Development Work," presented at the NEA Seminar on the Bituminization of Low and Medium Level Radioactive Wastes, Antwerp, May 18-19, 1976.

- Godbee, H.W. and Joy, D.S., "Assessment of the Loss of Radioactive Isotopes from Waste Solids to the Environment, Part 1: Background and Theory," ORNL-TM-4333, February, 1974.

- Bahr, W. and Kluger, W., "Bituminization of Radioactive Wastes at the Nuclear Research Center Karlsruhe," KFK-2119, presented at 1974 Winter Meeting of ANS, Washington, D.C., October 27-31, 1974.

- "Bituminization of Radioactive Wastes," Technical Reports Series No. 116, IAEA, Vienna, 1970.

- Eschrich, H., "The Bituminization of Radioactive Waste Solutions at Eurochemic," Eurochemic, Mol, Belgium, presented at Seminar on the Bituminization of Low and Medium Level Radioactive Wastes, Antwerp, Belgium, May 18-19,1976.

- Segawa, T. et al., "Review of the Research and Development Work and Experience on the Bituminization of Radioactive Wastes in Japan," presented at the Seminar on the Bituminization of Low and Medium Level Radioactive Wastes, Antwerp, Belgium, May 18-19, 1976.

- Tits, E., "Investigations on the Hazards Caused by Incorporating $NaNO_3$ and $NaNO_2$ into Bitumen," Industrial Development Laboratory Report No. 67, Royal Military School, Brussels, Belgium.

- Lefillatre, G. and Rodi, L., "Solidification of Liquid Waste of Medium Activity Using Bitumen, CEA-R-4378.

- Burns, R. and Clare, G. "Bitumen Incorporation - A.E.R.E. Operational Experiences," Atomic Energy Research Establishment, Harwell, Berkshire, United Kingdom, November, 1968.

- Demonie, M., "Commissioning and Start-up Tests of Eurochemic's Waste Bituminization Facility," Eurochemic, Mol, Belgium, presented at Seminar on the Bituminization of Low and Medium Level Radioactive Wastes, Antwerp, Belgium, May 18-19, 1976.

- Bernard, A. et al., "Long Term Leaching Tests on Life-Sized Blocks of Radioactive Wastes," CEA, Saclay, France, presented at the ORNL Conference on the Leachability of Radioactive Solids, Gatlinburg, Tennessee, December 9-12, 1980.

- Simpson, S. and Jessop, D., "Increasing Leach Resistance of Bituminized Evaporator Concentrates through Chemical Pretreatment," Associated Technologies, Incorporated, Charlotte, North Carolina, presented at the ORNL Conference on the Leachability of Radioactive Solids, Gatlinburg, Tennessee, December 9-12, 1980.

- Jessop, D. et al., "Volume Reduction and Bitumen Solidification of Radioactive Wastes at Barsebeck Nuclear Power Station, Associated Technologies, Inc., et al., prepared for 1979 Conference on Reactor Operating Experience, ANS, Arlington, Texas, August 6-8, 1979.

14. REFERENCES

1. Hespe, E.D., "Leach Testing of Immobilized Radioactive Waste Solids, a Proposal for a Standard Method," Division of Health, Safety and Waste Management, International Atomic Energy Agency, as printed in "Atomic Energy Review," Volume 9, No. 1, pp. 194-207, 1971.

2. Colombo, P. and Neilson, R.M., Jr., "Properties of Radioactive Wastes and Waste Containers, Progress Report No. 7," BNL-NUREG-50837, Nuclear Waste Management Research Group, Brookhaven National Laboratory, Upton, New York, published May 1978.

3. Lefillatre, G. et al., "Bituminizing of BWR and PWR Type Concentrates by Means of a Thin Film Evaporator Luwa L-150," Department of Chemical Applications and Analytical Studies, CEA, Cadarache, France, November 1979.

4. Colombo, P. and Neilson, R.M., Jr., "Properties of Radioactive Wastes and Waste Containers, Progress Report No. 9," BNL-NUREG-50966, Nuclear Waste Management Research Group, Brookhaven National Laboratory, Upton, New York, published November 1978.

5. "Regulations for the Safe Transport of Radioactive Materials, 1973 Revised Edition," IAEA Safety Standards, Safety Series No. 6, Section 120a (ii).

6. Marcus, F. et al., "Scandinavian Work on Disposal of Waste from Reactor Operation," Nordic Liaison Committee for Atomic Energy et al., Roskilde, Denmark, presented at the Waste Management 1980 Symposium, Tucson, Arizona, March 10-13, 1980.

7. Harfors, C., "Solidification of Low and Medium Level Wastes in Bitumen at Barsebeck Nuclear Power Station," Southern Sweden Power Supply, 1979.

8. Ikeoka, A. et al., "Bituminization of Radioactive Liquid Waste at Mihama Station (PWR)," Kansai Electric Power Company, presented at 1979 Annual Meeting of Atomic Energy Society of Japan.

9. Meguro, Y. et al., "The Performance of New Bitumen Solidification Facility at Tsuruga Power Station," Japan Atomic Power Company et al., presented at 1979 Annual Meeting of Atomic Energy Society of Japan.

10. Lefillatre, G., "The Conditioning in Bitumen of Low and Medium Level Activity Radwastes, French Experience," Department of Chemical Applications and Analytical Studies, CEA, Cadarache, France, 1977.

11. Arod, J., "Bituminous Conditioning of Radioactive Wastes, Safety Studies," CEA, Cadarache, France, presented at the ORNL Conference on the Leachability of Radioactive Solids, Gatlinburg, Tennessee, December 9-12, 1980.