REPORT NO. JGC-TR-001-NP-A

TOPICAL REPORT

THE DRUM MIXER PROCESS FOR VOLUME REDUCTION & SOLIDIFICATION

PREPARED FOR
U.S. NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555

NOVEMBER, 1981
REVISION1 - SEPTEMBER, 1983

JGC CORPORATION

NUCLEAR REPRESENTATIVE OFFICE
WASHINGTON, D.C. 20006

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Prepared for:

Office of Nuclear Reactor Regulation

Division of Standards and Special Projects Branch

U.S. Nuclear Regulatory Commission

Washington, D.C. 20555

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REVISION 1 - SEPTEMBER, 1983

by

JGC Corporation

Nuclear Representative Office

International Square 1875 Eye Street, N.W.

Washington, D.C. 20006

This revised report supersedes and replaces all earlier versions of the same numbered report.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

JUL 28 1983

Mr. Tomoyoshi Kagawa
General Manager
JGC Corporation
1875 Eye Street, N.W.
Washington, D.C. 20006

Dear Mr. Kagawa:

Subject: Acceptance for Referencing of Licensing Topical Report JGC-TR-001-P and JGC-TR-001-NP "The Drum Mixer Process for Volume Reduction and Solidification"

We have completed our review of the subject topical report submitted November 20, 1981 by JGC Corporation (JGC) letter. We find this report is acceptable for referencing in license applications for light water reactors to the extent specified and under the limitations delineated in the report and the associated (NRC) evaluation which is enclosed. The evaluation defines the basis for acceptance of the report.

We do not intend to repeat our review of the matters described in the report and found acceptable when the report appears as a reference in license applications except to assure that the material presented is applicable to the specific plant involved. Our acceptance applies only to the matters described in the report.

In accordance with established procedures (NUREG-0390), it is requested that JGC publish accepted versions of this report, proprietary and non-proprietary, within three months of receipt of this letter. The accepted versions should incorporate this letter and the enclosed evaluation between the title page and the abstract. The accepted versions shall include an -A (designating accepted) following the report identification symbol.

Should our criteria or regulations change such that our conclusions as to the acceptability of the report are invalidated, JGC and/or the applicants referencing the topical report will be expected to revise and resubmit their respective documentation, or submit justification for the continued effective applicability of the topical report without revision of their respective documentation.

Sincerely,

Cecil O. Thomas, Chief
Standardization & Special
Projects Branch
Division of Licensing

Enclosure:
As stated

TOPICAL REPORT EVALUATION

REPORT NUMBER: JGC-TR-001-P

REPORT TITLE: DRUM MIXER PROCESS FOR VOLUME REDUCTION AND SOLIDIFICATION

ORIGINATING ORGANIZATION: JGC CORPORATION

REVIEWED BY: METB, DSI, NRR
EG&G, IDAHO

SUMMARY OF REPORT

The report describes the design and operation of the JGC Corporation System (JGC), Drum Mixer Process for Volume Reduction and Solidification (DMP), which evaporates and combines wet radwastes (spent resin, evaporator bottoms, incineration ashes, etc.) with heated bitumen to obtain complete solidification and stable product for eventual offsite shipment to a licensed burial facility. In addition, the report describes process parameters and the system design features for developing and implementing a process control program to reasonably assure complete solidification of process wet radwaste and the absence of free water in the solidified products.

The principal findings in the report are: 1) the DMP System is capable of safely processing and solidifying wet radioactive wastes generated by light water reactors, 2) the acceptable process parameters and the system design features are provided for implementing a process control program to reasonably assure that the solid waste product is a homogeneous mixture of process waste in a bitumen binder and contains no free water, 3) there are no direct releases of radioactive material in liquid and gaseous effluents from the DMP System to the environment, 4) acceptable fire protection measures are recommended by JGC to their customers to be incorporated in all areas where asphalt and heating medium are used, and 5) the system design includes radiation protection measures to ensure that occupational exposure to personnel involved with the operation, maintenance and inspection of the DMP System is maintained as low as is reasonably achievable.

Any future license applications which reference the JGC-DMP System should include, in the Safety Analysis Reports, the information on 1) the types of process wet radwaste to be solidified, 2) the system process capacity comparing with design basis input waste volume, (3) plant interfaces with the DMP System, 4) type of bitumen to be used (straight, blown, etc.), 5) the applicant's own process control program based on the recommended DMP System process parameters, 6) the waste container to be utilized, 7) the plant fire hazards analysis information in accordance with CMEB Branch Technical Position 9.5-1, Rev. 2, dated July 1981 to show how safety related systems will be protected from possible fire associated with the combustibles contained in the JGC-DMP system, 8) the layouts and location of the DMP System equipment, and 9) any exceptions and/or deviations from the JGC Corporation Topical Report, JGC-TR-001-P, "Drum Mixer Process for Volume Reduction and Solidification," Rev. 1, dated March 16, 1983.

SUMMARY OF REGULATORY EVALUATION

In our evaluation of the JGC-DMP System, we have reviewed 1) the DMP System design description including piping and instrumentation diagrams, 2) the DMP method of operation, 3) the process parameters and the system design features to implement a process control program for the DMP System to reasonably assure that the proposed method of solidification is capable of solidifying the range of constituents expected to be present in the process wastes, 4) the DMP System quality group classification, 5) the quality assurance program for the design, construction, and testing of the DMP System, 6) the interfaces with other plant systems, 7) the DMP System design capacity in comparison with a standard 3400 MWt LWR design basis input waste volumes, 8) the fire protection measures recommended by JGC, and 9) the DMP System radiation protection design features to ensure occupational exposure is maintained as low as is reasonably achievable.

The DMP System utilizes a shell-type horizontal rotary drum mixer to provide volume reduction by evaporation while concurrently mixing the wet radwastes with a heated bitumen binder. The wet radwastes are metered into the drum mixer by an integrating automatic flow control valve, and brought into contact with the bitumen which is being agitated and heated to a temperature of 150-180°C. In the drum mixer, the water in the wet radwaste is evaporated, and at the same time, the resulting solid particles are uniformly mixed with the bitumen. The water is evaporated from the top of the drum mixer and condensed by the drum mixer condenser, and condensate is charged into the drum mixer distillate tank.

Noncondensible radioactive off-gases from the condenser are sent to the plant ventilation system via the off-gas cooler to remove water vapor in it, off-gas heater to control humidity, the HEPA filter to remove radioactive particulates, and then to the charcoal filter to remove radioiodines, all provided by JGC-DMP System. The steady state operation is continued until the required ratio of solid to bitumen is attained, in accordance with a process control program. Instrumentation is provided to control the temperature of the bitumen mixture in the drum mixer and heat transfer from heating medium (mineral oil) to the drum mixer. After attaining desired bitumen mixture in the drum mixer, the bitumen and radwaste mixture is discharged from the bottom of the drum mixer to a container (55 gallon drum) and cooled to become the stable product. The solidified product is a homogeneously dispersed mixture of radioactive solid in a bitumen matrix.

Complete solidification of wet radwastes are assured by the implementation of a process control program. The report establishes the various processing steps controls, and process parameters with boundary conditions within which the DMP System should be operated to assure complete solidification of wet radwastes. Major process parameters provided in the report include (1) preconditioning of wet radwastes (pH and solid content), (2) mixing ratio (solid/bitumen), and (3) operating conditions (feed rate, temperatures of bitumen, heating medium, and bitumen mixture).

The system design also provides appropriate instrumentation and wet radwaste sampling capability necessary for users to successfully develop and implement a plant specific process control program. Operating nuclear power stations (in Japan) utilizing the system process information and design features provided by JGC have successfully developed and implemented their process control programs and they have demonstrated assurance that they have achieved complete solidification of wet radwastes. We have reviewed the DMP System operating experience and operational data provided in the topical report and find them satisfactory. We consider, therefore, the DMP System has provided in the Topical Report adequate information and system design features for users to develop and implement a process control program to assure complete solidification of the variety of constituents expected to be present in the process wastes and the absence of free water in the solidified products.

The report defines the equipment normally furnished by JGC as a part of the DMP, the systems that will interface with the DMP System, and the equipment features (interlocks alarms, monitors, controls, etc.) which are required to be functional before processing of wet radwaste can commence. The DMP System scope of supply includes the following:

1) Waste feed system
2) Bitumen feed system
3) Evaporating/mixing system
4) Distillate recovery system
5) Heating medium system
6) Off-gas system
7) Drum handling system
8) Decontamination system
9) Control panel

The design, construction, quality group classification, and quality assurance provisions for the DMP System equipment are in accordance with Regulatory Guide 1.143, "Design Guidance for Radioactive Waste Management Systems Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants," Rev. 1, October

1979, and are therefore acceptable. The conformance of the seismic design criteria for the building that will house the DMP System will be reviewed for each individual application.

The DMP System will interface with 1) the plant service water system, 2) plant service air and electrical power systems, 3) plant ventilation system, 4) waste tank overflow connection, 5) dewatering outlet, 6) chemical reagents, and 7) the liquid radwaste (evaporation condensate) system. The DMP System has provisions both for interconnecting to the plant radwaste drains and to the ventilation exhaust system. Adequate interface information and requirements are provided in the topical report for users.

The system is capable of solidifying spent bead resins, filter precoat backwash, filter sludges, cellulose fibers, spent powdered resin, resin regeneration chemical wastes (sodium sulfate), boric acid evaporator concentrates, and incinerator ashes. The waste processing capacity of a DMP System is 150 ft^3 per week of wet wastes based on a 5 day/week and one-shift operation. This results in roughly 50 ft^3 of solidified waste average (depending upon the types of wet waste to be processed). Operation of 40 weeks per year will provide a processing capacity of 6,000 ft^3 of process waste per year for one-shift operation. If required, the system can be operated two shifts per day, 7 days/week, and 52 weeks/year by using more operators to increase the capacity to 21,840 ft^3/year of process wastes. We estimate that a 3400 MWt light water reactor will generate the following quantities of process wastes based on the licensees semi-annual reports to the NRC and normalized to 3400 MWt:

PWR Wet Wastes	ft^3	BWR Wet Wastes	ft^3
Deep bed	6,000	Deep bed	20,000
Pre-coat	10,000	Pre-coat	11,000
No condensate polishing system	5,500		

We conclude that the JGC-DMP System is adequate to handle the wet waste from a 3400 MWt LWR Power Plant except for a BWR with deep bed condensate cleanup system which may require two (2) trains of the DMP Systems to process wet radwastes depending on plant design basis input wet radwaste volume. Expected volume reduction factors of the JGC-DMP System for various process radwastes are as follows:

Type of Waste	VRF
Bead Resin	1.2
Powdered Resin	2.1
PWR Evaporator Concentrates	5.4
BWR Evaporator Concentrates	2.5

The radiation protection design features for the DMP System are consistent with the guidelines of Regulatory Guide 8.8, Rev. 2, "Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations will be As Low As Is Reasonably Achievable." Many of the design features incorporated in the DMP System are based on several years of operational experience in the nuclear plants. Waste container filling, capping, and decontamination operations are all performed remotely from a control panel. Overfilling the waste container is precluded by waste level sensor which provide a level alarm and automatic shutoff of the bitumen mixture flow at a predetermined fill level. The DMP System also has provisions to remotely cap and monitor the filled waste container for contamination.

JGC recommends installation of an automatic water spray system in all areas where asphalt and heating medium are used. We find this automatic water fire suppression system to be acceptable.

The DMP System is designed to minimize the accumulation and deposition of crud in system components. Pipe runs are designed to be as short as possible to minimize crud traps and blockage. All pipes and pump housings which have contact with radioactive wastes include valving and piping to permit complete flushing. These components are drained and flushed prior to maintenance work to minimize personnel exposure. These features are in accordance with those contained in Regulatory Guide 8.8 with respect to crud reduction to minimize personnel exposure.

The layout of the DMP System can be arranged such that all operations are controlled from the radwaste control area which will be located in a low radiation zone. Access to lower radiation areas where maintenance must be performed does not require passage through higher radiaton zones. Equipment is arranged to allow ease of component inspection and maintenance access. Valves not containing waste are located on a common valve rack and located in a low radiation area. All monitors associated with waste and drum handling are located external to the equipment, thus allowing for maintenance in low radiation zones.

REGULATORY POSITION

The JGC Topical Report, JGC-TR-001-P, Rev. 1. provides an acceptable basis for the following conclusions:

1) The JGC-DMP System can safely process solid wet radwastes at anticipated waste feed rates for 3400 MWt light water reactors.

2) The design, construction, quality assurance provisions and quality group classification of the JGC-DMP Systems are in accordance with Regulatory Guide 1.143, Rev. 1, October 1979, and Branch Technical Position ETSB 11-3, Rev. 2, July 1981.

3) JGC Corporation has provided in the Topical Report adequate information and system design features for users to develop and implement a process control program to reasonably assure complete solidification of process wet radwastes to meet the requirements of Branch Technical Position ETSB 11-3, Rev. 2, July 1981, and of waste form and characteristics set forth in 10 CFR Part 61.

4) JGC Corporation has recommended in the Topical Report an acceptable and adequate fire protection measures to be incorporated into the solid radwaste processing facility design.

5) The JGC-DMP System design features are consistent with the guidelines of Regulatory Guide 8.8 and intended to maintain radiation exposures as low as is reasonably achievable.

6) There are no direct releases of radioactive material in liquid and gaseous effluents from the operation of the JGC-DMP System.

Based on the information in the JGC Topical Reports, JGC-TR-001-P, Rev. 0, dated November 1981, and Rev. 1, dated March 16, 1983, and the JGC responses to our requests for additional information on the JGC Topical Report, Rev. 0, dated March 16, 1983, we find the JGC Topical Report JGC-TR-001-P, Rev. 1, acceptable. The reason for our acceptance is our conclusion that the applicant s design features are consistent with current guidelines of applicable regulatory guides, standard review plans, branch technical positions, and Federal regulations.

The capability of the plant radioactive waste treatment systems to meet the requirements of Appendix I to 10 CFR Part 50 is site dependent and will be evaluated for individual license applications. In addition, the packaging and shipping of all processed wastes in accordance with the applicable requirements of 10 CFR Part 71 and 49 CFR Parts 170-178 will be determined for individual license applications.

We conclude that JGC Topical Report, JGC-TR-001-P, Rev. 1, is acceptable for reference in future license applications for light water reactors. Any application incorporating this report by reference should include all deviations from this report.

ABSTRACT

The design and operation of a JGC Corporation DRUM MIXER PROCESS for volume reduction and solidification of low-level radioactive wastes generated in nuclear power plants is described in detail in this Topical Report.
The DRUM MIXER PROCESS utilizes a batch type horizontal mixer to provide volume reduction by evaporation while concurrently mixing the solid with a bitumen binder. The solidified product is a homogeneously dispersed mixture of radioactive solid in a bitumen matrix.

Chapter 2 gives the design basis of the DRUM MIXER PROCESS such as types of wastes to be treated and plant capacity.
Chapter 3 to 6 give detailed explanations of the process, process parameters, equipment and equipment layout of the DRUM MIXER PROCESS. Chapter 7 introduces all applicable regulations and guides according to which the specifications for the design and operation of the PROCESS have been determined. Chapter 8 explains JGC's quality assurance program. Chapter 9 to 11 describe research and development programs, operating experience, environmental impact and postulated accident analysis. Chapter 13 presents the answers to the questions given by NRC.

The following conclusions are obtained, based on the information presented in this Topical Report.

(1) The DRUM MIXER PROCESS is capable of solidifying low level wastes generated in PWR and BWR nuclear power plants, and achieves high volume reduction.

(2) Final products from the DRUM MIXER PROCESS conform to applicable guides and regulations.

(3) The DRUM MIXER PROCESS is designed and manuactured to minimize environmental impact during routine operation and maintenance, and during postulated accidents.

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CHAPTER 13

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1. INTRODUCTION

Low level radioactive wastes generated in nuclear power plants must be reduced in volume as much as possible and converted to solids having properties suitable for long term storage or land disposal.

JGC Corporation has taken up the radioactive waste volume reduction method using a bituminization process and has been proceeding with the development and commercialization of this process based on conditions such as the properties and volume of wastes to be treated. The major component of this process is a batch type horizontal mixer named DRUM MIXER.

The DRUM MIXER PROCESS has the following features:

(1) It is capable of accommodating many kinds of bitumen ranging from "Straight" to "Blown".

(2) It is capable of treating many kinds of wastes ranging from solution through sludge to powder.

(3) Cost of the equipment is relatively low.

(4) Optimum operating conditions that will produce a good quality product can be easily chosen.

(5) Decontamination can be easily attained by means of hot water and/or non-flammable solvent washing.

The basic principle of the DRUM MIXER PROCESS is as follows.

Wastes are brought into contact with heated bitumen in the DRUM MIXER, most of the water contained in the waste is evaporated, and radioactive solids are retained in the bitumen. The remaining solids assume the form of small particles and are uniformly dispersed throughout the molten bitumen. The bitumen mixture is then poured into a container (drum) and cooled to become the stable product.

The following wastes are solidified using the DRUM MIXER PROCESS.

(1) Evaporator concentrates composed mainly of sodium borate generated in PWR nuclear power plants.

(2) Evaporator concentrates composed mainly of sodium sulfate generated in BWR nuclear power plants.

(3) Spent ion exchange resins

(4) Incineration ashes

Since JGC delivered the first DRUM MIXER to the Japan Atomic Energy Reseach Institute in 1973, JGC has been conducting tests on bituminization using a bench-scale mixer, 50 l pilot plant, and a full-scale 200 l demonstration plant.
These tests have demonstrated that the satisfactory stable products can be obtained from the above wastes.
An evaporation capacity of 140 kg/hr can be obtained with the standard commercial plant with satisfactory allowances.

JGC with the assistance of International Energy Systems Corporation (IESC) of San Jose, CA, have had and are continuing to have technical and economic evaluation discussions with a number of major US utilities who are either operating or intend to operate nuclear power plants in the near future and who have expressed an interest in JGC's systems. It is expected that these discussions could lead to consideration of JGC's DRUM MIXER PROCESS for volume reduction and solidification of low-level radioactive wastes at several US nuclear power plants, and submittal through DOCKET file channels requests for NRC's evaluation, comments on and possible approval of JGC's DRUM MIXER PROCESS.

JGC with the assistance of IESC will commit its fullest resources to assure that its US operations will be able to adequately undertake the supply of any systems for which it may be selected to provide by US utilities and/or other US entities.

2. DESIGN BASIS

2.1 General

This covers the basic conditions used for establishing the basic design of the DRUM MIXER PROCESS, namely wastes to be treated in the PROCESS, and the amount generated per year, as well as the operating time and volume reduction factor in the case where wastes from PWRs and BWRs are treated in the PROCESS.

2.2 Wastes to be Treated

2.2.1 Types of Wastes

The wastes generated in a nuclear power plant can be largely classified into water-bearing sludge, evaporator concentrates, and solids.

The water-bearing sludge consists of powdered resin, bead resin, cellulose-based filter aids, and so on. The evaporator concentrate is a water solution composed mainly of sodium borate in PWRs and sodium sulfate in BWRs.
The solids consist of HEPA filter, activated charcoal, plastic, paper, wood, metal, rubber, and so on. If flammable solids included in the above are incinerated, they will appear in the form of ash.

Of the above wastes, the DRUM MIXER PROCESS can treat water-bearing sludge and evaporator concentrates, and can also treat the incineration ashes.

2.2.2 Volume and Radioactivity of Wastes

The characteristics of radioactive wastes from BWR and PWR nuclear power plants can be described within reasonable generic ranges, although they vary considerably between plants. The volume and radioactivity of the radwaste have been estimated and reported in several recent reports. The two most complete reports are WASH-1258 (Reference 1) and ERDA-76-43 (Reference 2).

ERDA-76-43 is a more recent document and also describes both reactors with deep-bed condensate cleanup and those with powdered resin condensate cleanup. Table 2-1 summarizes the expected annual volume and radio activity of the various waste streams (Reference 2).

Plants with deep bed condensate cleanup generate substantial volume of evaporator concentrates and small volume of resins. In case of plants with powdered resin condensate cleanup, the reverse is true.

2.2.3 Specific Activities

WASH-1258 provides an analysis by nuclide of the various waste streams. Thus, the nuclides species and their corresponding concentrations are summarized in Table 2-2 for the PWR wastes, and in Table 2-3 for the BWR wastes.

2.3 Plant Capacity

The operating time, number of drums generated, and the volume reduction factor in the case where the wastes generated in each 1,000 MWe plant are treated in the PROCESS are studied herein.

In this PROCESS, the water contained in the wastes is evaporated in heated bitumen. The amount of water to be treated is the most important factor in the determination of plant capacity. The operating time and number of drums generated are summarized in Table 2-4, and volume reduction factors are summarized in Table 2-5. The assumptions used in the calculation are set out below.

2.3.1 Assumptions for Plant Capacity

(1) Evaporation Rate

The evaporation rate of the standard DRUM MIXER is 140 kg/hr. This value enables the PROCESS to be operated under the most stable condition.

(2) Solidification agent — Straight asphalt

(3) Product container — 55 gallon drum (Net volume: 220 l)

(4) Mixing ratio (Solid/bitumen)

Evaporator concentrates	50/50
Incineration ashes	50/50
Spent resins	40/60

(5) Evaporator concentrates (PWR)

It is considered that 10 wt% of H_3BO_3 is neutralized with 25 wt% of NaOH and then poured into the bitumen. The form of the salts in the product is assumed to be $NaBO_2.1/2H_2O$.
The solid of 151 kg-dry can be incorporated in a 55 gallon drum.

(6) Evaporator concentrates (BWR)

The evaporator concentrate is assumed to consist of 25 wt% of Na_2SO_4.
The solid of 163 kg-dry can be incorporated in a 55 gallon drum.

(7) Bead resin
After simple dewatering, resin containing 60 wt% water is supplied to the PROCESS. The settled solid density of resin is assumed to be 380 kg-dry/m^3. The resin of 97 kg-dry can be incorporated in a 55 gallon drum.

(8) Powdered resin

Powdered resin is diluted to 10 wt% in water, and is fed to the PROCESS as a slurry. The settled solid density of the resin is assumed to be 210 kg-dry/m^3. The resin of 97 kg-dry can be incorporated in a 55 gallon drum.

(9) Incineration ashes

The solid of 165 kg-dry can be incorporated in a 55 gallon drum.

2.3.2 Volume Reduction Factor

There are various methods of defining the volume reduction factor. Here, it is defined as the ratio of the generation volume of wastes to the final product volume.

Volume Reduction Factor (VRF)

$$= \frac{\text{Generation volume of wastes } (m^3/yr)}{0.22\ (m^3/drum) \times (\text{number of drums}/yr)}$$

The volume reduction factors for bead resin, powdered resin and concentrated liquid waste are shown in Table 2-5.
The DRUM MIXER PROCESS can achieve high volume reduction compared with the conventional cementing process, and Table 2-6 shows the comparison of the volume reduction factors between the conventional cementing process and the DRUM MIXER PROCESS for each type of the waste to be treated.

Table 2-1 Volume and Radioactivity of Wastes

Type of Reactor	Waste	Generation Volume m^3	Radioactivity Ci	Radioactivity Ci/m^3
PWR with Powdered Resin Condensate Cleanup	Powdered Resin	93	5	0.054
	Bead Resin			
	(High)	8.5	5,500	650
	(Low)	11.3	25	2.2
	Evaporator Concentrate (10 wt% H_3BO_3)	17	5	0.018
PWR with Deep-Bed Condensate Cleanup	Bead Resin			
	(High)	8.5	5,500	650
	(Low)	25.5	27	4.9
	Evaporator Concentrate (10 wt% H_3BO_3)	310	10	0.032
BWR with Powdered Resin Condensate Cleanup	Powdered Resin			
	(High)	4.8	1,100	230
	(Low)	152	95	0.63
	Bead Resin	6	10	1.7
	Evaporator Concentrate (25 wt% Na_2SO_4)	0.14	1	7
BWR with Deep-Bed Condensate Cleanup	Powdered Resin	101	50	0.5
	Bead Resin			
	(High)	4.8	1,000	210
	(Low)	18.4	20	1.1
	Evaporator Concentrate (25 wt% Na_2SO_4)	280	5	0.018

Table 2-2 Radioactivity and Nuclide Composition of PWR Wastes*

(Ci/yr/reactor)

Nuclide	Clean Waste	Dirty Waste	Steam Generator Blowdown	Building	Total
(Corrosion and Activation Products)					
Cr-51	0.0049	0.26	0.036	0.00001	0.30
Mn-54	0.0015	0.044	0.0059	a	0.051
Fe-55	0.0085	0.23	0.032	0.00001	0.27
Fe-59	0.0035	0.14	0.019	0.00001	0.16
Co-58	0.065	2.3	0.31	0.00009	2.7
Co-60	0.010	0.28	0.038	0.00001	0.33
Np-239	a	0.073	0.015	a	0.088
(Fission Products)					
Rb-86	0.037	0.02	0.0030	a	0.062
Sr-89	0.0026	0.097	0.013	a	0.11
Sr-90	0.00010	0.0027	0.00036	a	0.0031
Sr-91	a	0.0016	0.0051	a	0.0067
Y-90	0.00011	0.0013	0.00002	a	0.0015
Y-91m	a	0.0011	0.0028	a	0.0039
Y-91	0.64	0.054	0.0008	a	0.69
Y-93	a	0.00004	0.00001	a	0.00005
Zr-95	0.00045	0.016	0.0022	a	0.019

Table 2-2 Radioactivity and Nuclide Composition of PWR Wastes* (continued)

(Ci/yr/reactor)

Nuclide	Clean Waste	Dirty Waste	Steam Generator Blowdown	Building	Total
Nb-95	0.00055	0.016	0.0021	a	0.018
Mo-99	0.029	0.61	0.012	a	0.65
Tc-99m	0.027	0.58	0.011	a	0.62
Ru-103	0.00028	0.012	0.0017	a	0.014
Ru-106	0.00011	0.0030	0.00041	a	0.0035
Rh-103m	0.00028	0.012	0.0017	a	0.014
Rh-106	0.00011	0.0030	0.00041	a	0.0035
Te-125m	0.00022	0.0080	0.0011	a	0.0094
Te-127m	0.0024	0.078	0.011	a	0.091
Te-127	0.0024	0.079	0.015	a	0.096
Te-129m	0.0077	0.36	0.050	0.00001	0.42
Te-129	0.0050	0.23	0.032	0.00001	0.27
Te-131m	a	0.14	0.044	0.00001	0.18
Te-131	a	0.025	0.0081	a	0.033
Te-132	0.00094	4.1	0.74	0.00020	4.9
I-130	a	0.014	0.021	0.00005	0.035
I-131	0.25	60	9.0	0.025	69
I-132	0.00097	4.3	0.85	0.00061	5.1
I-133	a	11	5.5	0.014	17
I-135	a	0.077	1.1	0.0020	1.1
Cs-134	32	7.1	0.97	0.00027	40

Table 2-2 Radioactivity and Nuclide Composition of PWR Wastes* (continued)

(Ci/yr/reactor)

Nuclide	Clean Waste	Dirty Waste	Steam Generator Blowdown	Building	Total
Cs-136	3.5	3.0	0.44	0.00012	7.0
Cs-137	23	5.0	0.68	0.00019	29
Ba-137m	22	4.7	0.64	0.00018	27
Ba-140	0.00098	0.11	0.016	a	0.12
La-140	0.0011	0.094	0.010	a	0.10
Ce-141	0.00037	0.018	0.0025	a	0.021
Ce-143	a	0.0029	0.00086	a	0.0038
Ce-144	0.00032	0.0093	0.0013	a	0.011
Pr-143	0.00015	0.015	0.0020	a	0.017
Pr-144	0.00032	0.0093	0.0013	a	0.011
All others	0.00002	0.00005	0.00003	a	0.00008
Total[b]	82	110	21	0.042	210

a: Nuclides not shown are less than 10^{-5} Ci/yr

b: Except tritium and dissolved noble gases. Tritium release is 350 Ci/yr/reactor.

*: Taken from WASH-1258, Table 2-39, Pages 2-137, 138 and 139.

Table 2-3. Radioactivity and Nuclide Composition of BWR Wastes*

(Ci/yr/reactor)

Nuclide	High Purity	Low Purity	Chemical	Total
(Corrosion and Activation Products)				
Na-24	0.0032	1.0	0.00006	1.0
P-32	0.00019	0.089	0.66	0.75
P-33	0.00069	0.33	3.8	4.1
Cr-51	0.0036	1.7	21.0	23
Mn-54	0.00034	0.17	3.3	3.5
Fe-55	0.013	6.2	130	140
Fe-59	0.0047	2.3	34	36
Co-58	0.025	12	200	210
Co-60	0.0029	1.4	29	30
Ni-63	0.00023	0.11	2.3	2.4
Nb-92m	0.00072	0.33	1.7	2.1
Sn-117m	0.00018	0.084	0.061	0.70
W-185	0.00011	0.052	0.88	0.93
W-187	0.013	4.6	0.014	4.7
U-237	0.00008	0.036	0.10	0.14
Np-239	0.0043	1.8	0.38	2.2
(Fission Products)				
Sr-89	0.024	11	180	190
Sr-90	0.0012	0.58	12	13
Sr-91	0.018	4.6	a	4.6
Y-90	0.0082	0.17	9.2	9.4
Y-91	0.20	1.1	0.79	2.1
Y-92	0.0095	0.20	a	0.21
Y-93	0.11	0.28	a	0.39

Table 2-3 Radioactivity and Nuclide Composition of BWR Wastes* (Continued)

(Ci/yr/reactor)

Nuclide	High Purity	Low Purity	Chemical	Total
Zr-95	0.00027	0.13	2.1	2.3
Zr-97	0.0023	0.074	0.00002	0.075
Nb-95	0.00023	0.11	2.3	2.5
Nb-97m	0.00022	0.071	0.00001	0.072
Nb-97	0.00023	0.075	0.00002	0.075
Mo-99	0.051	0.22	a	0.27
Tc-99m	0.049	0.21	a	0.26
Ru-103	0.00018	0.086	1.2	1.3
Ru-106	0.00005	0.025	0.50	0.53
Rh-103m	0.00018	0.086	1.2	1.3
Rh-105	0.00021	0.082	0.0027	0.085
Rh-106	0.00005	0.025	0.50	0.53
Te-127m	0.00005	0.023	0.42	0.44
Te-127	0.00016	0.053	0.42	0.47
Te-129m	0.00021	0.10	1.4	1.5
Te-129	0.00014	0.066	0.87	0.93
Te-131m	0.00067	0.25	0.0032	0.26
Te-131	0.00012	0.046	0.00059	0.047
Te-132	0.0062	2.7	1.5	4.3
I-130	0.00048	0.14	0.00001	0.14
I-131	0.037	17	640	660
I-132	0.0065	2.8	1.6	4.4
I-133	0.089	31	0.37	31
I-135	0.016	3.6	a	3.6
Cs-134	0.023	1.1	21	22
Cs-136	0.0080	0.38	2.3	2.7
Cs-137	0.016	0.77	15	15

Table 2-3 Radioactivity and Nuclide Composition of BWR Wastes* (Continued)

(Ci/yr/reactor)

Nuclide	High Purity	Low Purity	Chemical	Total
Ba-137m	0.015	0.72	14	14
Ba-140	0.040	19	130	150
La-140	0.019	11	150	160
Ce-141	0.00081	0.39	5.1	5.5
Ce-143	0.00080	0.31	0.0065	0.31
Ce-144	0.00015	0.072	1.4	1.5
Pr-143	0.00029	0.14	1.3	1.4
Pr-144	0.00015	0.072	1.4	1.5
Nd-147	0.00010	0.045	0.26	0.30
All others				
Total[b]	0.83	150	1600	1800

a: Nuclides not shown are less than 10^{-5} Ci/yr.

b: Except tritium and dissolved noble gases. Tritium release is 20 Ci/yr/reactor.

*: Taken from Wash-1258, Table 2-17, Pages 2-95, 96 and 97.

Table 2-4 Operating Time and Number of Drums for DRUM MIXER PROCESS

Type of Plant	Type of Waste	Amount of Radwaste: Volume (m^3/Y)	Amount of Radwaste: Amount of Solids (kg/Y)	Input to DRUM MIXER: Amount of Water (kg/Y)	Input to DRUM MIXER: Amount of Solid (kg/Y)	Required Annual Operating Time (hr)	Number of Drums per Year
PWR with Powdered Resin Condensate Cleanup	Bead Resin	19.8	7,524	9,029	7,524	65	78
	Powdered Resin	93	19,344	174,096	19,344	1,244	200
	Evaporator Concentrate	17	1,785	20,310	2,160	145	14
						Total 1,454	292
PWR with Deep Bed Condensate Cleanup	Bead Resin	34	12,920	15,504	12,920	111	134
	Evaporator Concentrate	310	32,550	370,350	39,400	2,645	261
						Total 2,756	395
BWR with Powdered Resin Condensate Cleanup	Bead Resin	6	2,280	2,736	2,280	20	24
	Powdered Resin	156.8	32,614	293,530	32,614	2,097	337
	Evaporator Concentrate	0.14	42	126	42	1	1
						Total 2,118	362
BWR with Deep Bed Condensate Cleanup	Bead Resin	23.2	8,816	10,579	8,816	76	91
	Powdered Resin	101	21,008	189,072	21,008	1,351	217
	Evaporator Concentrate	280	84,000	252,000	84,000	1,800	516
						Total 3,227	824

Table 2-5 Volume Reduction Factor of DRUM MIXER PROCESS

Type of Waste	VRF
Bead Resin	1.2
Powdered Resin	2.1
PWR Evaporator Concentrates	5.4
BWR Evaporator Concentrates	2.5

Table 2-6 Comparison of Volume Reduction Factor between Conventional Cementing Process and DRUM MIXER PROCESS

Type of Waste	Cement	DRUM MIXER	DRUM MIXER / Cement
Bead resin	0.5	1.2	2.4
Powdered resin	0.5	2.1	4.2
PWR evaporator concentrates	0.5	5.4	10.8
BWR evaporator concentrates	0.5	2.5	5.0

IMAGE EVALUATION
TEST TARGET (MT-3)

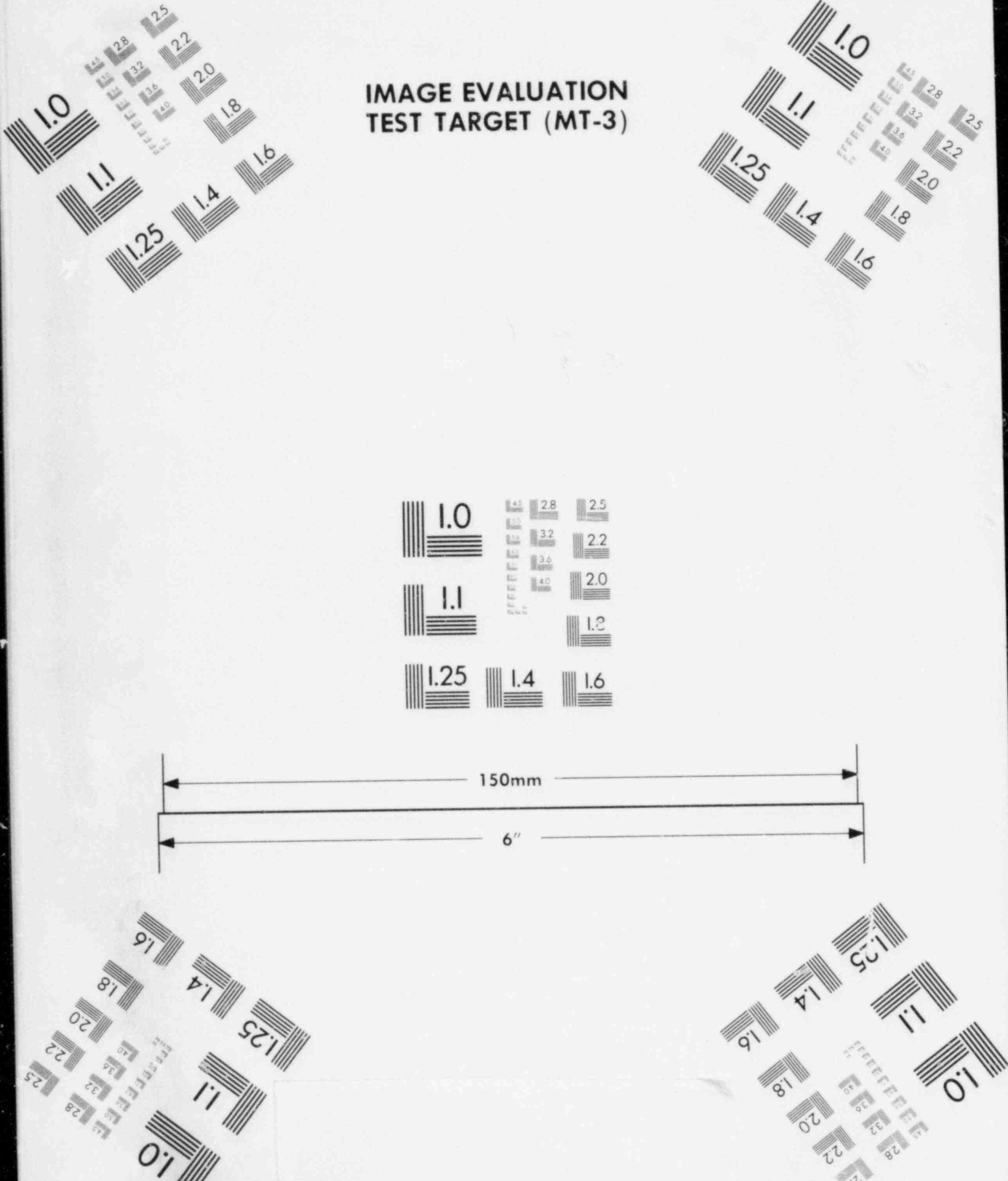

IMAGE EVALUATION
TEST TARGET (MT-3)

150mm

6"

3. PROCESS DESCRIPTION

3.1 General

Basic composition of the DRUM MIXER PROCESS is as shown on Figure 3-1.

The DRUM MIXER PROCESS mainly consists of the following systems.

(1) Waste feed system

(2) Bitumen feed system

(3) Evaporating/Mixing system

(4) Distillate recovery system

(5) Heating medium system

(6) Off-gas system

(7) Drum handling system

(8) Decontamination System

Outline of DRUM MIXER PROCESS is explained below.

One batch of bitumen is charged to the DRUM MIXER which is the major equipment of this process.

Then, radwastes are supplied to the DRUM MIXER in which the bitumen is being agitated at an elevated temperature.

In the DRUM MIXER, the water in the radwaste is evaporated and at the same time the resulting solid particles therein are uniformly mixed with the bitumen.

After the required cummulative amount of the liquid waste has been charged and evaporated, the mixture of fine solid radwaste and bitumen is discharged from the DRUM MIXER and directly poured in drums.

Thus, radwaste can be solidified into highly volume-reduced products.

The process flow is explained below, referring to Fig. 3-2 P & ID.

3.2 Feed System

3.2.1 Waste

(1) Evaporator Concentrate

Evaporator concentrate, which requires sampling and pretreatment by reagent, is sent to the Liquid Waste Feed Tank (T-1). An agitator is used to perform accurate sampling and pretreatment and also to maintain uniform liquid supply. The liquid waste feed valve controls the flow rate of concentrated liquid waste in order to keep the required temperature of bitumen in the DRUM MIXER.

In order to obtain the pre-determined salt/bitumen ratio of the products, the volume of one batch of liquid waste is preset by means of the integrating flowmeter.

The temperature of the wastes holding in the piping and equipment is held at adequate temperature by electrical heating to prevent from crystallization.

(2) Spent Resin

Spent resin slurry is sent to the Resin Slurry Dewaterizer (M-9) from the spent resin tank, where, the spent resins are dewatered and supplied to the DRUM MIXER by using the Resin Feeder (P-9). Other dewatering equipment (e.g. centrifuge) are also applicable.

The rate of supplying spent resins to the DRUM MIXER is controlled by the Resin Feeder (P-9) to ensure uniform mixing.

(3) Incineration Ash

Incineration ash is charged to the Ash Hopper (T-8) from the ash transportation drum. The received ash is supplied to the DRUM MIXER through Ash Feeder (P-8), by which the feeding rate is also controlled to ensure uniform mixing with bitumen in the DRUM MIXER.

3.2.2 Bitumen

(1) Bitumen is received into the Bitumen Tank (T-3) by means of a tank truck, etc. and is stored in a molten state. Therefore, Bitumen Tank (T-3) is provided with steam coils at the bottom for heating.

(2) When operating the DRUM MIXER, one batch of the bitumen is first charged by Bitumen Feed Pump (P-3) to the DRUM MIXER which has been already heated by heating medium to a temperature of 130°C. Pipings are steam traced to keep the temperature at 130°C.

3.2.3 Antifoaming Reagent

The antifoaming reagent is put into the Antiforming Tank (T-7). When a concentrated liquid waste is vaporized upon being mixed with bitumen, sometimes it foams over. To obtain a stable bituminized product and to reduce the entrainment, it is necessary to annihialate such foam by adding an antiforming reagent.

3.3 Evaporating/Mixing System

Evaporating/mixing operations are accomplished by the DRUM MIXER. As shown in Fig. 5-1, the DRUM MIXER is of shell type with heating jackets and a horizontal rotary mixing drum.

In the DRUM MIXER, wastes are brought into contact with heated bitumen, and the salt and solid in wastes is dispersed throughout the molten bitumen. Accordingly, evaporation and mixing are simultaneously accomplished by the DRUM MIXER. The following are the procedure for the evaporating/mixing operations:

(1) The heating medium is further heated up to 230-260°C, and liquid waste is fed when the temperature of bitumen within the DRUM MIXER has reached 150 - 180°C. The feed rate of liquid waste is regulated automatically by control valve to keep the temperature of bitumen in the DRUM MIXER at a constant value.

(2) After the temperature of heating medium, that of bitumen in the DRUM MIXER, and the feed rate of liquid waste have become a predetermined constant value respectively, steady state of the operation is kept. Of the above-mentioned three parameters, if two are pre-set, the rest is automatically controlled.

(3) The steady state operation is continued until the required ratio of solid components (salts) to bitumen is attained. The required amount of liquid waste per batch is calculated based on the solid content in the liquid waste.

(4) The water is evaporated from the top of the DRUM MIXER and condensed and subcooled by Condenser (M-1) and then is charged into the Distillate Tank (T-4). The decontaminatin factor (DF) of about 1,000 is attainable.

(5) After evaporating/mixing operation for hours, the sequence of the heating medium system is changed from heating to cooling. Due to this operation the temperature of the products in the DRUM MIXER is lowered and then the product is discharged from the bottom of the DRUM MIXER into an empty drum which is supplied by the conveyor unit.

3.4 Auxiliary Systems

3.4.1 Distillate Recovery System

The water vapor arising from the DRUM MIXER is sent to the Condenser (M-1) to be condensed and subcooled. Then the distillate or condensate is stored at the Distillate Tank (T-4). The distillate in the Distillate Tank (T-4) is sent to the Oil Separator Unit (M-5) by using the Distillate Pump (P-4) to remove the entrained oil.

The recovered oil free condensate is sent to the plant. The oil content of the condensate is periodically analyzed and if the oil content of the condensate exceeds the specified value, it is circulated again to the Oil Separator Unit (M-5) for further oil removal.

3.4.2 Drum Handling System (M-7)

(1) An empty drum is loaded onto the drum conveyor at the empty drum loading point and conveyed to the drumming point by remote control.

(2) After completion of drum filling, the drums are conveyed to the capping point and capped. Then, they are transferred to the drum storage area and stored there for the prescribed period. The series of drum handling work such as conveyance, capping, storage, etc., is remotely controlled.

3.4.3 Off-gas System

Off-gas evacuated from the Condenser (M-1) and Liquid Waste Feed Tank (T-1), is sent to the Off-gas Cooler (M-13) to remove water vapor in it. Off-gas from which water vapor has been removed is dried by the Off-gas Heater (M-4) and are sent to the ventilation exhaust system by the Off-gas Fan (P-13) through the Off-gas Filter (M-14) which consists of the HEPA filter and the activated chacoal.

3.4.4 Heating Medium System

(1) The DRUM MIXER is heated by the heating medium. In general, mineral oil is used as the heating medium. The properties of a typical heating medium are shown in Table 3-1. The heating medium is heated up to 250°C by electric heaters (Heating Medium Heater (M-2)) and circulated in the rotor and jacket of the DRUM MIXER in order to heat the bitumen and to allow water in the waste to vaporize.

Circulation is done by the Heating Medium Circulation Pump (P-6).

(2) In the upper part of the system, a Heating Medium Surge Tank (T-6) is provided to absorb thermal expansion due to an increase in temperature of the heating medium.

(3) A Heating Medium Storage Tank (T-5) is provided to collect the dumped heating medium in the system. When restarting, the heating medium is sent therefrom into the sytem by the Heating Medium Feed Pump (P-5).

In case of emergency, the Heating Medium Storage Tank (T-5) is also used for the purpose of dumping the heating medium inside the system to maintain safety inside the system.

Further, the gaseous phase of the Heating Medium Surge Tank (T-6) and Heating Medium Storage Tank (T-5) is replaced and sealed with N_2 gas.

(4) The Heating Medium Cooler (M-3) is provided to allow forced cooling of the bitumen mixtures in the DRUM MIXER after completion of evaporation and mixing. To start the cooling operation, the flow of the heating medium is switched automatically from the heating side to the cooling side.

3.4.5 Decontamination System

(1) It is not necessary to decontaminate the DRUM MIXER after each operation thereof. At the time of maintenance of the DRUM MIXER, cleaning and removal of contaminant are performed by using a mixture of organic solvent and water. The solvent in the Solvent Tank (T-10) is charged to the DRUM MIXER by the Solvent Feed Pump (P-11). Water is supplied to the DRUM MIXER through a service water line or some other pipings.

(2) Simultaneously with the cleaning of the DRUM MIXER, the solvent and water are vaporized and condensed at the Condenser (M-1). Such condensate is circulated to the DRUM MIXER. During this operation, the inside of the DRUM MIXER and the Condenser (M-1) are decontaminated. After decontamination, decontamination liqud waste is discharged to a drum.

3.5 Process Monitoring and Sampling

The following monitoring and sampling are carried out regularly. When the radioactive level exceeds the specified value, an alarm is issued in the control room, requiring the operators to take necessary action.

(1) An iodine sampler is installed after the Off-Gas Filter (M-14) to measure the radioiodine concentration regularly.

(2) An off-gas monitor is installed at the exhaust outlet of the DRUM MIXER PROCESS to monitor radioactive gas in the off-gas.

(3) The surface dose of drums containing solidified products is monitored.

(4) The surface contamination of drums is surveyed.

3.6 Control Systems

3.6.1 Instrumentation and Control

The DRUM MIXER PROCESS is controlled remotely and automatically from the control panel. The instrumentation list for major control system is shown in Table 3-2.
The main control functions in normal operation are as follows:

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3.6.2 Interlock and Alarm

The DRUM MIXER PROCESS is interlocked to prevent mechanical damage, to maintain proper operating sequence, and to ensure safety. Major safety interlocks are provided for overflow in liquid tanks, ignition of heating medium, and leaks in equipment or lines. Especially, for ignition of the heating medium, the following interlocking and/or alarming systems are provided to ensure protection against fire;

(1)

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3.7 Design and Operating Conditions

The provision of the following design and operating conditions for the standard DRUM MIXER PROCESS will enable ideal mixing and evaporation for a wide range of radioactive wastes, thereby ensuring a product of suitable properties.

(1)	Evaporation rate	140 kg/hr
(2)	Mixing ratio (Solid/bitumen weight ratio)	40/60 to 50/50
(3)	Heating medium temperature	220 to 260°C
(4)	Evaporating/mixing temperature	150 to 180°C
(5)	Roter speed	60 rpm

3.8 P & I D

Typical piping and instrumentation diagram of the DRUM MIXER PROCESS is shown in Figure 3-2.

Table 3-1. Properties of Heating Medium

Flash point	263°C
Latent heat	313 kcal/kg
Density at 260°C	720 kg/m^3
Thermal conductivity at 260°C	0.0975 kcal/m hr°C
Heat capacity at 260°C	0.67 kcal/kg°C
Heat of combustion	10,000 kcal/kg
Chemical composition	H = 12 wt%
	C = 85 wt%
	S = 3 wt%

Table 3-2. Instrumentation List

System	Item	Equipment or Line
Waste feed system	LIS	Liquid Waste Feed Tank (T-1)
	FS	Reagent Feed Line
	FIC	Liquid Waste Feed Line
Bitumen feed system	LIS	Bitumen Tank (T-3)
	TIS	Bitumen Tank (T-3)
	FIS	Bitumen Feed Line
Evaporating/mixing system	TIC	DRUM MIXER (M-8)
Distillate recovery system	LIS	Distillate Tank (T-4)
Heating medium system	TIC	Heating Medium Circulation Line
	LS	Heating Medium Surge Tank (T-6)
Drum handling system	LS	Drum
	WIS	Drum
Decontamination system	LIS	Solvent Tank (T-10)
	FS	Solvent Feed Line

Note: L = Level F = Flow-rate T = Temperture

W = Weight I = Indicator C = Control and Switch

S = Switch .

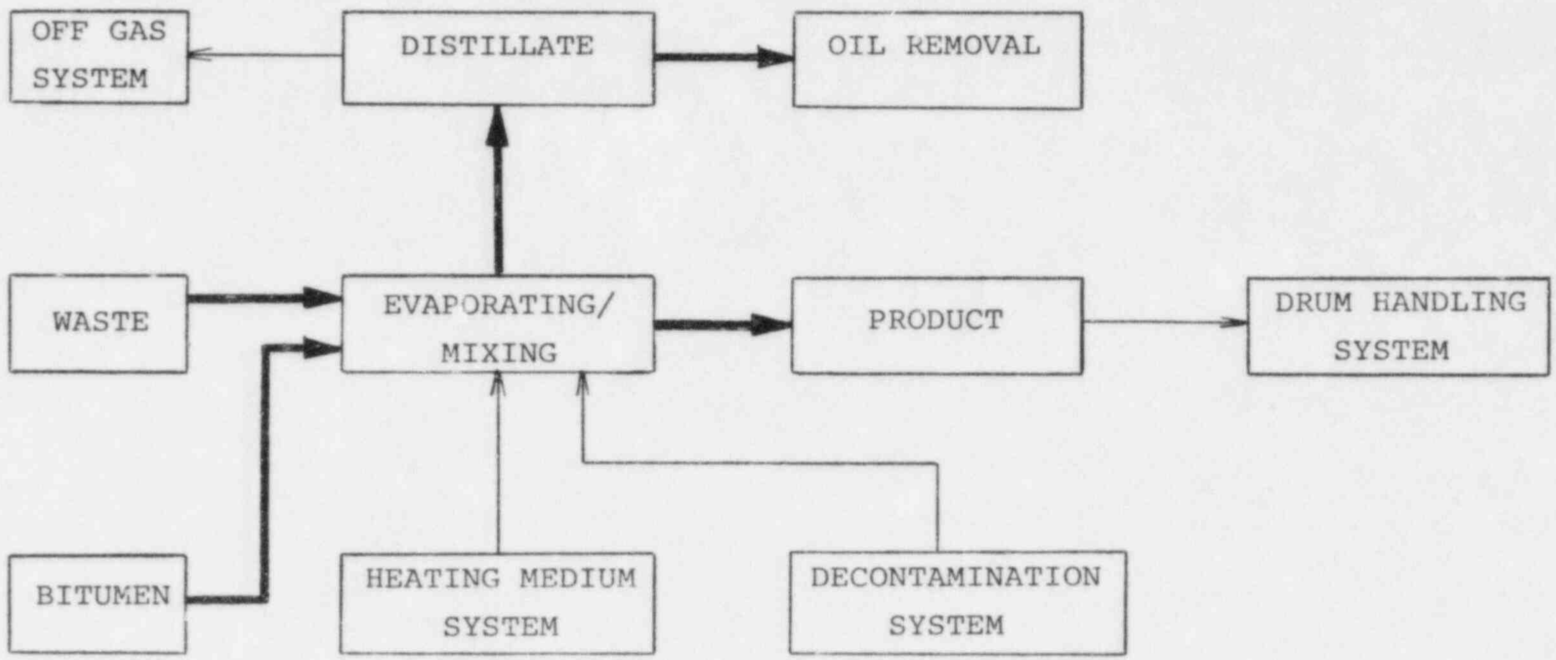
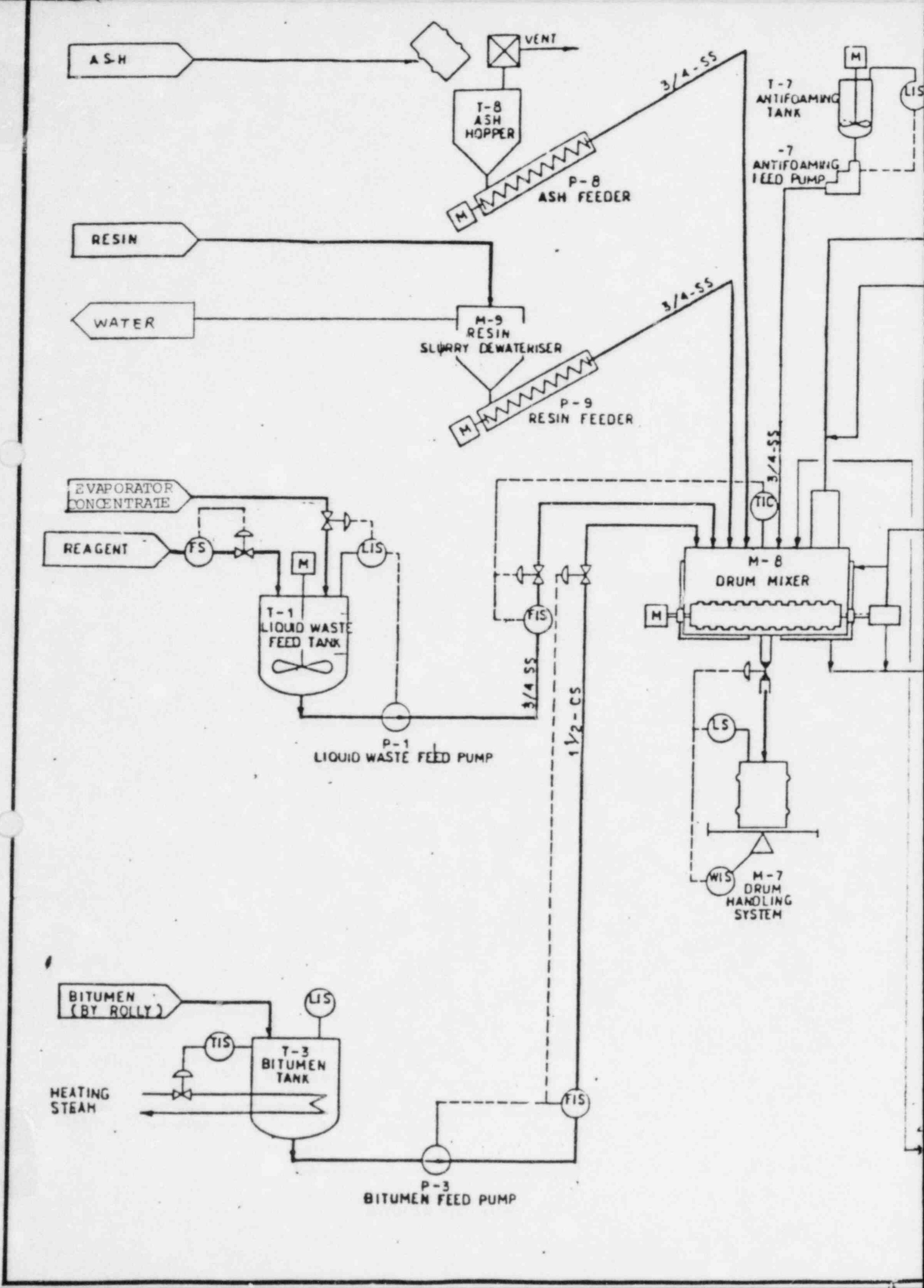


Fig. 3-1 Basic Composition of DRUM MIXER PROCESS



ASH
VENT
T-8
ASH
HOPPER
3/4-SS
T-7
ANTIFOAMING
TANK
LIS
-7
ANTIFOAMING
FEED PUMP
M
P-8
ASH FEEDER
RESIN
WATER
M-9
RESIN
SLURRY DEWATERISER
3/4-SS
P-9
RESIN FEEDER
EVAPORATOR
CONCENTRATE
REAGENT
FS
LIS
T-1
LIQUID WASTE
FEED TANK
3/4 SS
FIS
TIC
3/4-SS
M-8
DRUM MIXER
1 1/2 - CS
P-1
LIQUID WASTE FEED PUMP
LS
WIS
M-7
DRUM
HANDLING
SYSTEM
BITUMEN
(BY ROLLY)
LIS
TIS
T-3
BITUMEN
TANK
HEATING
STEAM
FIS
P-3
BITUMEN FEED PUMP

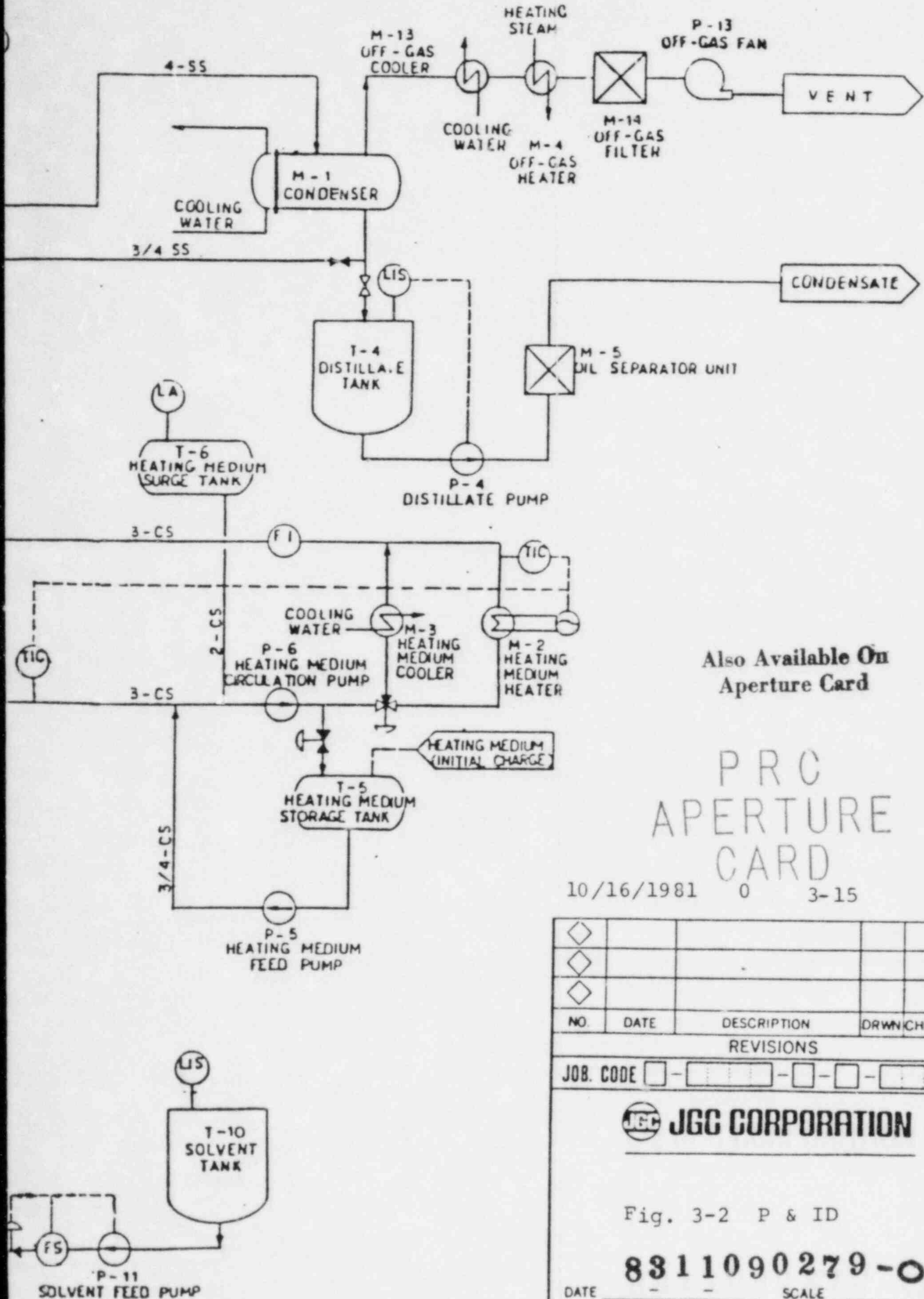


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Fig. 3-2 P & ID

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4. PROCESS PARAMETER

4.1 Process Control Program

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4.2 Feed Characteristics

The DRUM MIXER PROCESS is widely applicable to the treatment of many kinds of wastes such as evaporator concentrates, spent ion-exchange resin and incineration ash, etc.

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4.3 Solidification Binder

Bitumen is used as the solidification binder in the DRUM MIXER PROCESS.

Solidification binders for radioactive wastes must be:

(1) Capable of capturing radwastes,

(2) Highly impervious to water and very durable,

(3) Easy to handle

(4) Available with ease, etc.

Considering these requirements, bitumen possessing the following features can be selected as one of the most suitable solidification binders.

(1) Changable from molten state to semi-solid or solid state with temperature.

(2) Capable of withstanding considerable deformation.

(3) Adhesive

(4) Highly impervious to water

(5) Comparatively cheap

Commercial asphalt can be roughly divided into two groups, namely, straight and blown asphalt. Either asphalt is usable in the DRUM MIXER PROCESS. The physical properties of typical straight and blown asphalts are shown in Table 4-1.

4.4 Product Properties

Safety of the bitumen packages must be maintained under the conditions of their storage, transportation and disposal.

The properties of bituminized products vary according to the following various factors:

(1) Types of wastes to be treated

(2) Types of bitumen

(3) Mixing ratio (Solid/bitumen ratio)

(4) Operating conditions

  (a) Temperature history

  (b) Mixing conditions

The bituminizing process conditions under which products of the desired properties can be obtained must be confirmed experimentally by investigating the effects of above factors on the properties of the product.

With the assistance of Japanese utilities and research laboratories, JGC has been conducting such researches and experiments for more than ten years, accumulating various data.
The properties of products usually taken up are as follows:

(1) Specific gravity

(2) Softening point

(3) Flash point

(4) Residual water content

(5) Leaching rate

(6) Swelling tendency

Examples of pilot plant operating conditions and product properties are shown in Table 4-2 under the classification of radwaste types.

Generally speaking, the following tendencies have been found with individual products:

(1) Specific gravity

Following values are obtained:

Waste	Mixing Ratio	Specific Gravity
PWR concentrates	50/50	1.37
BWR concentrates	50/50	1.48
Spent resins	40/60	1.10
Incineration ashes	50/50	1.50

Rerationship between specific gravity and mixing ratio for borate waste is shown in Figure 4-1.

(2) Softening point

The softening point of the raw bitumen has a decisive effect on that of the product. Straight 40/60 asphalt gives a product with a softening point of 50°C to 60°C (Fig. 4-2). Higher softening points can be obtained using blown asphalt.

(3) Flash point

Flash points of 330°C or higher can be obtained with straight 40/60 asphalt (Fig. 4-3). Slightly lower flash points are obtainable with blown asphalt.

(4) Residual water content

Residual water of 1.0% or lower is easily attainable in case of evaporator concentrates. For spent resins, a finishing period of about an hour is required after mixing to obtain a residual water content of less than 1.0%, however, there is no free water in the product produced by DRUM MIXER PROCESS.

(5) Swelling and leaching tendencies in water

The correlation between the bituminizing process conditions and the swelling tendency of the product is very complex and is presently an item of study. No swelling tendency is observable with solid/bitumen = 40/60 product during 200 days as shown in Figure 4-4.

The observed leaching rate values of 10^{-3} to 10^{-5} g/cm^2.day are considered to be better than that of cement products by a factor of some 10 to 100.

Figure 4-5 shows the leaching rate over a period of 300 days.
While these values are based on the results of measuring the leaching rate of Na which is non-radioactive, similar values are expected in the case of radioactive Cs. (Reference 4)

Table 4-1. Properties of Bitumen

		Straight 40/60	Blown 20/30
Penetration	(0.1 mm)	51	22
Softening point	(°C)	52.6	87
Specific gravity	(25/25°C)	1.03	1.03
Evaporation loss	(163°Cx5hr, wt%)	0.06	0.01
Penetration after evaporation (%)		106	90.9
Viscosity (cSt)	140°C	430	5000
	160°C	180	1000
	180°C	90	350

Table 4-2. Properties of Bituminized Products (Pilot Plant)

Waste	Sodium Sulfate	Sodium Borate	Ion-Exchange Resin
Operating conditions			
Bitumen	Straight 40/60	Straight 40/60	Straight 40/60
Mixing ratio (Solid/Bitumen)	50/50	50/50	56/44
Mixing temperature (°C)	170	180	150
Mixer rotation rate (rpm)	120	120	60
Product Properties			
Specific gravity	1.476	1.372	1.146
Penetration (0.1 mm)	27	11	20
Softening point (°C)	70.5	81.0	64.0
Residual water content (wt%)	0.05	0.2	0.53
Leaching rate* ($g/cm^2 \cdot day$)	$2x10^{-3}$	$1.3x10^{-3}$	-

Notes: *: Leaching rate with regard to Na^+ at one week is indicated.

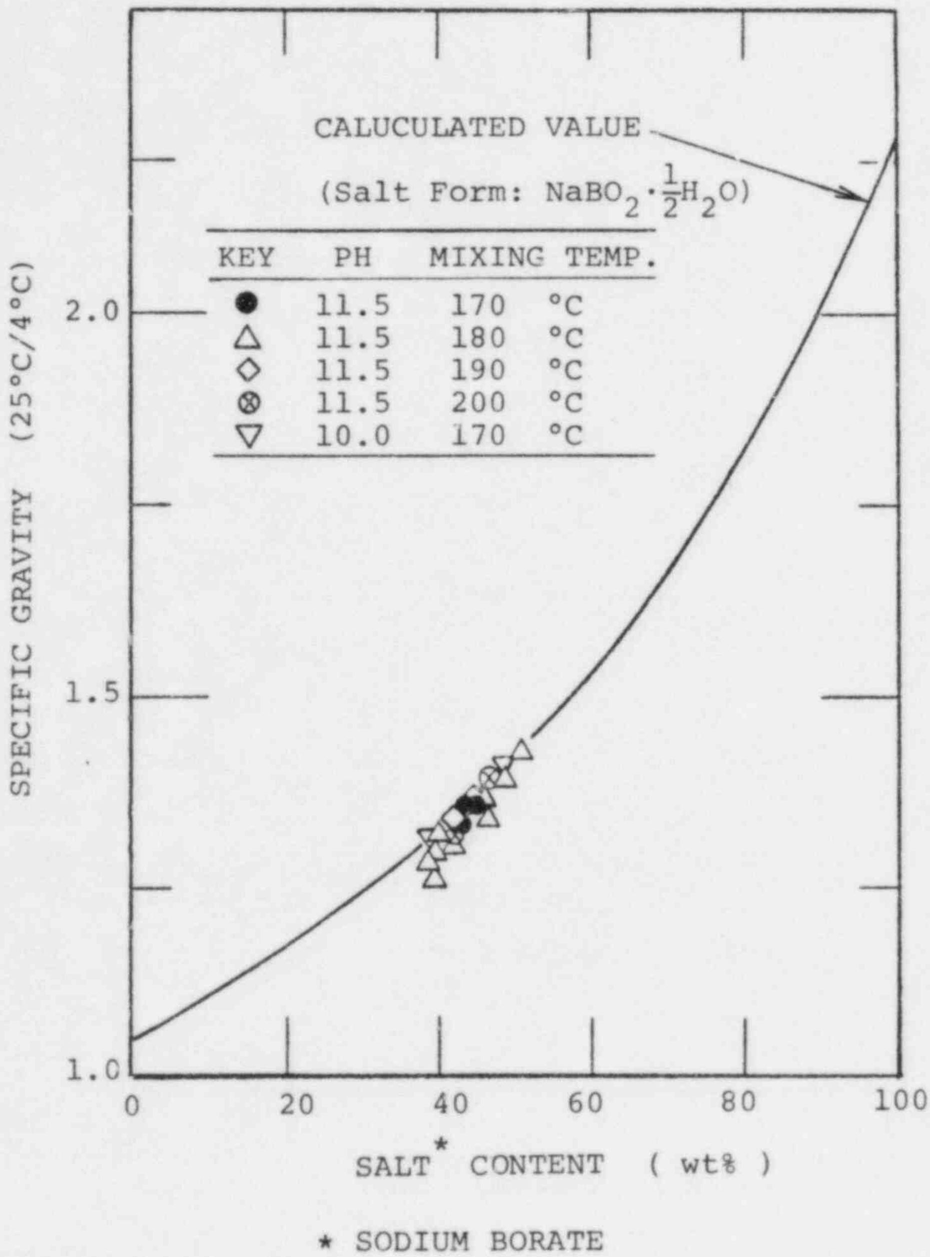
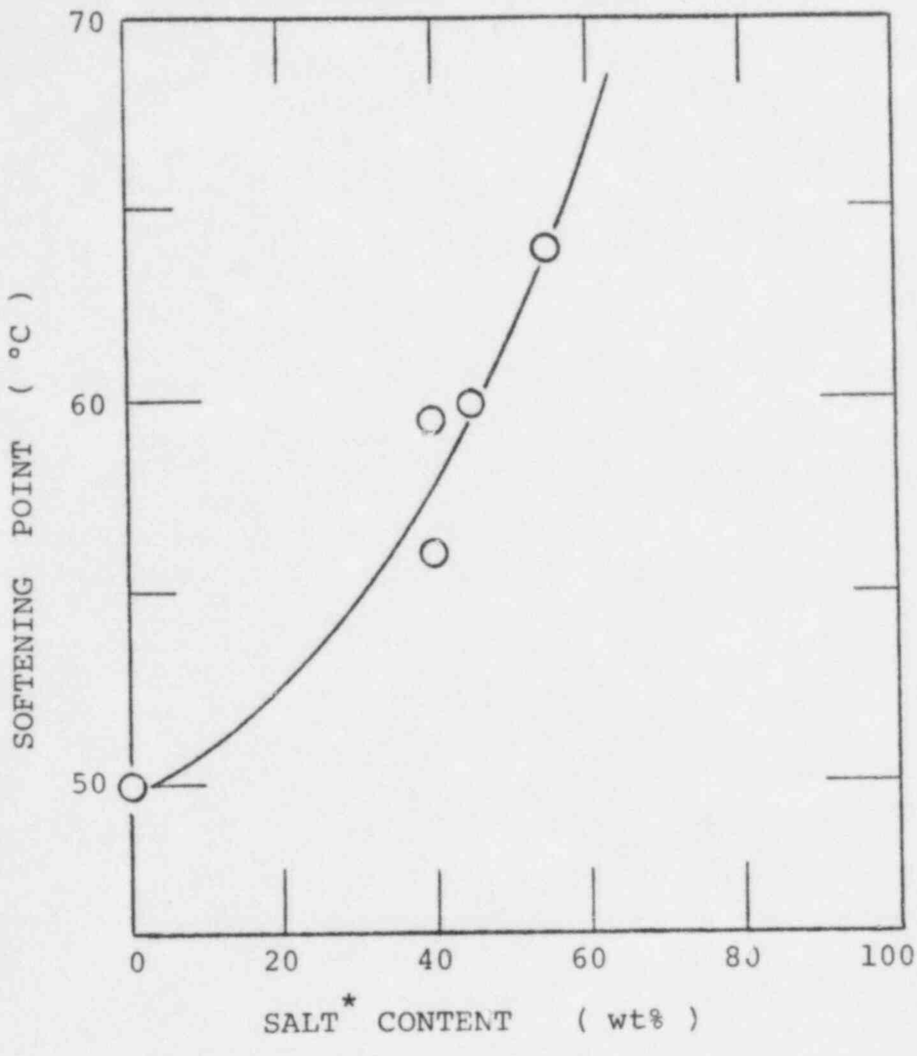


Fig. 4-1 Specific Gravity



* SODIUM BORATE

Fig. 4-2 Softening Point

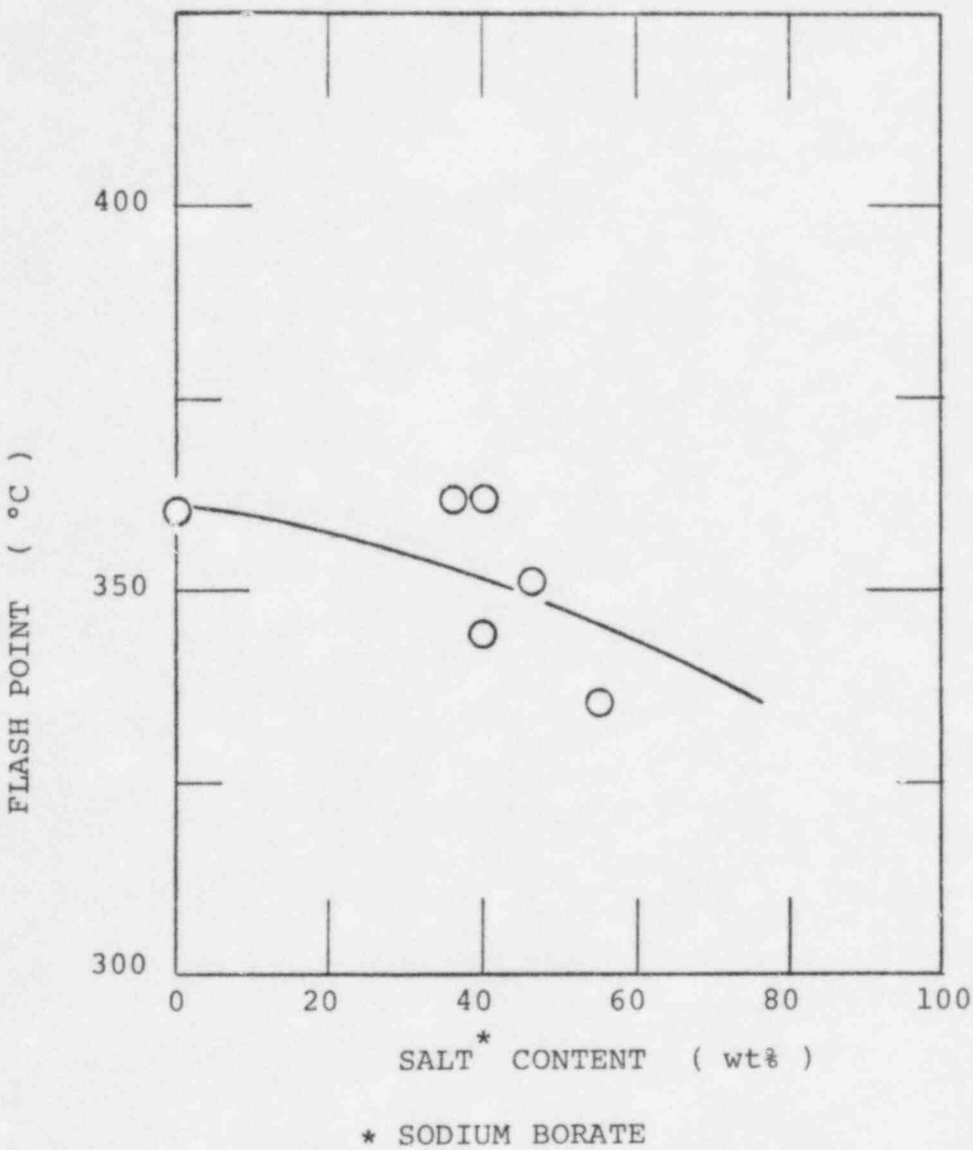


Fig. 4-3 Flash Point

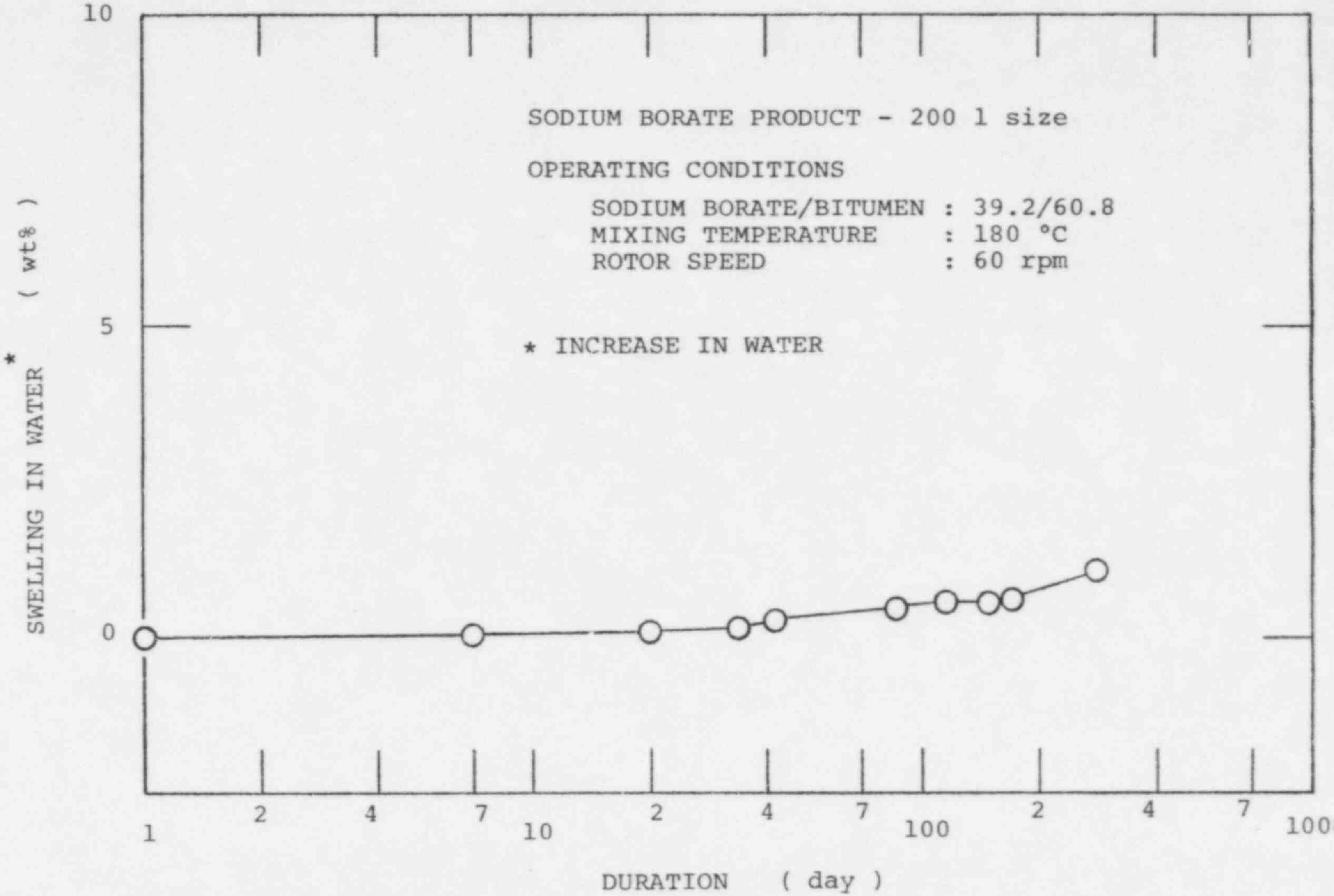


Fig. 4-4 Swelling and Leaching Tendencies in Water

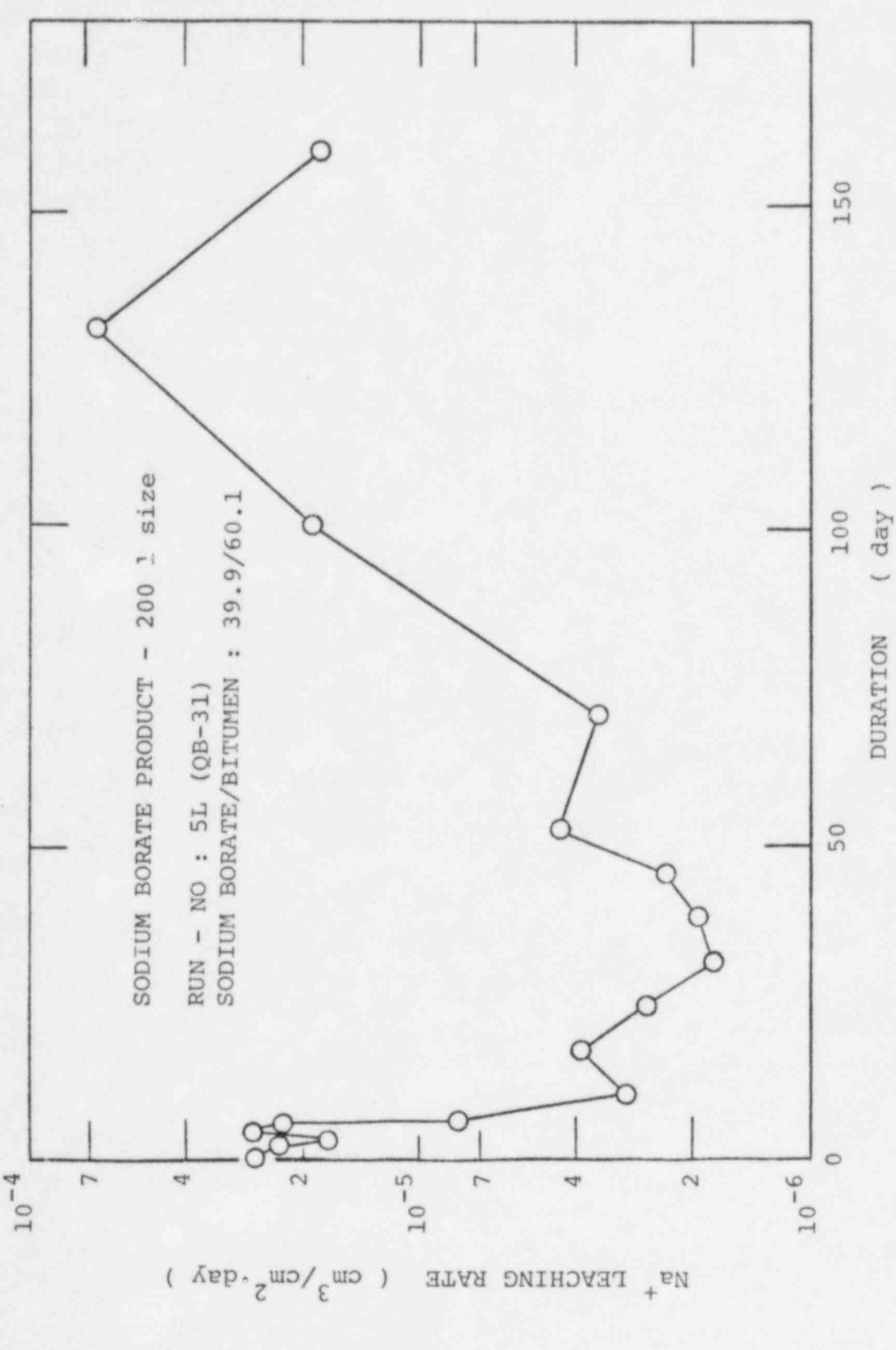


Fig. 4-5 Leaching Rate of Na^+ in Water

5. EQUIPMENT DESCRIPTION

In this chapter, features of each equipment in the DRUM MIXER PROCESS are described, however, the specifications of equipment described here are the typical examples, except for the DRUM MIXER which is the standard equipment. The equipment list for major systems is shown in Table 5-1.

5.1 DRUM MIXER (M-8)

The constructional outline of the DRUM MIXER is shown in Fig. 5-1. Bitumen and wastes are fed into the DRUM MIXER and stirred at temperatures ranging from 150 to 200°C, preferably 160 to 180°C.
Heating is effected by a heating medium which flows inside the DRUM MIXER jacket and horizontal rotor.

Typical specification of the DRUM MIXER for 1,000 MWe PWR plant is as follows:

Effective volume	:	200 l
Dimension, length	:	1,800 mm
width	:	800 mm
Material	:	Stainless steel
Rotor speed	:	Max. 85 rpm
Motor	:	7.5 KW
Evaporation capacity	:	140 kg/hr

The DRUM MIXER is possible to be decontaminated by heating and stirring after solvent has been fed. Special double mechanical seals completely prevent molten bitumen leakage at both penetration parts of the axial shaft of the inner roter.

5.2 Tank

Typical specification of the tanks in the DRUM MIXER PROCESS for 1,000 MWe PWR plant is shown in Table 5-2.

5.2.1 Liquid Waste Feed Tank (T-1)

The function of the liquid waste feed tank is to receive and hold liquid waste to enable sampling and pretreatment with reagent, prior to feeding the liquid waste to the DRUM MIXER. It is equipped with an agitator for accurate sampling and pretreatment and spray nozzles for flushing. In order to prevent the precipitation of salt and the like, the electric heater is installed on the exterior wall of the tank.

5.2.2 Bitumen Tank (T-3)

The bitumen tank stores bitumen to be fed to the DRUM MIXER. A steam coil is installed inside the tank for the purpose of maintaining the temperature at a level, where bitumen transfer is possible.

5.2.3 Distillate Tank (T-4)

The distillate tank temporarily receives the condensate of water vapor generated at the DRUM MIXER. The volume of the tank corresponds to one drum of product.

5.2.4 Heating Medium Storage Tank (T-5)

The heating medium storage tank is a tank which feeds the heating medium to the heating medium system, and also serves as a drain tank for heating medium from the heating medium system.
The tank, therefore, must have a capacity sufficient to receive all of the heating medium in the system.

5.2.5 Heating Medium Surge Tank (T-6)

The heating medium tank has the capacity to receive an amount of heating medium equal to the increase due to thermal expansion with increasing temperature. The inside of the tank is sealed with nitrogen gas to prevent ignition.

5.2.6 Antifoaming Tank (T-7)

The antifoaming tank contains antifoaming reagent to prevent the foaming during mixing/evaporating in the DRUM MIXER. The volume of the tank corresponds to 10 or more drums of product. The concentration of antifoaming reagent solution is 20%. Accordingly, an agitator is installed inside the tank to uniformly mix such water solution.

5.3 Hopper and Feeder

5.3.1 Resin Slurry Dewaterizer (M-9) and Resin Feeder (T-9)

The resin slurry dewaterizer and resin feeder, which are in the same unit, dewaterize resin slurry and feed dewaterized resin to the DRUM MIXER. The resin slurry dewaterizer is a hopper inside which resin slurry is decanted and supernatant water overflows for recycling to the resin tank. As stated in 3.2.2, other dewatering equipment, such as centrifuge, are also applicable.

The resin which settles at the bottom of the hopper is fed upward through a screw type resin feeder, during which resin is dewaterized since the water flows downward. Dewaterized resin containing about 50% of water is thus fed to the DRUM MIXER through the outlet of the resin feeder. It is possible to wash the inside of the hopper by passing water through the flushing nozzle.

5.3.2 Ash Hopper (T-8) and Ash Feeder (P-8)

The ash hopper is made of stainless steel and, temporarily receives incineration ash. The feeder is made of stainless steel and is of a screw type for feeding incineration ash to the DRUM MIXER. The feed rate can be controlled.

5.4 Drum Handling System

The drum handling system consists of a conveyor for delivering empty drums and product drums, a drum lifting machine (for setting empty drums at the drum filling hood provided at the outlet of the product filling line), and a capping machine for product drums. Product filling is carried out after the drum has been lifted at the drum filling hood by the drum lifting machine. In this case, the drum filling hood is evacuated and the vent gas goes to the off-gas system. In addition, the weight of the product drum can be measured to record product weight. The product drums are transported from the drum handling system to the drum storage area where the drums can be stored for 30 days or more, and smear survey and decontamination equipment are available.

5.5 Container (Drum)

Standard 55-gallon carbon steel drums (DOT 17C) are used in the DRUM MIXER PROCESS.

5.6 Heat Exchanger

5.6.1 Condenser (M-1)

The condenser is a shell and tube type heat exchanger which is made of stainless steel and condenses steam generated in the DRUM MIXER. It is capable of sub-cooling the condensate down to temperatures of 50°C or lower.

5.6.2 Heating Medium Cooler (M-3)

The heating medium cooler is a shell and tube type heat exchanger which is made of stainless steel and cools the heating medium at the cooling operation with the DRUM MIXER. It is capable of cooling the bitumen mixture of 180°C in the DRUM MIXER down to 150°C in about 30 minutes.

5.6.3 Heating Medium Heater (M-2)

The heating medium heater is an electric type heater which has an output of 280 KW and can heat up the heating medium to the operating temperature ranging from 220°C to 250°C in about 1.5 hours. The material in contact with the liquid is stainless steel.

5.6.4 Off-gas Cooler (M-13)

The off-gas cooler, which is made of stainless steel, is a double tube type heat exchanger employing fin tubes for the inner tubes.
It is capable of cooling off-gas down to 45°C and condensing the moisture in the gas.

5.6.5 Off-gas Heater (M-4)

The off-gas heater, which is made of stainless steel, is a double-tube type heat exchanger having sufficient capacity to heat up the gas of 45°C (discharged from the off-gas cooler) up to 65°C, which is most suitable temperature for off-gas filtration.

5.7 Pump

In the PROCESS, non-seal type centrifugal pumps are used for the service described below to prevent liquid leakage.

(1) Transferring of radioactive liquid

Liquid waste feed pump (P-1), Distillate pump (P-4)

(2) Transferring of heating medium

Heating medium circulation pump (P-6)

(3) Transferring of solvent

Solvent feed pump (P-11)

Of these, the liquid waste feed pump is designed to prevent the transfer of slurry.

In addition, the pumps, described below, for transferring highly viscous fluid, are of the geared type.

Heating medium feed pump (P-5), Bitumen feed pump (P-3).

All these pumps are made of stainless steel.

5.8 Piping and Valve

The piping connections of the PROCESS are of the welded type. Connections with equipment, such as pumps and instruments which require maintenance, are of the flange type.

It is possible to flush radioactive liquid and slurry from the lines with water or hot water.

An electric heat tracing unit is provided for the line used for receiving liquid waste, and also for the feed line to the DRUM MIXER to prevent precipitation of salt.

Non-seal type valves, such as bellow valves, are used for the lines handling liquid waste, solvent and heating medium to prevent leakage of liquid. As in the case of the piping, an electric heat tracing unit is provided for the valves on the liquid waste line.

The materials of both piping and valves are as follows:

(1) Evaporator concentrate, resin slurry, reagent, solvent, off-gas:

Stainless steel

(2) Bitumen, heating medium: Carbon steel

5.9 Ventilation

Room ventilation is required to control the flow of air from areas of lower potential contamination to areas of higher potential contamination, and to remove the heat generated by the PROCESS, especially the heating medium system.

Ventilation exhaust gas should preferably be treated, with the vessel off-gas which has been treated in the off-gas system, through HEPA filters to release from the plant stack to the environment.

5.10 Electric Power

Main electric power users in the DRUM MIXER PROCESS are: Heating medium heater, DRUM MIXER, heat tracing system, pumps, drum handling system, mixer and feeders. Total electric usage normally is less than 350 KW.

5.11 Fire Protection

The PROCESS must be coordinated with the total plant fire protection system.
A fire protection system, that is a water spray system, is recommended to be provided in all areas where asphalt and heating medium are used.

5.12 Control Panel

Major operations in the PROCESS are controlled from a centralized control panel. On the control panel, indicators are available for controlling major processes and systems, thereby ensuring fully automatic operation from the panel. In other words, the individual processes ranging from the preparations for drum mixing through to drum filling can be automatically operated with push-buttons.

Interlocking also ensures the safety of the PROCESS during typical abnormal operations such as overflow in the tank, overheating of the heating medium and leakage from the equipment, abnormal rise in temperature in the DRUM MIXER, and so on. For such abnormal conditions, the PROCESS is designed so that the interlocks for emergency shutdown and/or emergency cooling operate automatically.

5.13 Instrumentation

The instrumentation are designed with consideration to operability and maintenability, and the main instrumentation are mounted on the panels.
Signals fed to panel indicators are electrical or pneumatic signals obtained by converting the measured quantities by transmitters located in the operation area, thereby keeping the process fluid away from the control panel.

5.14 Scope of Supply and Interface

JGC will provide the following major systems in the DRUM MIXER PROCESS to properly execute its work to assure proper operation of the PROCESS.

(1) Waste feed system

(2) Bitumen feed system

(3) Evaporating/mixing system

(4) Distillate recovery system

(5) Heating medium system

(6) Off-gas system

(7) Drum handling sytem

(8) Decontamination system

For other systems, such as reagent supply system, utility systems (deminerized water, cooling water, steam, electric power, etc.), room ventilation, instrumentation, fire-fighting equipment and so on, the scope of supply and interface will be determined by the individual utility company.

Table 5-1. Equipment List

Waste Feed System

Item No.	Equipment Name
T-1	Liquid Waste Feed Tank
P-1	Liquid Waste Feed Pump
T-8	Ash Hopper
P-8	Ash Feeder
M-9	Resin Slurry Dewaterizer
P-9	resin Feeder

Bitumen Feed System

T-3	Bitumen Tank
P-3	Bitumen Feed Pump

Evaporating Mixing System

M-8	DRUM MIXER
M-1	Condenser
T-7	Antiforming Tank
P-7	Antiforming Feed Pump

Distillate Recovery System

T-4	Distillate Tank
P-4	Distillate Pump
M-5	Oil Separator Unit

Table 5-1. Equipment List (Continue)

Heating Medium System

Item No.	Equipment Name
T-5	Feating Medium Storage Tank
T-6	Heating Medium Surge Tank
P-5	Heating Medium Feed Pump
P-6	Heating Medium Circulation Pump
M-2	Heating Medium Heater
M-3	Heating Medium Cooler

Off-gas System

M-4	Off-gas Heater
M-13	Off-gas Cooler
M-14	Off-gs Filter
P-13	Off-gas Fan

Drum Handling System

M-7	Drum Handling System

Decontamination System

T-10	Solvent Tank
P-11	solvent Feed Pump

Table 5-2. Typical Specification of Tanks

	Effective Volume m^3	Material
Liquid waste feed tank (T-1)	1.6	Stainless steel
Bitumen tank (T-3)	15	Carbon steel
Distillate tank (T-4)	1.6	Stainless steel
Heating medium storage tank (T-5)	0.5	Carbon steel
Heating medium surge tank (T-6)	0.5	Carbon steel
Antifoaming tank (T-7)	0.1	Stainless steel

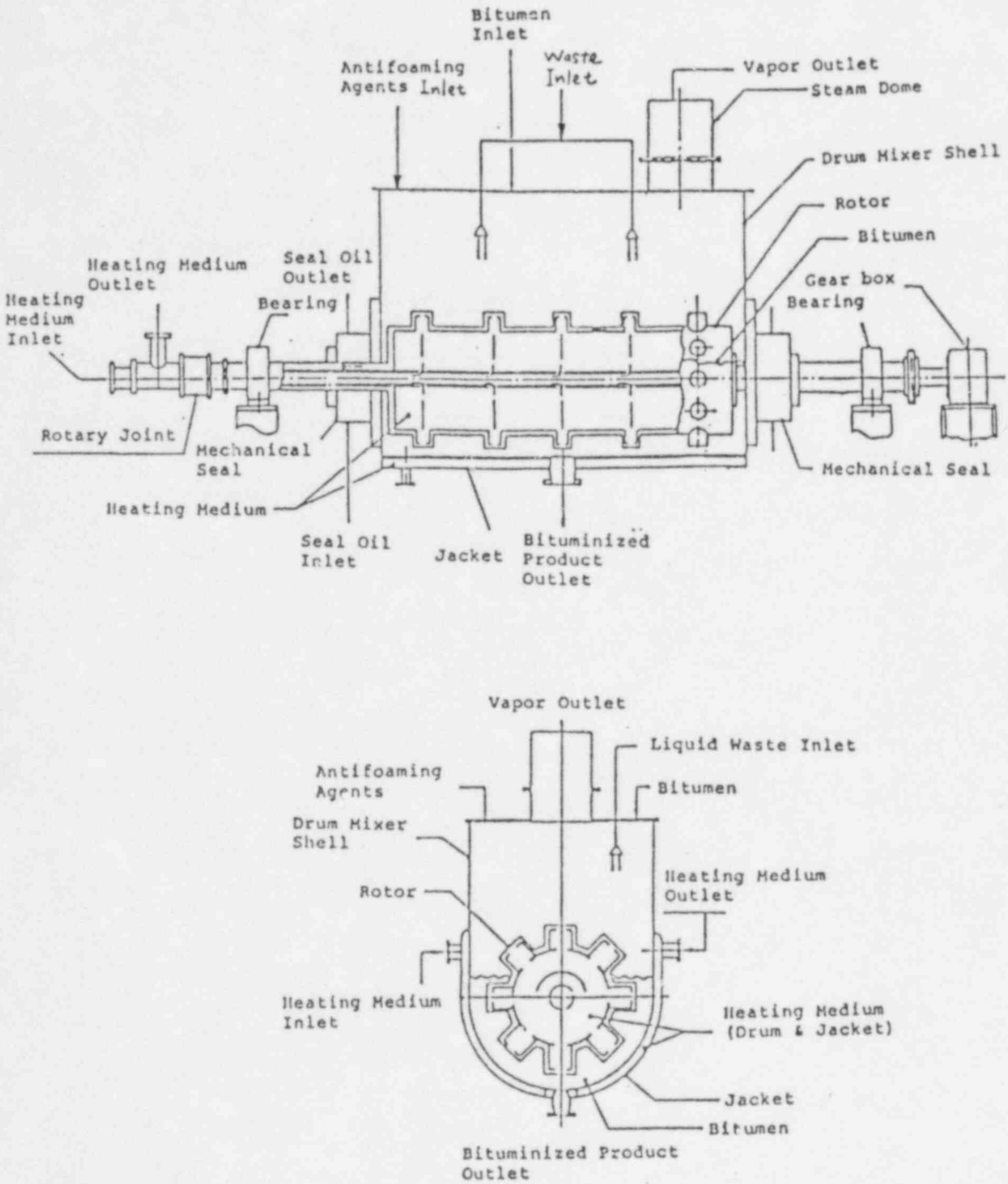


Fig. 5-1 Constructional Outline of DRUM MIXER

6. EQUIPMENT LAYOUT

6.1 Recommended Layout

Various layout plans for the DRUM MIXER PROCESS are feasible, according to plant conditions such as the type and capacity of waste to be treated, and the space provided for the DRUM MIXER PROCESS.
An example of the recommended equipment layout of the DRUM MIXER PROCESS is shown in Fig. 6-1. In this example, the space for the equipment layout is to be provided as a part of the existing plant.

6.2 Drum Storage Area

The product drums are remotely carried from the drum filling station to the drum storage area where they are temporarily stored.
The drum storage area will be capable of accommodating at least the number of drums that are generated over a period of 30 days.
A smear survey unit is provided in the storage area, for checking the surface contamination of the drums before removing them from the storage area.
Also, a unit for decontaminating the surfaces of drums will be provided in this area.

Biological shielding is required around the storage area. Transfer of drums within the storage area will be done by a remotely operated overhead crane.

6.3 Truck Loading Bay

Truck loading bay is provided next to the drum storage area. Transfer of drums to the truck loading bay from the drum storage area will be done by remotely operated overhead crane.

6.4 Radiation Exposure Control

The facility is divided into areas in accordance with the dose rates from the equipment, in order to keep the radiation exposure of the operators as low as is reasonably achievable, and equipment in which radioactive materials are handled, are shielded with concrete.
The personnel radiation exposure is controlled by limiting the access time of the operators in each radiation area.

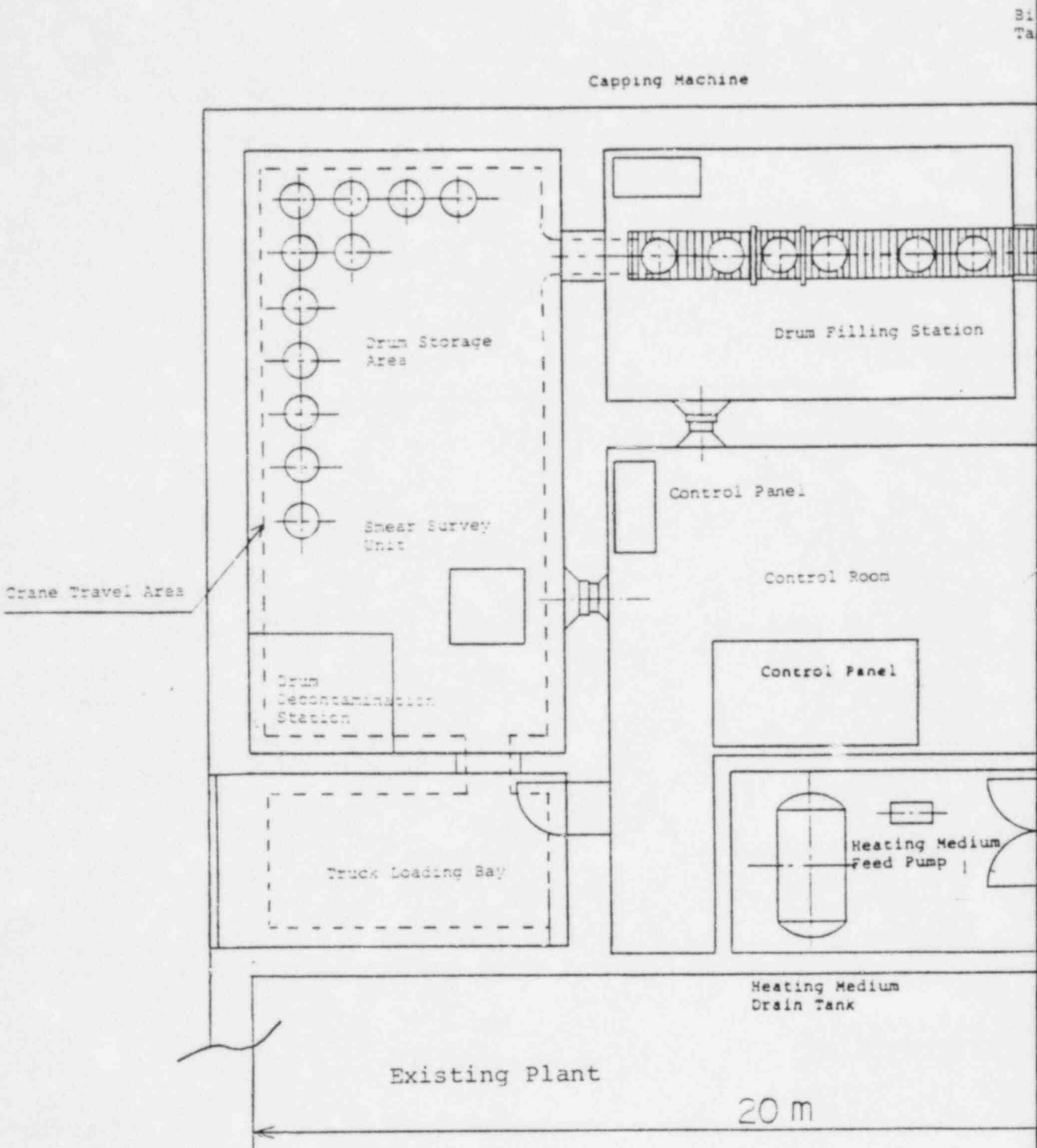
The ventilation system is provided to decrease the inhalation exposure of personnel.

6.5 Maintenance Accessibility

Provisions will be made to install a monorail, hoist, lifting hook and so on to readily carry in and take out, inspect and repair equipment during maintenance.
Operators can drain liquid from the equipment at a location of the low possible dose rate.
After draining liquid from equipment and pipings which accommodate highly-radioactive liquid and/or slurry, it will be possible to wash the equipment and pipings by flushing. Thus, all major radiation sources can be removed from the area prior to the entry of maintenance personnel.

6.6 Secured Access Entries

As stated in 6.1, the space for the equipment layout of the DRUM MIXER PROCESS is within the existing plant, the entry control to the DRUM MIXER PROCESS will be provided by monitoring and security systems in the existing plant.


Bi
Ta
Capping Machine
Drum Storage Area
Drum Filling Station
Control Panel
Smear Survey Unit
Crane Travel Area
Control Room
Control Panel
Drum Decontamination Station
Truck Loading Bay
Heating Medium Feed Pump
Heating Medium Drain Tank
Existing Plant
20 m

1st Floor

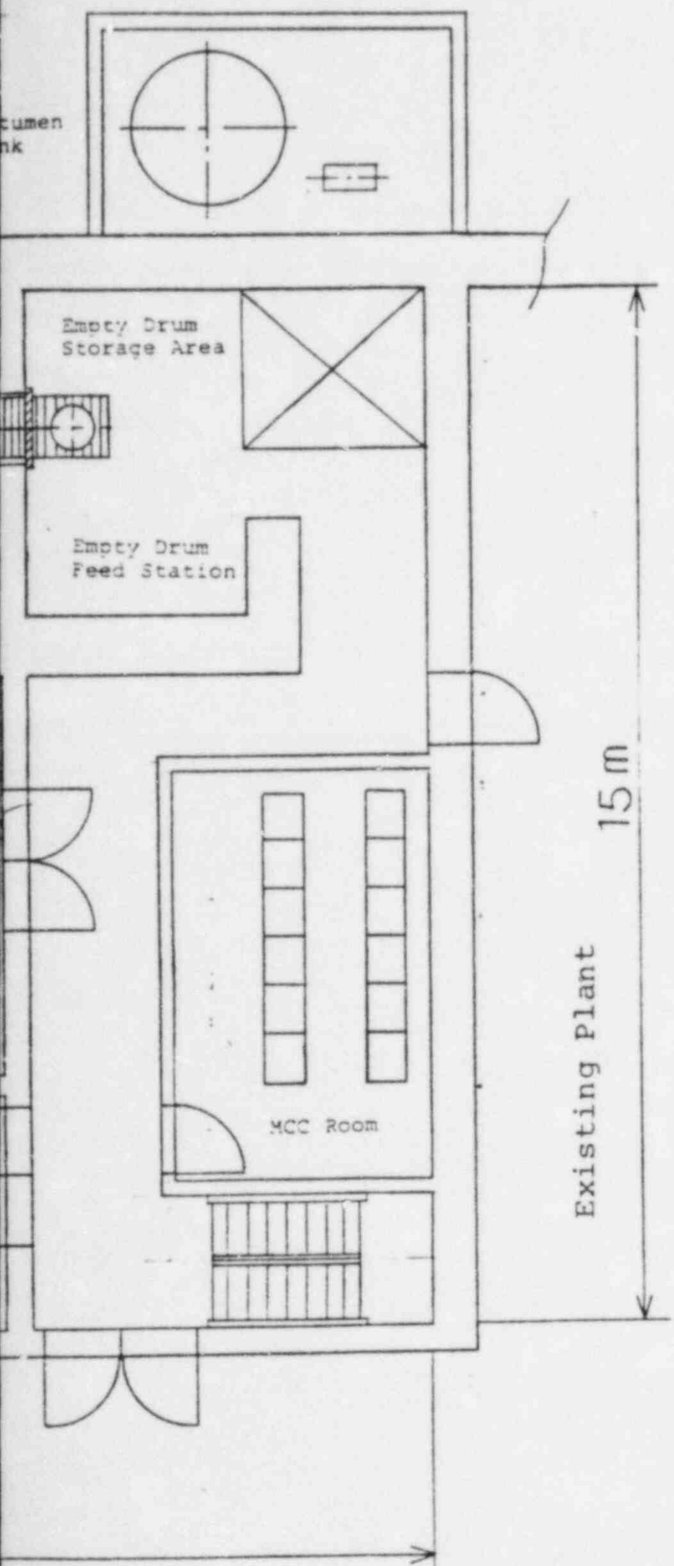


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Fig. 6-1 Equipment Layout(1)

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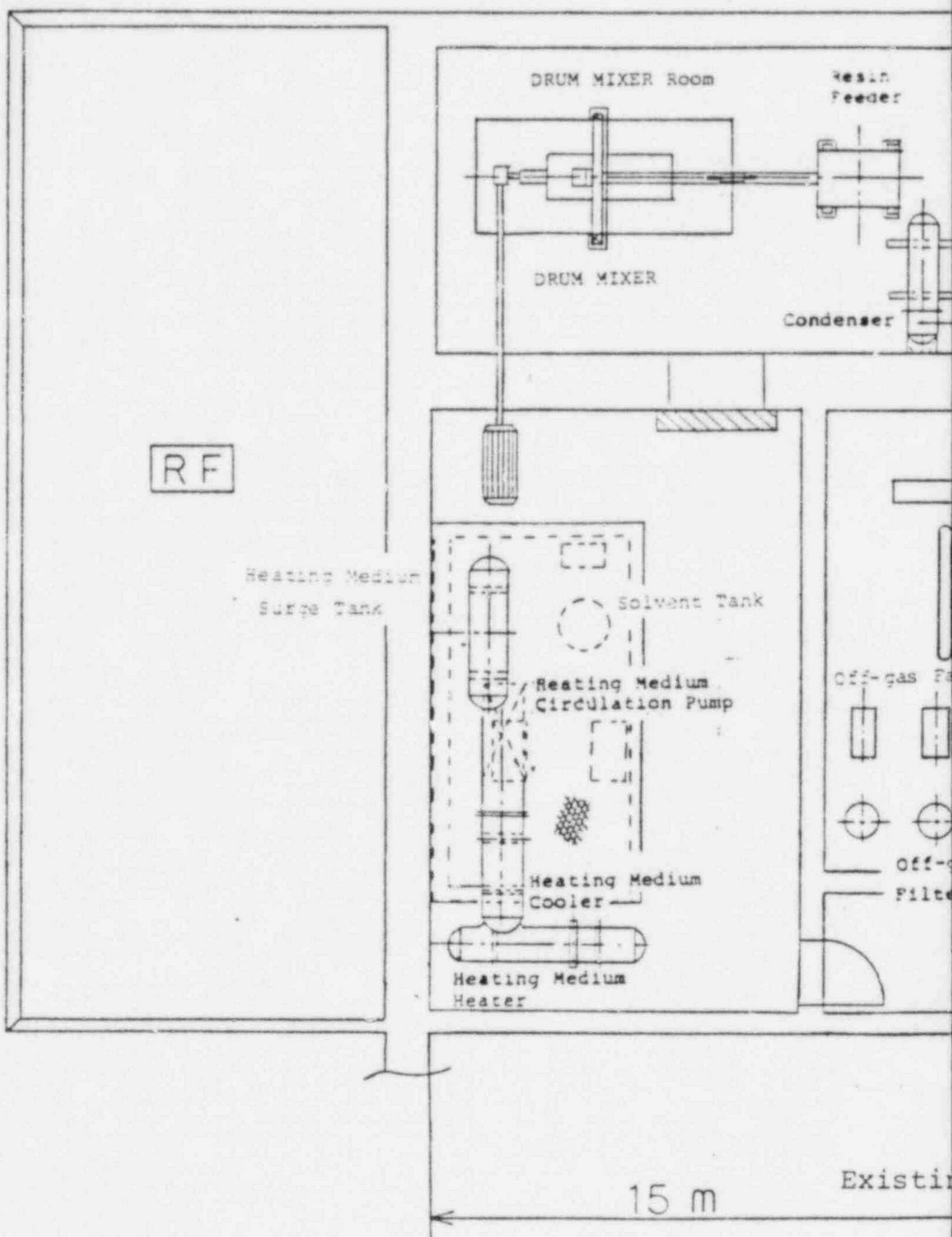

DRUM MIXER Room
Resin Feeder
DRUM MIXER
Condenser
RF
Heating Medium Surge Tank
Solvent Tank
Heating Medium Circulation Pump
Off-gas Fa
Off-g Filte
Heating Medium Cooler
Heating Medium Heater
15 m
Existi

2nd. Floor

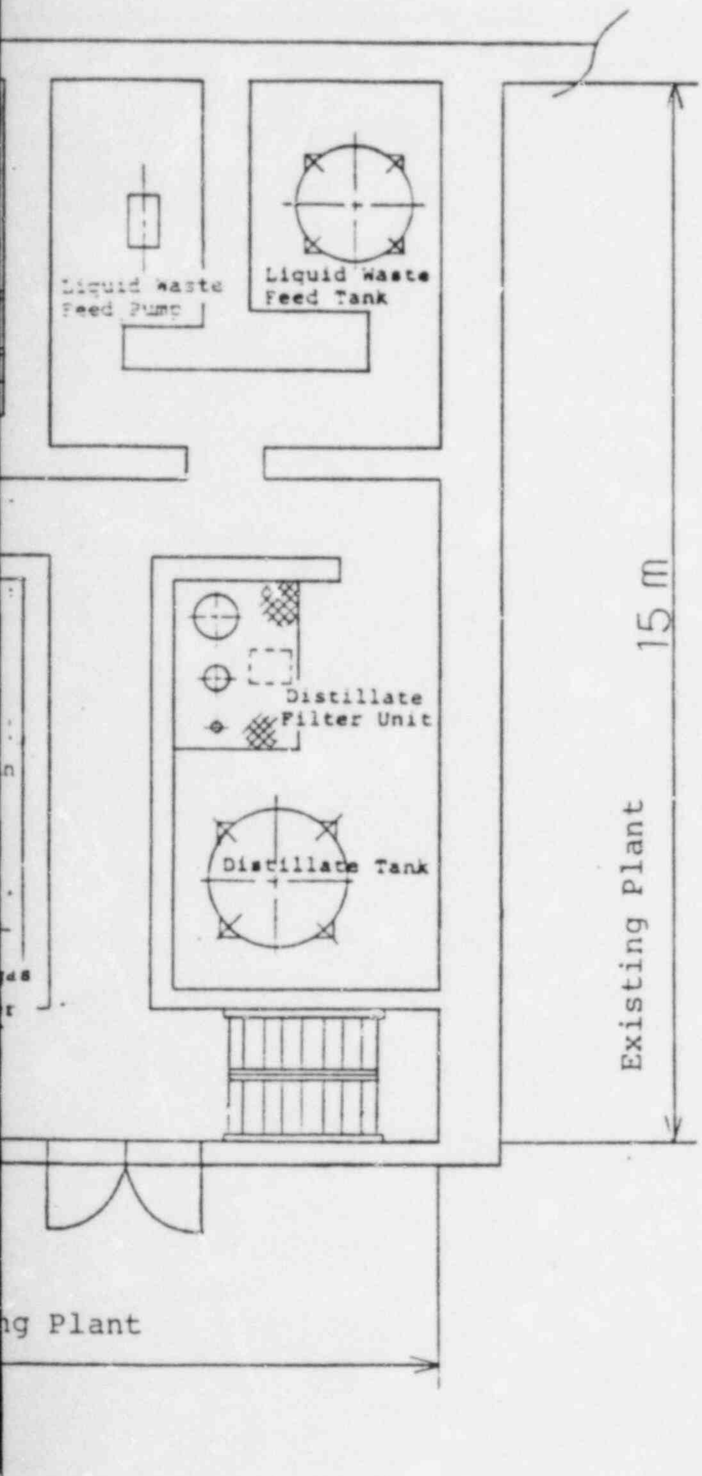

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Fig. 6-1 Equipment Layout(2)

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7. CODES AND REGULATIONS

7.1 General

The design, fabrication, and operation of the DRUM MIXER PROCESS are consistent with the currently applicable guides, regulations and standards. These standards are listed below.

(1) Titles 10 and 49 Code of Federal Regulations

(2) Regulatory Guides of the Nuclear Regulatory Commission

(3) National Fire Protection Association Standards

(4) Commercial Burial Site Regulations and State Regulation

7.2 Federal Regulations

10 CFR PART 20 — Standards for Protection Against Radiation

Exposure of individuals operating and maintaining the DRUM MIXER PROCESS will be kept as low as is reasonably achievable and will be less than that specified. Concentration of radioactive materials in restricted areas will be less than that specified in Appendix B, Table I.
Radiation levels in unrestricted area will be much less than that specified. Concentration in effluents will be much less than that specified in Appendix B, Table II.

10 CFR PART 50 Licensing of Production and Utilization Facilities

The quality assurance program of the DRUM MIXER PROCESS are based on the guidelines specified in Appendix B. Design and construction will be optimized so that the release of radioactive material are controlled to achieve the intent of this regulation, and to be well within the guidelines specified in Appendix I and to be "As Low As is Reasonably Achievable".

49 CFR PART 173 Transportation

Packaging, handling and transportation of the radioactive solidified material will be in accordance with this regulation.

7.3 NRC Regulatory Guides

R.G. 1.16 Quality Group Classifications and Standards for Water, Steam and Radioactive Waste Containing Components of Nuclear Power Plants

All components of the DRUM MIXER PROCESS are consistent with the quality standard of Quality Group D.

R.G. 1.43 Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light Water Cooled Nuclear Power Plants

Management, structure, and components of radioactive waste are consistent with the requirements of this guide. Facility and equipment design of the DRUM MIXER PROCESS is specified to meet the intent of ALARA.

R.G. 8.8 Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations will be As Low As is Reasonably Achievable

The DRUM MIXER PROCESS is designed and fabricated to minimize occupational radiation exposure during both normal operation and maintenance.
Detailed information will be given to the plant operator during the early design and fabrication stages to allow for proper implementation of any revisions based on the operator's review to ensure that occupational radiation exposure will be ALARA.

7.4 National Fire Protection Association

Standard for Intrincsically Safe Apparatus for Use in Class I Hazardous Locations and its Associated Apparatus

Classification with respect to flammability is determined as Class I, Group D. Areas immediately adjacent to an open container at the drum filling station are classified as Class I, Group D, Division 1 and the surrounding zones are classified as Class I, Group D, Division 2 as described in NFPA No. 493.

7.5 Commercial Burial Site Regulations and State Regulations

It is intended that the final product from the DRUM MIXER PROCESS will be sutable for commercial burial sites and meet the requirements of the state regulations. This is based on data on the properties of the solid material such as the leaching rate, flash point and water content (as described in Chapters 4, 9 and 10).

It is also intended that the product from the DRUM MIXER PROCESS meets the technical requirements for disposal package described in the NRC's proposed 10 CFR Part 61, "Licensing Requirements for Land Disposal of Radioactive Waste" (July 24, 1981).

8. QUALITY ASSURANCE PROGRAM

8.1 General

A Quality Assurance Program (QA Program) is provided to assure that the required effort, equipment, procedures, and management are directed toward satisfying the quality objectives of providing safe and reliable structures, system, and components, and complying with the provisions of the following documents: Appendix B of 10 CFR Part 50 "Quality Assurance Criteria for Nuclear Power Plants", NRC Regulatory Guide 1.28, "Quality Assurance Program Requirements", ANSI/ASME N 45.2-1977, "Quality Assurance Program for Nuclear Power Plants", and Article NCA-4000 for Sec. III of ASME Boiler and Pressure Vessel Code, "Quality Assurance".

This chapter describes the QA Program for application to the safety-related functional aspects of structures, systems, and components within the JGC scope of supply for the DRUM MIXER PROCESS. These structures, systems, and components are classified "Important to Safety" in that they prevent or mitigate the consequences of postulated accidents that could cause undue risk to the health and safety of the public. The principal objectives of the QA Program and the key functions and elements are not expected to change over the duration of a project. However, circumstances may make advisable changes in the organization, or in the implementing detail, and such changes will be made in accordance with normal management practices.

The QA Program is designed to provide assurance that the safety-related work elements for structures, systems, and components are identified and controled. Specific responsibilities of personnel and organizations are assigned and documented for safety-related activities throughout the major steps of design and construction of the project.

In addition to the quality assurance organizations, project, engineering, procurement and manufacturing organizations have specifically assigned quality assurance responsibilities. Each organization adminsters its own activities and conducts self-audits in addition to audit of JGC subcontractors and vendors to assure compliance with the QA Program for their assigned scope of responsibilities.

8.2 Organization

Organizational structure and functional responsibility assignment in the JGC Nuclear Project Division is based on recognition of quality assurance as an inter disciplinary function with safety-related activities being performed by many organizational components and individuals.

In executing a project, the authority and responsibility are vested in the project manger. The quality assurance manager is responsible for the excution of the QA Program. On the other hand, the General Manager of the Nuclear Project Division is responsible for the settlement of safety-related problems which cannot be resolved between the quality assurance, projects, engineering, procurement and construction organizations.

An organization with clearly defined tasks, authority and responsibility, and communication flow, is formed for the execution of the QA Program.

The organization is set up with due consideration to the following:

(1) The person who executes the work concerned is basically responsible for obtaining the necessary quality.

(2) The verification of quality should be performed by personnel who are not directly responsible for the products and activities to be verified.

(3) Necessary authority should be vested in the personnel who carry out the verification of quality, as well as in personnel who perform auditing, and give advice for corrective actions to ensure that appropriate quality assurance activities are effectively implemented.

Figure 8-1 indicates the fundamental organization for carrying out quality assurance activities.

When JGC awards the contract for the DRUM MIXER PROCESS with US utilities and/or other US entities, JGC will send the key staff such as project control group to the United States of America, and form the unique project organization to adequately undertake the supply of any systems of the DRUM MIXER PROCESS for its US customer.

8.3 Document Control

This section covers the methods of controlling the preparation, check, and approval of important documents, such as Quality Assurance Manual (QA Manual), specifications, procedures, instructions and drawings, associated with the implementation and verficiation of quality assurance activities. Personnel who are to be responsible for document preparation, check and approval are clearly designated. The document controller controls the issue and distribution of the documents, using a list showing the documents to be distributed, to assure that correct and proper documents are fully utilized by the persons concerned.

As a rule, revision of the documents is carried out by the persons who first prepared, checked and approved the original documents, based on the requirements. Information relating to revisions must be given to the persons concerned as soon as possible.

8.4 Design Control

Design conditions are prepared and distributed to all the design groups concerned to ensure that applicable codes and regulations, design requirements such as specifications, procedures, instructions, drawings, etc., are properly incorporated in the design documents. In addition, methods of selecting fabrication/installation procedures for the materials, parts, components, and equipment which play a vital role in the function of safety-related items, and studying the acceptability or otherwise of the application of these methods are established. The design documents are reviewed by those who have not been involved in the original design.

The interfaces of the design work among disciplines are specified in the documents. Responsibilities for the preparation, check, approval, issuance, distribution and revision of the design documents are specified for each of the groups concerned.

Design verification is carried out by those who have not been involved in the original design, and the results of such verification are properly recorded.

Changes in design (including field changes) are implemented in the same manner as those arising in the preparation of the original design.

Any information relating to design changes is conveyed in writing to the groups concerned.

8.5 Procurement Control

In order to procure products and services of the proper quality, JGC specifies, in procurement-related documents including applicable specifications, drawings, etc., the following requirements regarding quality;

(1) Scope of work to be carried out by the contractor to whom contract has been awarded.

(2) Design conditions, applicable codes regulations and standards, and procedures.

(3) Examinations and inspections

(4) JGC's inspection and audits to the contractor's facilities

(5) Details of documents for approval or verification by JGC, such as specifications, procedures, drawings, quality assurance records, methods and time of submission.

(6) Maintenance and discard of quality assurance records.

(7) Submission of contractor's QA Manual to JGC.

(8) Terms and conditions for the requirements given in the procurement documents to subcontractors of the contractor.

Prior to the selection of vendors, JGC evaluates their capabilities to determine whether they can supply products and services satisfying the requirements of the procurement documents.

JGC controls procurement by confirming objective evidence and records, and inspections and audits at the vendors concerned to ensure that the purchased products and services meet the requirements of the procurement documents. Measures shall be established to ensure that the persons concerned utilize, before the use of the products, the quality assurance records to verify that the purchased products satisfy the requirements of the procurement documents.

8.6 Control of Equipment and Materials

Measures shall be established to identify the use of appropriate equipment and materials, including parts and components. Consideration shall be given to such measures to assure that welding number, lot, parts, and equipment numbers are properly indicated, and also to enable adequate identification of equipment and materials throughout fabrication, installation and operation. Such control methods shall apply to nonconforming items, and measures shall be established so that the histories of such items can be investigated, as necessary.

In order to protect materials against damage, deterioration, or loss, JGC shall establish and implement methods for their handling, storing, and cleaning, packing, delivery and transportation.

8.7 Control of Fabrication and Installation

Work associated with fabrication and installation is controlled to comply with the requirements of JGC standard specifications, as well as those of the procedures and drawings. Special processes such as non-destrictive examination, welding, and heat treatment are carried out by the workers, methods or equipment authorized in accordance with the requirements of the applicable codes and standards, JGC standard specifications.

The working area is provided with an appropriate environment by setting up work blocks and controlling humidity, etc., to ensure that the work concerned is properly carried out.

Equipment, jigs and tools having the specified functions and accuracy shall be used and control methods thereof established and implemented.

Newly adopted construction methods and work procedures, where necessary, shall apply to the actual work after the acceptability or otherwise thereof has been confirmed in an appropriate manner.

8.8 Control of Inspection and Examination

In order to verify that products and services comply with the requirements of the applicable specifications, procedures, instructions and drawings, inspection or examination procedures shall be established duly in advance of inspections or examinations (hereinafter called "inspections"). Inspections are implemented based on these procedures for work which must conform to the quality requirements, by those who have not been involved in the work being inspected.

In cases where inspections after fabrication or assembly are impossible or inapplicable, the work concerned is indirectly controlled by observing the fabrication processes, including observation of the equipment and confirmation of work performance.

Inspection hold points shall be indicated in the fabrication sequence drawings.

The results of inspections, and acceptance or otherwise thereof shall be documented.

Testing and measuring equipment for use in inspections shall be periodically calibrated in order to ensure correctness and accuracy, and the term of validity shall be indicated. In order to ensure that the testing and measuring equipment are properly used, the responsible person shall control the use of equipment by using testing/measuring equipment control registers.

8.9 Control of Nonconforming Items

In order to avoid careless use or installation, nonconforming items are identified with marking tags or by isolating them from conforming items.

When nonconforming items occur or are discovered, they shall be dealt with after the disposition policy described in the nonconformance reports have been approved by the design groups concerned.

In nonconformance reports, the causes for nonconformance, the disposition policy, and the confirmation of the actions taken, etc., shall be described.

When the recurrence of nonconforming items are presumed, the quality assurance engineer shall instruct the persons concerned to take preventive measures and confirm the implementation, informing the persons concerned of the results.

The repair of important defects or the use of nonconforming items without modification shall be made with the approval of the client.

8.10 Quality Assurance Record

For the effective execution of the QA Program, JGC shall prepare proper quality assurance records which cover the data objectively evidencing the quality of products, and the quality assurance activities at each phase from design to procurement, fabrication, installation, test operation, etc.

The methods of collecting, indexing, storing and handling quality assurance records are based on established JGC engneering standards prescribing the scope of quality assurance records to be collected, periods of storage, and measures against loss.

8.11 Auditing

In accordance with the JGC engineering standards, the quality assurance engineer executes timely audits to examine the implementation of the QA Program and its effectiveness. JGC also carries out audits according to the requirements of the client during specified periods. The auditing is performed by the fully experienced and duly authorized quality assurance engineer. The audit reports are circulated to the project manager and managers of the groups subjected to audits. The groups audited shall take corrective actions, if any, regarding matters pointed out in the audits, by the specified date. The quality assurance engineer shall confirm that the necessary corrective actions have been taken, and record such actions.

Fig. 8-1 Fundamental Relation sh
and Project Execution Organizati

Contracting
Nuclear Project Division, Sales Dept

JGC Permanent Organization ⟷ Project Execution Organization

Auditing
Nuclear Project Div, Quality Assurance Dept

→ QA Manager/ QA Engi

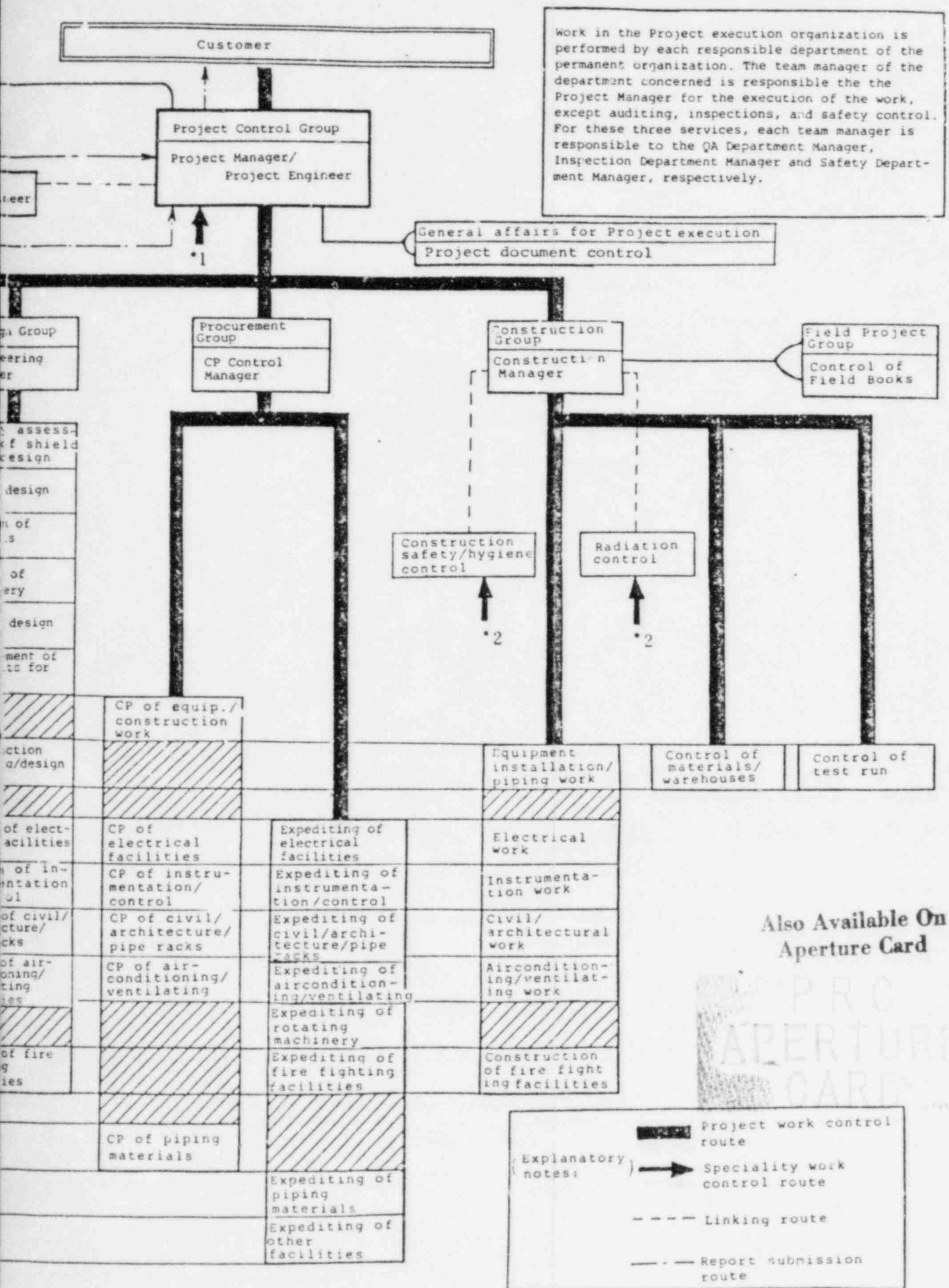
Inspection Group
General Manager of Inspection

Desi
Engin Manag

Division	Department	Team	Services	Inspection Group	Desi
Nuclear Project Div	Sales Dept		Sales/contracting		
	Project Dept		Project control → *1		
	Nuclear & Process Engineering Dept	No.1 Team	Shielding/safety assessment		Safet ment -ing
		No.2 Team	Basic design		Basic
	Mechanical Engineering Dept	No.1 Team	Design of vessels		Desic vesse
		No.2 Team	Design of machinery		Desig machi
		No.3 Team	Piping design		Pipin
		No.4 Team	Approval of construction program		Arrang Docume AACP
	Construction Cost & Procurement Dept	CP Team	Cost estimating/ issuance of P.O./cost control		
		Construction Team	Supervision	Inspection of Piping construc -tion	Constr Planni
Design Engineering Div	Electrical Dept	No.1 Team	Design/Procurement/ inspection/ expediting	Inspection of electrical facilities	Design rical
	Instrumentation & Control Dept	No.4 Team	Design/Procurement/ inspection/ expediting	Inspection of instrumentation equipment	Desig strum /cont
	Civil & Architectural Dept	No.3 Team	Design/procurement/ inspection/ expediting	Inspection of civil & architec -tural work	Design archite pipe ra
		No.3 Team	Design/Procurement/ inspection/expediting	Inspection of aircondition-ing/ventilating	Design condit ventila facili
	Rotary Machinery Dept	No.1 Team	Inspection & ex-pediting of Pump/ turbine/compressor	Inspection of rotating machinery	
	Mechanical (piping) Engineering Dept	Fire Protect-ion Design Team	Design/procurement/ inspection/expediting	Inspection of fire fighting facilities	Design fightin facilit
Project Support-ing & Administ-ration Div	Purchasing Dept	Purchasing Team	Purchase of piping materials		
		Coordination Team	Expediting of piping materials		
		Expediting Team	Expediting of equipment/ materials		
Safety & Inspection Engineering Center		Inspection Dept	Inspection of vessels/ machinery/ piping materials	Inspection of vessels/machi-nery/piping materials	
		Safety Dept	Construction safety/ hygiene, radiation protection → *2		

Note (1) Inspection work is involved

i› between JGC's Permament Organization



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9. RESEARCH AND DEVELOPMENT PROGRAM

9.1 General

Solidification of radioactive wastes with bitumen has a number of preferable features compared with solidification with cement.
Technologies on bituminization have been mainly developed in European countries such as the Federal Republic of Germany, France and Belgium and some of these are in practical use at present.

JGC has been making great efforts to improve the bituminization process since 1970 and has developed a batch process technique which is capable of treating not only the radioactive wastes generated in laboratories but also radioactive wastes generated in PWR and BWR nuclear power plants.

In 1973, JGC constructed the first bituminization plant, namely DRUM MIXER PROCESS, in Japan for the Japan Atomic Energy Research Institute (JAERI) Oharai.

In 1976, JGC re-started a research program in order to develop the DRUM MIXER PROCESS technique which is capable of treating wastes generated by nuclear power plants.
Subsequently, in 1977, JGC constructed a pilot plant at its Kinuura Laboratory and conducted a series of experiments, assigning a considerable number of laboratory personnel and skilled technicians to the work.

In 1978, JGC carried out a full scale demonstration operation of the DRUM MIXER at its Kinuura Laboratory. From this operation, JGC confirmed the reliability of a commercial size DRUM MIXER. The main equipment of this demonstration plant was delivered to the Genkai Nuclear Power Plant of the Kyushu Electric Power Company and has been being operated without any trouble since, 1980. Besides, DRUM MIXER PROCESS delivered to the Ikata Nuclear Power Plant of the Shikoku Electric Power Company has entered into the hot operation in 1981.

9.2 Pilot Plant Operation

9.2.1 System

The JGC pilot plant at its Kinuura Laboratory consists of a DRUM MIXER, Waste feed system (250 l tank and pump), Bitumen feed system (bitumen melter and pump), Heating medium system, and Distillate recovery system, etc.

The specification of the DRUM MIXER is as follows:

Effective volume	:	50 l
Dimension, length	:	1,200 mm
width	:	300 mm
Material	:	Stainless steel
Rotor speed	:	Max. 150 rpm
Motor	:	3.7 KW

9.2.2 Performance Data

This pilot plant has now been in operation for 5,000 hours since it was installed in 1977. In our own research, the joint researches with laboratories, such as the Japan Atomic Energy Research Institute, the Central Research Institute of Electric Power Industry and with all Japanese utilities, which were performed during that period, the mixing performance tests for various types of wastes, such as evaporator concentrates, spent resins, filter sludges, incineration ashes, etc., the mechanical performance test of the DRUM MIXER, and the testing of bitumen product properties were carried out to confirm the performance of the DRUM MIXER PROCESS. Typical results of cold operations conducted at this pilot plant are shown in Table 9-1.

9.3 Full Scale Cold Operation

9.3.1 System

The demonstration plant comprises a DRUM MIXER, Waste feed system, Bitumen feed system, Distillate recovery system, Heating medium system, Off-gas system, etc.

The specification of the full scale DRUM MIXER is as follows:

Effective volume	:	200 l
Dimension, length	:	1,800 mm
width	:	800 mm
Material	:	Stainless steel
Rotor Speed	:	Max. 85 rpm
Motor	:	7.5 KW

9.3.2 Performance Data

(1) Waste

Test operations were conducted using following simulated wastes.

- o Boric acid waste — 12 wt% H_3BO_3
- o Detergent waste — 10 wt% solid contents
- o Boric acid/Detargent mixture waste — 10 wt% solid contents

In the bituminization of the above waste, the liquid waste is treated after further raising pH with 25 wt% aqueous solution of sodium hydroxide. Although a solution containing sodium hydroxide and boric acid has complex features in general, a "Sodium Metaborate" solution, wherein the ratio of sodium to boron molar fraction is unity, shows relatively simple behaviour. For this reason, it was decided that, for the period of the test operations, bituminization be carried out after adjusting the ratio of sodium to boron molar fraction in the liquid to unity.

(2) Evaporation capacity

As compared with the design capacity of 140 kg/hr, the actual capacity was found to be as high as 200 kg/hr maximum.

(3) Mechanical performance

It has been confirmed that the pumps and related instruments for transporting liquid waste, bitumen, and heating medium possess the required accuracy and reliability.

Furthermore, it has been found that the thermal elongation of the DRUM MIXER and rotating mixer is within allowable limits, and that the durability and tightness of the seal unit (that is the mechanical seal and the rotary joint) are adequate.

(4) Decontamination of the DRUM MIXER

In the case of maintenance, it is necessary to enable workers to have access to the DRUM MIXER with radiation exposure as low as is reasonably achievable. It is possible to decontaminate the DRUM MIXER by washing it with hot water and/or nonflammable organic solvent.

(5) Condensate water

The condensate water contains oil likely to have originated from bitumen. It is possible, however, to reduce the oil content to less than 1 ppm by using an oil separator and active charcoal bed, thus enabling clean condensate to be obtained. Decontamination factor for the condensate water, which is normally 10^3 for sodium and boron, decreases to 10^2 where a foaming phenomenon occurs during the operation. For this reason, the use of anti-foaming agent is recommended.

(6) Typical operation data

Shown in Table 9-2 are typical operation data. Moreover, record charts representing the temperature inside of the DRUM MIXER and that of heating medium are shown in Fig. 9-1.

Table 9-1. Typical Operation Data at Pilot Plant

Item		PWR Conc.	BWR Conc.	Spent Resins PWR Conc.
Simulated Liquid Waste				
Boric acid	(kg)	20.7		10.3
Caustic soda	(kg)	13.4		6.7
Sodium sulfate	(kg)		31.5	
Beed resin	(kg)			4.2
Water	(kg)	146.9	94.6	
pH	(-)	11.5	-	11.5
Bitumen				
Type		Straight 40/60	Straight 40/60	Straight 40/60
Quantity	(kg)	25	31.5	25
Mixing Ratio (Salt/Bitumen)		50/50	50/50	10/30/60*
Heating Medium				
Flow rate in jacket	(m^3/hr)	6.0	6.0	6.0
Flow rate in mixer	(m^3/hr)	6.0	6.0	6.0
Temperature (ave.)	(°C)	256	258	190/250**
Mixing Conditions				
Temperature	(°C)	171	168	150/170**
Roter speed	(rpm)	120	120	60/120**
Feed Rate	(l/hr)	25.8	31.7	25/26.3**
Product				
Specific gravity	(-)	1.393	1.525	1.244
Softening point	(°C)	70	66.5	67.5
Residual water	(wt%)	0.1	Trace	0.71

* Resin/Borate/Bitumen weight ratio

** During treatment of resin/during treatment of concentrates

Table 9-2. Typical Operation Data for PWR Wastes at Demonstration Plant

Item		Borate	Detergent	Borate/ Detergent
Simulated Liquid Waste				
Boric acid	(kg)	71.0		35.8
Caustic soda	(kg)	46.3		15.6
Detergent	(kg)		96.3	48.2
Water	(kg)	602.6	770.4	648.1
Total salt content	(wt%)	16	11	13
pH	(-)	11.2	10.4	10.0
Bitumen				
Type		Straight 40/60	Straight 40/60	Straight 40/60
Quantity	(kg)	130	130	130
Mixing Ratio (Salt/Bitumen)		40/60	40/60	40/60
Heating Medium				
Flow rate in jacket	(m^3/hr)	15	15	15
Flow rate in rotating mixer	(m^3/hr)	25	25	25
Temperature (ave.)	(°C)	232	245	244
Mixing Conditions				
Temperature (ave.)	(°C)	184	178	178
Rotor speed	(rpm)	60	60	60
Feed Rate	(l/hr)	150	150	150
Product				
Specific gravity	(-)	1.304	1.314	1.272
Softening point	(°C)	54.0	58.5	61.0
Residual water	(wt%)	0.5	Trace	0.2

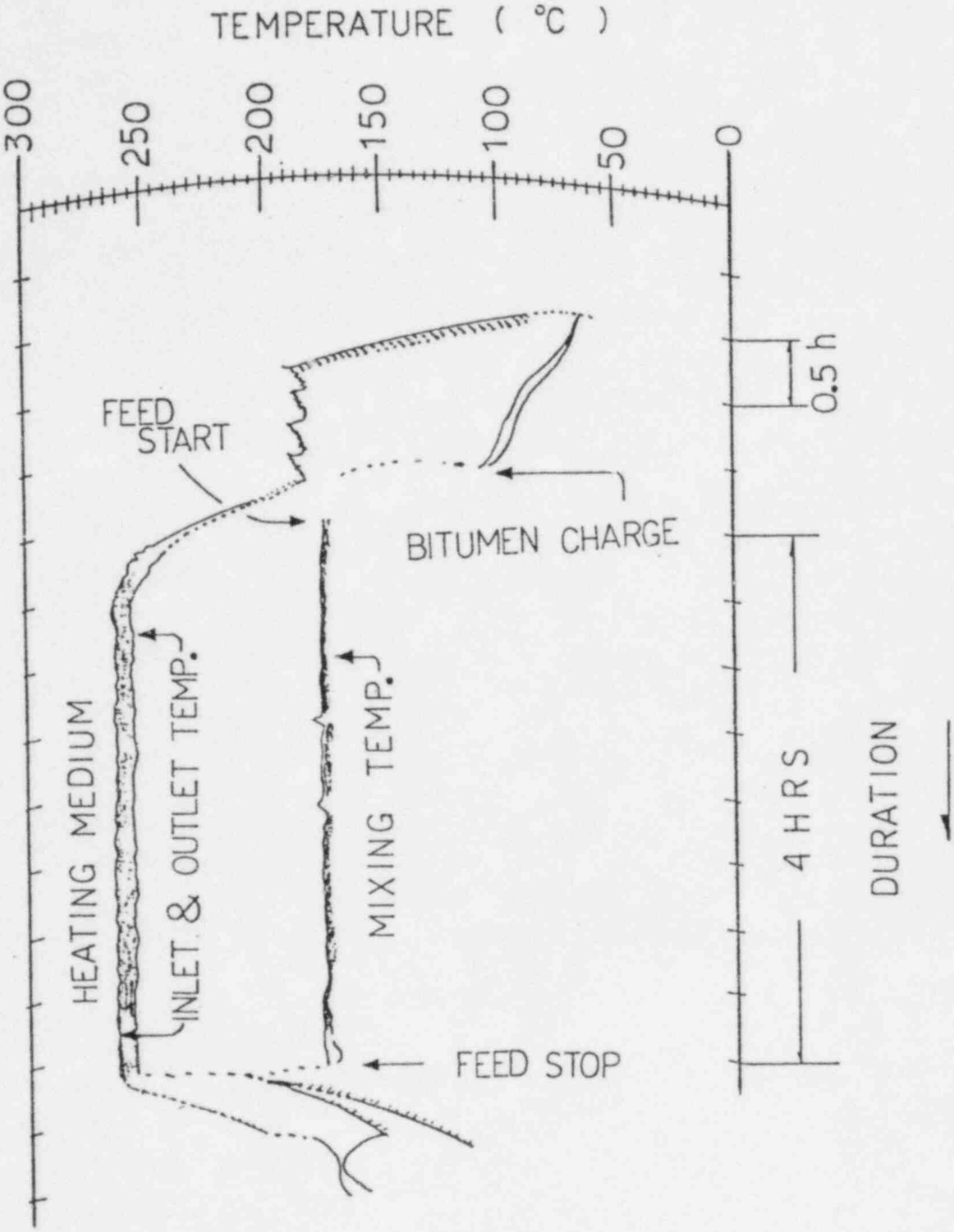


Fig. 9-1   Typical Temperature Record Chart

10. OPERATING EXPERIENCE

10.1 General

JGC Corporation has been awarded various contracts related to bituminization plants based on the DRUM MIXER PROCESS as cited in Table 10-1. The JAERI Oharai plant constructed by JGC came into hot operation in December 1973, and is the first bituminization plant in Japan.

As for the Genkai plant of the Kyushu Electric Power Company, hot operation started in the middle of April 1980 after extensive test (cold test) operations. The results of both operations are summarized as follows:

10.2 JAERI (Reference 5)

10.2.1 System

The JAERI Oharai plant consists of a DRUM MIXER, freezing and thawing unit, vacuum filter unit, bitumen feed system, oil removal unit and heating medium system with a propane gas furnace, etc.

The specification of the DRUM MIXER is as follows:

Effective volume	:	100 l
Dimension, length	:	800 mm
width	:	500 mm
Material	:	Stainless steel
Rotor speed	:	Max. 80 rpm
Motor	:	5.5 KW

10.2.2 Performance Data

The operation data obtained at JAERI Oharai are shown in Table 10-2. The waste treated therein was chemical precipitation sludge generated from low level liquid radioactive waste. Straight 60/80 asphalt was used.

10.3 LWR (References 3, 6)

10.3.1 System

The Genkai plant has such systems for bituminization plants in LWRs as DRUM MIXER, Waste feed system, Bitumen feed system, Distillate recovery system, Heating medium system, Off-gas system, Drum handling system, and so on.

10.3.2 Performance Data

(1) Type of Waste

The total volume of liquid waste treated from April to September 1980 at Genkai amounted to 75 m^3, as shown below.

Waste	Total Volume (m^3)	Radio-activity (μCi/ml)	Solid Content (wt%)
Evaporator Concentrates (Equipment Drain)	23	10^{-5}	10.0
Evaporator Concentrates (Equipment + Detergent Drains)	52	10^{-3}	2.0

(2) Overall volume reductivity

75 m^3 of liquid waste was bituminized into 41 drums, each of 200 l capacity. Overall volume reduction ratio, 9.1, seems rather high. This may be accounted for by the fact that the equipment/detargent drains had not been preliminarily concentrated to a sufficient extent due to the early stage of the hot test operation.

(3) Mechanical performance

It has been confirmed that the good mechanical performance same as of full-scale cold operaton has been obtained.

(4) Decontamination of the DRUM MIXER

After a month's operation, decontamination by using solvent and water was tried and the dose rates were measured and found to be 2.0 mrem/hr and less than 0.1 mrem/hr at the outer surface of the DRUM MIXER (including thermal insulation) before and after decontamination, respectively.

(5) Typical operational data

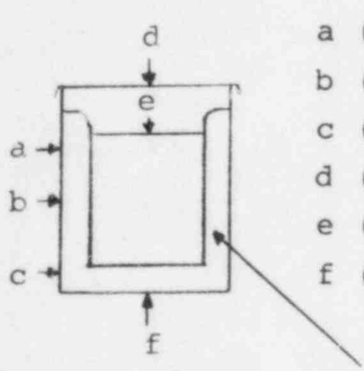
Shown in Table 10-3 are typical operational data.

Table 10-1. DRUM MIXER PROCESS Experience (Oct. 1981)

Customer	Location	Waste Type	Capacities (kg/hr)	Status
JAERI	Oharai	LAB wastes	70	Operation
JAERI	Tokai	LAB wastes	80	Operation
Kyushu Elec. Power Co.	Genkai	PWR Wastes	140	Operation
Shikoku Elec. Power Co.	Ikata	PWR wastes	140	Test Operation by Feb. 1982
Kansai Elec. Power Co.	Ohi	PWR wastes	140x2	Test Operation by Feb. 1982
Kyushu Elec. Power Co.	Sendai	PWR wastes	140	Construction
Kansai Elec. Power Co.	Takahama	PWR wastes	140	Construction

Table 10-2. Data at JAERI (Oharai, Ibaraki Pref.)

	Case 1	Case 2	Case 3
Bitumen charged (kg)	85.6	87.0	86.5
Sludge			
Solid content (kg dry)	51.6	41.9	50.6
Radioactivity (α μ-Ci/g)	$7.1x10^{-2}$	$6.4x10^{-2}$	$4.4x10^{-2}$
Radioactivity (γ μ-Ci/g)	$3.6x10^{-2}$	$3.7x10^{-2}$	$2.53x10^{-1}$
Filter aid (kg)	3.5	4.5	4.2
Mixing Conditions			
Temperature (°C)	218	218	207
Time (hr)	6.5	7.0	5.2
Condensate			
Radioactivity (α μ-Ci/g)	$8.2x10^{-8}$	$9.1x10^{-8}$	-
Radioactivity (γ μ-Ci/g)	$5.3x10^{-9}$	$1.4x10^{-8}$	-
Product			
Specific gravity	1.44	1.34	1.45
Weight (kg)	145	139	145
Radioacitvity (mCi)	4.8	3.3	2.6
Surface Dose Rate			
a (mrem/hr)	5.5	6.0	5.0
b (")	11.5	11.5	9.0
c (")	8.5	10.5	8.0
d (")	7.0	6.9	6.0
e (")	19.5	23.0	22.0
f (")	10.5	9.5	7.5



concrete lining
(50 mm thickness)

Table 10-3. Typical Operation Data at Genkai Plant

Bitumen charge per batch	(kg)	130
Liquid waste feed rate	(l/hr)	150
Mixing ratio (Solid/bitumen weight ratio)	(-)	40/60
Mixing temperature	(°C)	180
Heating medium temperature (inlet ave.)	(°C)	242
Heating medium flow rate (rotor)	(m^3/hr)	25
(jacket)	(m^3/hr)	15
Rotation rate of mixing rotor	(rpm)	60
Average duration per batch (equipment drain)	(hr)	6
(equipment and detergent drain)	(hr)	40
Volume reduction factor (equipment drain)	(-)	4.3
(equipment and detergent drain)	(-)	18.6

11. POSTULATED ACCIDENT ANALYSIS

11.1 General

This Chapter discusses the environmental impact of the DRUM MIXER PROCESS. Environmental impact of the bitumen products from the PROCESS has been analyzed (as shown in Chapters 4, 9 and 10), and the products met codes and regulations. Based on data such as the residual water content, leaching rate, and flash point of the waste solid form, it can be concluded that the environmental impact would be negligible and that no credible accident would occur once the wastes are incorporated in the solid form.

Releases of the radioactive material to the environment could conceivably include gaseous or liquid wastes. However, release of radioactive material to the environment during normal operation will be limited by process design and equipment design, as follows:

(1) The water vapor arising from the DRUM MIXER will be sent to the condenser to be condensed and subcooled. Then the distillate will be sent to the oil separator unit from the distillate tank to remove entrained oil. The oil-free distillate will be sent to the existing plant. The oil content of the distillate will be periodically analyzed and if the oil content exceeds the specified value, it will be circulated again to the oil separator unit for further oil removal.

(2) The off-gas released during the operation of the PROCESS will be sent to the off-gas cooler to remove water therefrom. Off-gas from which water has been removed will be dried by the off-gas heater, treated by the HEPA filter and activated charcoal filter, and then transferred to the plant stack for adequate dilution and final release.

Protection of plant personnel from radiation exposure is a primary factor in process design and equipment layout:

(1) Inventories in waste tanks and the associated operations will be batched with limited quantities of wastes.

(2) All operations during normal processing are controlled from control panels behind radiation shielding walls. The concentration of radioactive material in the air will be sufficiently decreased by the ventilation system in order to minimize occupational radiation exposure ALARA.

Based on the above design configuration, there would be little environmental impact due to normal operation of the DRUM MIXER PROCESS.

Operations required to process wastes using the DRUM MIXER PROCESS have also been evaluated to determine probable abnormal occurrences that could have some enviromental impact. In cases where postulated accidents are assumed to be credible, prevention systems should be included in the design.

The following two postulated accidents have been analysed:

(1) Release of radioactive material due to failure of liquid waste feed tank.

(2) Fire accident due to break of heating medium piping and ignition.

11.2 Failure of Liquid Waste Feed Tank

The following assumptions were used to estimate the environmental impact upon failure of the liquid waste feed tank.

(1) 1.6 m^3 of the waste will be spilled onto the floor.

(2) Activity of the waste is 1 μ Ci/cc.

(3) Spilled waste is spread onto the floor with a radius of 2 m.

(4) Radioactivity is due to ^{60}Co or ^{137}Cs.

The dose rate from the spilled waste will become 0.24 rem/hr for ^{60}Co or 0.06 rem/hr for ^{137}Cs at 30 cm from the source edge on the floor.

In the DRUM MIXER PROCESS, a drain pit is installed in the tank room. If the waste should be spilled entirely due to a tank failure accident, it would be collected in the drain pit and then transferred to a sump tank. Therefore, no contaminated material would be released to the environment.

11.3 Break of Heating Medium Piping

To estimate the possiblity of fire when a heating medium piping breaks in the DRUM MIXER room, the accident conditions and the properties of the heating medium were assumed as shown in Tables 11-1 and 3-1 respectively. Provided that the spilled heating medium does not ignite, it takes a few minutes for the heating medium to be cooled to its flash point of 263°C from the initial temperature of 270°C by the heat transfer of natural convection, conduction and evaporation. During these few minutes, the vapor of the heating medium could ignite due to static electricity, sparks from machines, or the like.

In a severe case in which fresh air is fully supplied to the DRUM MIXER room, the fire duration is estimated to be about 3.4 minutes by the estimation shown in Table 11-2. The fire would last longer than this because of incomplete combustion.

The condenser is installed in the same room as the DRUM MIXER, so the fire will heat the condenser as well as the DRUM MIXER.

In general, when a equipment body is directly exposed to fire flame, the heat transfer rate to the body from the fire, Q, is given by the following empirical formula (Reference 7).

$$Q = 61,000\ A^{0.82} \qquad (kcal/hr) \qquad (11\text{-}1)$$

where, A (m^2) is the exposed area of the body.

Provided that the exposed area of the DRUM MIXER and the condenser is 9 m^2 and 2.2 m^2 respectively, the heat transfer rate for each equipment is estimated by Eq. (11-1) as shown in Table 11-3.

To estimate the risk of ignition of the DRUM MIXER, the total heat capacity and the initial temerature of the DRUM MIXER, and the fire duration were assumed as shown in Table 11-4. If no water were evaporated and the temperature of the DRUM MIXER were to rise uniformly, the average temperature rise in the DRUM MIXER was calculated to be about 30°C. The final average temperature of the bitumen mixture in the DRUM MIXER is 210°C and is much lower than its flash point of 330°C. Therefore, it is concluded that the bitumen mixture in the DRUM MIXER would hardly ignite even if the above postulated fire accident did occur.

On the other hand, it is considered that the condenser would scarcely trap the water vapor from the DRUM MIXER during the fire duration as shown in Table 11-5.

To estimate the activity release to the environment when all the distillate from the DRUM MIXER released because the off-gas filters lost their funcions by excess water vapor due to the functional loss of the condenser, the conditions as shown in Table 11-6 were assumed. If the functional loss duration of the condenser and the filters was 4 minutes, the activity release from the DRUM MIXER PROCESS was calculated to be 93 u Ci.

As mentioned above, the activity released to the environment from the DRUM MIXER PROCESS is estimated to be 93 u Ci if none of the instrumentation for accident protection came into action.

The DRUM MIXER PROCESS is equipped with the following Fire Protection Systems:

(1) Interlock instrumentation for fire protection

(2) Fire alarm

(3) Interlock instrumentation for fire detection

(4) Fail safe

(5) Fire extinguishers

(6) Facility for isolating fires

Plant operators will prevent the occurrence of fires beforehand with the aid of the above protection systems even if a large amount of heating medium is spilt on the floor of the DRUM MIXER room due to a breakage of heating medium piping.

Table 11-1 Postulated Accident Conditions

Total effluent volume of heating medium	2 m^3
Duration of heating medium outflow	3 min.
Initial temperature of heating medium	270°C
Volume of DRUM MIXER room	80 m^3
Floor area of DRUM MIXER room	24 m^2
Thickness of concrete floor	0.75 m
Initial temperature of floor	40°C
Initial temperature of air	40°C

Table 11-2 Estimate of Fire Duration

Combustion rate (descending rate of oil surface level), V_B, is represented by the following formula (Reference 8) and is for the case of general combustion of surface oil in open air.

$$V_B = 0.0076\ H_C/H_V \qquad \text{(cm/min.)}$$

Where H_C = Heat of combustion

H_V = Latent heat of evaporation at boiling point

The combustion rate of the heating medium is

$$V_B = 0.0076\ (10000/31.3) = 2.43 \qquad \text{(cm/min.)}$$

Therefore, the fire duration T_B is calculated as

$$T_B = (2/24)(100)(1/2.43) = 3.4 \qquad \text{(min.)}$$

Table 11-3 Heat Transfer Rate from Fire

DRUM MIXER	3.7×10^5 kcal/hr
Condenser	1.2×10^5 kcal/hr

Table 11-4 Postulated Fire Accident for DRUM MIXER

Heat Capacity of DRUM MIXER is:	
Weight of the body stainless steel	4,100 kg
Heat capacity of the body	0.15 kcal/kg°C
Weight of bitumen mixture	230 kg
Heat capacity of bitumen mixture	0.4 kcal/kg°C
4,100 x 0.15 + 230 x 0.4 = 707 kcal/°C	
Initial Temperature of DRUM MIXER	180°C
Fire Duration	3.4 min.

Table 11-5 Comparison of Cooling Capacity of Condenser with Heat from Fire

Cooling Capacity of Condenser	1.0×10^5 kcal/hr
Heat from Fire	1.2×10^5 kcal/hr

Table 11-6 Radioactivity Release during Fire

Functional loss time of condenser and filters	4 min.
Vaporizing rate of liquid waste from DRUM MIXER	140 kg/hr
Radioactivity of liquid waste	1 μ Ci/cm^3
Decontamination factor of vaporization process	10^2

Radioactivity release is

$$(140 \times 10^3)(4/60)(1 \times 10^{-2}) = 93\ \mu\ Ci$$

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13. AMENDMENT

This Amendment presents the answers to the questions prepared in connection with JGC Corporation's Topical Report "THE DRUM MIXER PROCESS FOR VOLUME REDUCTION AND SOLIDIFICATION", Report No. JGC-TR-001-P, November 1981.

Article 1 gives answers to the general questions on JGC Corporation's Topical Report. Subsequent Articles give answers to the questions on each chapter of the Topical Report as follows:

Article 2 on Chapter 3 - PROCESS DESCRIPTION

Article 3 on Chapter 4 - PROCESS PARAMETER

Article 4 on Chapter 5 - EQUIPMENT DESCRIPTION

Article 5 on Chapter 6 - EQUIPMENT LAYOUT

Article 6 on Chapter 11 - POSTULATED ACCIDENT ANALYSIS

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ARTICLE 1. ANSWERS TO GENERAL QUETIONS ON JGC CORPORATION'S TOPICAL REPORT

QUESTIONS

(1) The generation volumes of wastes which are described in your Topical Report seem to be small. JGC Corporation should re-evaluate the amount of wastes generated at nuclear power generating stations in the U.S. on the basis of the published data for adopting the capacity of the DRUM MIXER.

(2) In your Topical Report, JGC Corporation should clarify if the solidified products from the DRUM MIXER PROCESS will meet the criteria for 10 CFR Part 61.

ANSWER

(1) Taking, for example, a solidification plant of standard specifications having one DRUM MIXER, the Topical Report (Reference 1) covers the description of the process, the main equipment, the equipment layout and the safety analysis, and can be said to show an entire picture of the DRUM MIXER PROCESS.

Accordingly, in designing for a specific power plant, it is necessary to specifically review and to take into account the types of wastes to be solidified, the generation volumes of the wastes, the philosophy on the plant operation method, etc.

Presented hereinafter are the trial calculations of the annual operation time and required number of DRUM MIXERs on the basis of the average waste generation rates received from NRC.

1.1 EVALUATION OF AMOUNT OF WASTES GENERATED

According to the data (refer to Tables 1-1 - 1-3) received from NRC, the amount of wet wastes generated from 3,300 MWt P/S is summarized as shown below.

Type of Reactor		Volume (m^3/Y)
PWR	Deep bed	400
	Powdered resin	500
	No CPS	300
BWR	Deep bed	1100
	Powdered resin	550

The above amounts show the total of wet waste, and the wet waste consists of spent resin and evaporator concentrate. Determining this rate and solid contents from ERDA data and Japanese experience and calculation of the amount generated per waste shown in the NRC data, the results are as shown below.

Type of Reactor		Waste	Rate (%)	Volume (m^3/Y)	Solid Content (wt%)
PWR	Deep bed	Spent resin	10	40	20
		Concentrate	90	360	10
	Powdered resin	Spent resin	87	435	20
		Concentrate	13	65	10
BWR	Deep bed	Spent resin	30	330	20
		Concentrate	70	770	25
	Powdered resin	Spent resin	10	550	20
		Concentrate	-	-	-

1.2 OPERATING TIME AND REQUIRED NUMBER OF DRUM MIXERS

The operating time and necessary number of drums are calculated on the basis of the above amounts generated. The results of the calculation are shown in Table 1-4. Also, the required number of DRUM MIXERs is found on the basis of an operating time of 20 hours/day, taking the number of operating days as 250 days/year (5,000 operating hours/year). Its summary is shown below together with the results of calculation as above-mentioned.

Type of Reactor		Required Annual Operating Time (hr)	Number of Drums per Year	Required Number of DRUM MIXERs
PWR	Deep bed	3060	401	1
	Powdered resin	6052	955	2
BWR	Deep bed	9193	2098	2
	Powdered resin	7072	1134	2

With regard to the number of DRUM MIXERs, JGC considers that the matters mentioned below are standard from the standpoint of past installation conditions in Japan.

PWR: One per unit
BWR: Two per unit

In the case of the two DRUM MIXERs per unit, it is necessary to provide the two trains of the Evaporating/Mixing System, the Distillate Recovery System (Condenser) and of the Heating Medium System. Further, it is necessary that the second floor of the relevant building given in the Equipment Layout (Fig. 6-1 (2) in Reference 1) has an area approximately 1.5 - 2.0 times of the originally designed area for one-DRUM MIXER per unit.

(2) 10 CFR PART 61 and BITUMEN PRODUCT

The items directly related to the conditions of disposal packages in 10 CFR Part 61 are (a) waste classification and (b) waste characteristics.

Regarding the item (a), it will be appropriate to consider the quality of bitumen product according to the Class C requirements, in view of the activity level of concentrated waste, spent resin, and incinerator ash which constitute the radwastes of the DRUM MIXER PROCESS.

The quality of waste products up to Class C specified under the item (b) waste characteristics can be summarized into the following three points.

- Structual stability
- Free-water content
- Void spaces

Regarding structual stability, we consider that the integrity of our product is maintained in view of the following points.

- o As a result of long-term immersion tests, changes in the weight are very small.
- o The leaching rate of nuclides is 10^{-3} - 10^{-6} g/cm^2.day, or very low.
- o Asphalt is derived from petroleum distilled reside and it is inconceivable that microorganisms, etc. will attack the bitumen.

o The radiation resistance is 10^8 rad, and there is no problem with regard to low level reactor wastes.

Meanwhile, the free-water content (0.5% or less) of bitumen product packed in steel drums is stipulated.

Under the DRUM MIXER PROCESS, wastes are mixed into bitumen heated at 150°C - 180°C for several hours or more, and free water does not exist.

Furthermore, the void spaces between wastes and containers can be easily controlled, because the DRUM MIXER PROCESS is operated by means of batch operation (1 batch - 1 drum).

Consequently, we consider that the quality of the bitumen product produced by the DRUM MIXER PROCESS will satisfactorily meet the criteria for 10 CFR Part 61.

TABLE 1-1 NRC DATA

AVERAGE ANNUAL ADJUSTED WET WASTE VOLUMES

NORMALIZED TO A 3,300 MWt PLANT AT 0.8 CAPACITY:

PWRs

Plant	Volume (m^3)	Number of Reactor-Years
Deep Bed CPS		
Beaver Valley 1	200	3
Crystal River 3	1,300	2.5
Ginna	350	9
Millstone 2	180	4
Rancho Seco	350	5
Powdered Resin CPS		
Davis Besse 1	390	2
Oconee 1, 2, 3	570	12
Three Mile Island 1	200	2
No CPS		
Calvert Cliffs 1, 2	250	3
Cook 1, 2	300	2
Farley	320	1
Fort Calhoun	1,000	6
Haddam Neck	200	12
Indian Point 1, 2, 3	440	12
Kewaunee	58	6
Maine Yankee	220	7
Palisades	580	7
Point Beach 1, 2	93	18

TABLE 1-1 NRC DATA

AVERAGE ANNUAL ADJUSTED WET WASTE VOLUMES

NORMALIZED TO A 3,300 MWt PLANT AT 0.8 CAPACITY:

PWRs

(Continued)

Plant	Volume (m^3)	Number of Reactor-Years
Prairie Island 1, 2	95	10
H.B. Robinson 2	490	8
St. Lucie	320	2
San Onofre *1	370	6
Surry 1, 2 *2	200	8
Trojan	120	3
Turkey Point 3, 4	370	12
Zion 1, 2	280	10
Mean Volume (weighed by number of reactor-years)	330	-
Median Volume	280	-
Mean Volume Excluding Ft. Calhoun and Crystal River 3	290	-

Note

*1: 1981 anomalous data deleted from average

*2: 1979 anomalous data deleted from average

TABLE 1-2 NRC DATA

AVERAGE ANNUAL ADJUSTED WET WASTE VOLUMES

NORMALIZED TO A 3,300 MWt PLANT AT 0.8 CAPACITY:

BWRs WITH DEEP BED CONDENSATE DEMINERALIZERS

Plant	Volume (m^3)	Number of Reactor-Years
Brunswick 1, 2	1,400	4
Dresden 1, 2, 3	1,000	24
Fitz Patrick	950	4
Millstone 1	1,500	9
Nine Mile Point 1	810	10
Oyster Creek	1,200	10
Pilgrim	830	7
Mean Volume (weighed by number of reactor-years)	1,100	-
Median Volume	1,000	-

TABLE 1-3 NRC DATA

AVERAGE ANNUAL ADJUSTED WET WASTE VOLUMES

NORMALIZED TO A 3,300 MWt PLANT AT 0.8 CAPACITY:

BWRs WITH POWDERED RESIN CONDENSATE DEMINERALIZERS

Plant	Volume (m^3)	Number of Reactor-Years
Browns Ferry 1, 2, 3	440	8
Cooper Station	280	4
Duane Arnold	1,100	5
Hatch 1	740	4
Monticello	420	9
Peach Bottom 2, 3	740	10
Quad Cities 1, 2	440	14
Vermont Yankee	460	7
Mean Volume (weighed by number of reactor-years)	550	-
Median Volume	440	-

TABLE 1-4 OPERATING TIME AND NUMBER OF UNITS FOR DRUM MIXER PROCESS

Type of Reactor	Type of Waste	Amount of Radwaste		Input to Drum Mixer		Required Annual Operating Time (hr)	No. of Drums Per Year
		Volume (m^3/Y)	Amount of Solids (ton/Y)	Amount of Water (ton/Y)	Amount of Solid (ton/Y)		
PWR Deep Bed	Spent Resin	40	8	72	8	514	83
	Concentrates	360	39.6	356.4	47.9	2,546	318
						Total 3,060	401
Powdered Resin	Spent Resin	435	87	783	87	5,593	897
	Concentrates	65	7.2	64.3	8.7	459	58
						Total 6,052	955
BWR Deep Bed	Spent Resin	330	66	594	66	4,243	680
	Concentrates	770	231	693	231	4,950	1,418
						Total 9,913	2,098
Powdered Resin	Spent Resin	550	110	990	110	7,072	1,134

ARTICLE 2. ANSWERS TO QUESTIONS ON CHAPTER 3 PROCESS DESCRIPTION

Q1. SEC. 3.2.1 (1) EVAPORATOR CONCENTRATE

Please discuss the sampling of evaporator wastes and the addition of reagents. In particular address whether the sampling is part of the Process Control Program (PCP), how often, for what purpose, etc. On addition of reagents used for evaporator concentrates, what reagents are allowed? If only NaOH is used or allowed, this should be stated in the PCP. How is the predetermined salt/bitumen ratio to be used in solidifying determined for a particular batch of waste? Is this part of the Process Control Program?

ANSWER

(1) The sampling is part of the PCP. It is necessary before the Evaporating/Mixing Operation.

(2) For processing PWR evaporator wastes, the sampling has two purposes.
The first purpose is to measure the pH value of the wastes to determine the quantity of reagent to be added for pH adjustment.
The second purpose is to measure the salt concentration of the wastes after pH adjustment.

(3) For processing BWR evaporator wastes, sampling is necessary only for the second purpose, because pH adjustment is not required.

(4) Caustic soda is used as a reagent because of its economy and availability.

(5) The volume of waste required to obtain one drum of product with a pre-determined salt/bitumen ratio is determined on the basis of the salt concentration measured. Control of volume is done by manually presetting the integrating flowmeter.

(6) For further details about the PCP, please refer to Q15's answer.

Q2. SEC. 3.2.1 (2) SPENT RESIN

Please discuss what type of spent resin feeder is used.
Also is the extent of resin dewatering controlled by the PCP or does the process place no limits on this?

ANSWER

The information on this page is proprietary.

Q3. SEC. 3.2.1 (3) INCINERATION ASH

Describe the limits placed on amounts of ash supplied to the DRUM MIXER and the basis upon which this was determined. Where is this described in the PCP?

ANSWER

(1) Though the limit in the amount of mixture of ash is 60 wt%, the amount is designed at 50 wt%, taking a design margin into account. In the case of 55 gal drums (net volume: 220 l), the amount of ash per drum is 210 kg at a mixing ratio of 60 wt%, and 165 kg at a mixing ratio of 50 wt%.

(2) Generally, the mixing ratio of solids depends on (a) Mixability and (b) Property of products.

With regard to (a), a mixability in excess of 60 wt% will adversely affect the dispersibility of ash, the fluidity of the bitumen mixture will be lowered, the bumping time from the DRUM MIXER will be lengthened, and the residual amount of mixture in the DRUM MIXER will be increased.

On the other hand, with regard to (b), as a result of comparing the weight increase ratio of the products by performing an immersion test, it is found that the ratio is 1 - 2% at 100 days immersion for mixing ratios of 40, 50, and 55 wt%. Therefore, large differences cannot be seen.

Accordingly, it has been determined that the standard ash mixing ratio is 50 wt%.
Typical examples of the values of physical properties of the products at a mixing ratio of 50 wt% are shown in Table 2-1.

(3) The above matters are described in the PCP.

Table 2-1 Properties of Ash Product

1.	WASTE	Ashes
2.	BINDER	Bitumen Straight 40/60
3.	MIXING RATIO (WASTE/BINDER)	50/50
4.	PRODUCT PROPERTIES	
	(1) Specific gravity	1.50
	(2) Softening point (°C)	65
	(3) Residual water content (wt%)	0.05
	(4) Water resistance* (wt%)	+1.5**
	(5) Leaching tendency*	10^{-4}***
	(6) Burning point (°C)	295

* IAEA size test data

** Change in weight at 100 days

*** Cs-137 leach ratio at 1,000 days

Q4. SEC. 3.2.3 (2) ANTIFOAMING REAGENT

Please discuss any limitations placed on the anti-foaming agents used and whether they affect operation of the distillate recovery system. How does the PCP control this?

ANSWER

The information on this page is proprietary.

Q5. SEC. 3.3 (1) EVAPORATING/MIXING SYSTEM

What restrictions or controls are placed on the bitumen type or grade?

ANSWER

(1) The bitumen can be broadly classified into two types, i.e. straight and blown. The largest difference in physical property is in particle size, as shown in Table 4-1 in Reference 1. This is related to (a) the temperature at transportation and (b) the limitation of temperature during the mixing operation.

Namely, a temperature of more than 130°C is required for the straight type and more than 150°C is required for the blown type to be transferred through a pipe.

Though the mixing temperature is 150 - 180°C in the straight asphalt, the blown asphalt requires 180 - 200°C as a mixing temperature to improve dispersibility and to reduce the motor load of the DRUM MIXER.

(2) It is necessary to confirm the type and grade of the bitumen before receiving it into the Bitumen Tank.

Q6. SEC. 3.4.1 DISTILLATE RECOVERY SYSTEM

What are the expected radiation levels associated with the condensate in the distillate tank and the oil free condensate? Describe the operator action if there is a high radiation alarm traced to this source.

ANSWER

(1) The expected radiation levels associated with the condensate in the Distillate Tank (T-4) for various types of waste are shown in Table 2-2.

The decontamination factor for the DRUM MIXER (M-8) is 10^2 for iodine and 10^3 for the particulates other than iodine. Therefore, the expected radioactivity of the condensate in the Distillate Tank (T-4) is approximately 1/200 of that of the feed waste to the DRUM MIXER (M-8) in the case of PWR waste (total) shown in Table 2-2 in Reference 1 and is 1/220 in the case of BWR waste (total) shown in Table 2-3 in Reference 1.

It is desirable to provide two distillate tanks when the difference between the maximum and the minimum radioactive waste activity is large.

The expected radioactivity of the oil free condensate is the same as that of the condensate in the Distillate Tank (T-4) because it can hardly be expected that radioactive nuclides will be removed by the Oil Separator Unit (M-5).

(2) The radioactivities of the wastes to be treated by the DRUM MIXER PROCESS depend strongly upon the type of wastes as well as the plant in which the wastes are generated. Therefore, a high radiation alarm is at the option of the applicant. If the radioactivity of the distillate is high, the distillate should be transferred to the Liquid Waste Feed Tank (T-1) and should be processed again after removing that which causes the misprocessing.

Table 2-2 Radiation Levels Expected from Distillate Tank

Waste*		Activity (Ci/m^3)	Dose Rates (mR/hr) At Surface	Dose Rates (mR/hr) At 1 m
Bead Resin	(High)	3.22	3,200	640
	(Low)	5.0×10^{-3}	4.0	0.80
Powdered Resin	(High)	0.54	440	88
	(Low)	1.3×10^{-4}	0.13	0.026
PWR Evaporator Concentrate	(High)	1.6×10^{-4}	0.16	0.031
	(Low)	8.9×10^{-5}	0.089	0.081
BWR Evaporator Concentrate	(High)	3.2×10^{-2}	26	5.1
	(Low)	8.1×10^{-5}	6.6×10^{-2}	1.3×10^{-2}

*: The generation volume and radioactivity are specified in Table 2-1 in Reference 1.

Q7. SEC. 3.4.2 DRUM HANDLING SYSTEM

Discuss to what extent JGC's process interfaces and places requirements or restrictions on the plant's drum handling system, shielding and ventilation.

ANSWER

JGC can provide all the drum handling systems consisting of Drum Conveyer System, Drum Storage System, Smear Survey Unit, Drum Decontamination Unit, and Truck Loading Bay. (Refer to Fig. 6-1 in Reference 1.) In this case, JGC's interface is the truck entrance.

The product filling position of the Drum Conveyer System should be installed just below the DRUM MIXER.

The shielding of these systems is, for example, as shown in Fig. 6-1 in Reference 1.

A ventilation system is also required in these areas as well as in other areas.

Q8. SEC. 3.4.3 OFF-GAS SYSTEM

Where is off-gas sent after filter M-14, back to the plant H & V system or to a separate release point? This is not clear.

ANSWER

Off-gas is sent to the plant H & V system after the Off-gas Filter (M-14).

Q9. SEC. 3.4.4 HEATING MEDIUM SYSTEM (1)

Mineral oil is mentioned as a typical heating medium and its properties given. Does the process control program restrict the heating medium to this material or are others allowed? Discuss also if there is a possibility of the heating medium boiling, if not why not, and if so what the expected effects would be. In the event that heating medium leaks into the asphalt in the DRUM MIXER, what are the expected consequences and how would they be addressed?

ANSWER

(1) The PCP restricts the heating medium to a special mineral oil which is superior in heat stability, with a high flash point.

(2) A temperature alarming system is provided to prevent the operating temperature of the heating medium from exceeding 260°C as mentioned in Sec. 3.6.2 (1) in Reference 1. The boiling point of a typical heating medium is about 420°C. Therefore, there is no possibility of the heating medium boiling.

(3) In the event that the heating medium leaks into the bitumen mixture in the DRUM MIXER (M-8), the low liquid level in the Heating Medium Surge Tank (T-6) will be detected and not only will an alarm be given to notify the operators but also the DRUM MIXER PROCESS will be put into emergency cooling operation. In the DRUM MIXER (M-8) the leaked heating medium will be mechanically mixed with bitumen.

Therefore, even if the heating medium leaks at 270°C which is higher than its normal operation temperature (250°C), the temperature of the heating medium will immediately fall to that of the bitumen mixture (180°C in normal operation). Because the flash point of the heating medium is 263°C (Table 3-1 in Reference 1) and the flash point of the bitumen mixture is over 330°C (Fig. 4-3 in Reference 1), there is no possibility of a fire.

Q10. SEC. 3.4.4 HEATING MEDIUM SYSTEM (3)

Discuss the N_2 cover gas system for the heating medium storage tank. In particular address the pressure maintained, the source of N_2 gas and what precautions or methods are used to assure no oxygen is present. This should be addressed in the Safety Analysis.

ANSWER

(1) The Heating Medium Surge Tank (T-6) is supplied with N_2 gas from a N_2 gas cylinder or the like, and the tank pressure is controlled at approx. 50 mmAq by the pressure regulator.
By this means, the tank is sealed with N_2 gas so that no oxygen (air) will enter the tank. In the event that the presetted pressure is not kept, the alarm system notifies operators.

(2) In accordance with your comment, JGC will revise Sec. 11.3 Page. 11-6 in Reference 1 as follows:

The DRUM MIXER PROCESS is equipped with the following Fire Protection Systems:

(a) Interlock instrumentation for fire protection

(b) Fire alarm

(c) Interlock instrumentation for fire detection

(d) Fail safe

(e) Fire extinguishers

(f) Facility for isolating fires

(g) N_2 cover gas system

Plant operators will prevent the occurrence of fires beforehand with the aid of the above protection systems even if a large amount of heating medium is spilt on the floor of the DRUM MIXER room due to a breakage of heating medium piping.

Q11. SEC. 3.4.5 DECONTAMINATION SYSTEM (1)

Describe the DRUM MIXER decontamination in more detail with reference to fire safety. Of interest is what is the solvent or solvents used, their flash point if flammable, and maximum allowed temperature during decontamination operations. What is the mutual solubility of the solvent and water? Also is credit taken for the water as part of fire prevention? Are there provisions for inerting the gas in the solvent tank? Is the decontamination procedure part of the Process Control Program? What are the criteria for deciding that decontamination is complete?

ANSWER

The information on this page is proprietary.

Table 2-3 Properties of Typical Solvent

Chemical formula	The information on this page is proprietary.
Density at 20°C	
Boiling point at 1 atm	
Viscosity at 20°C	
Heat capacity at 20°C	
Latent heat at boiling point	
Mutual solubility	
Hydroscopic	
Azeotropic point of a mixture of solvent and water	
Content of azeotrope	
Solvent	
Water	
Flash point	

Q12. SEC. 3.5 PROCESS MONITORING AND SAMPLING

Indicate on the P & ID where the iodine sampler and the off-gas monitor are located. Discuss.

ANSWER

JGC Corporation cancels the iodine sampler and the off-gas monitor described in Sec. 3.5 in Reference 1, because they are not considered within JGC Corporation's scope of work. This is the responsibility of the main contractor or utility. A total plant evaluation is necessary to determine such locations, and whether they should be included within or outside of our proposed system. JGC Corporation cannot solely determine these locations.

Q13. 3.6.2 INTERLOCK AND ALARM (1)

Please discuss what actions or procedures occur in the event that the heating medium cooler M-3 fails or otherwise becomes inoperative. Is its operability required as part of the Process Control Program?

ANSWER

In the event that the Heating Medium Cooler (M-3) fails, the following detections and interlocks ensure a safety operation.

(1) In the case where the flow rate or the pressure of cooling water drops:

- The Heating Medium Heater is off.
- The mixing/evaporating procedure stops or does not start.
- The alarming system notifies the operators.

(2) In the case where the entrance valve (automatic valve) to the Heating Medium Cooler does not open in the cooling procedure:

- The alarming system notifies the operators.

(3) The entrance valve is designed fail-safe, so that it opens in the case where electricity or instrument air is down.

By means of the above interlocks, in the case where the Heating Medium Heater (M-3) fails, the temperature of the heating medium can not still more rise up. And the temperature is expected to cool naturally. Therefore the operator's action is not required, and the operability is not required as part of the PCP.

Q14. SEC. 3.6.2 INTERLOCK AND ALARM (2)

Please describe the kind of leak detector used for detecting leaks from the heating medium.

ANSWER

The leak from the heating medium is detected by means of the following devices:

(1) Level gauge is installed in the Heating Medium Surge Tank (T-6). A level "Low" alarm notifies operator of a leakage.

(2) Level gauges are installed in the drain pits in the Heating Medium System rooms. A level "High" alarm notifies operator of a leakage.

ARTICLE 3. ANSWERS TO QUESTIONS ON CHAPTER 4 PROCESS PARAMETERS

Q15. GENERAL COMMENTS ON CHAPTER 4

This chapter comes the nearest to describing the Process Control Program. However, as written, it is inadequate for the purpose. It describes what the process parameters are and gives recommended ranges for some of them. The chapter uses words such as "usually", "recommended", "available", "suitable". It is not clear what should or must be controlled.

A process control program is a description of the combination of hardware and administrative or operator procedures by which control of the process is maintained and quality of the process result is assured.

And an adequate process control program description should state what the major process parameters are, what the nominal values are, and the allowed range of variation they may have and under what conditions. It should address how values of parameters are obtained (e.g., hardware indicator, sample analysis, grade or quality of purchased imput feeds, etc.), and how control over these is exercised. Automatic and procedural controls (actual procedures if desired) should be given. In procedural controls the parameters whose values are logged should be described, and what action the operator is to take in the event a parameter exceeds its allowed range. Also of importance is a description of what samples are to be taken as part of the PCP, how often and for what purpose, and how they are analyzed as well as a clear statement as to how the results are to affect the future course of the process.

If the PCP has hold points these should be described. In addition, the PCP should state the criteria upon which the results of the process (i.e., a filled drum) are considered acceptable, as well as what actions are taken if it does not meet acceptance criteria. The PCP should also address what actions or procedures are followed in the event the waste is off standard (e.g., inadvertent oil in the evaporator waste).

ANSWER

In accordance with your general comments, JGC will revise Sec. 4.1 in Reference 1 as follows:

4.1 Process Control Program

In the DRUM MIXER PROCESS, the following items are to be controlled from the standpoint of operability and product quality.

The information on this page is proprietary.

Each item is controlled through the Process Control Program consisting of the following procedures.

The information on this page is proprietary.

In order to comply with the above requirement, the following operations should be carried out.

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The information on this page is proprietary.

Q16. SEC. 4.1.1 CONDITIONS OF FEED WASTE pH (3)

It is stated that for PWR sodium borate waste pH should be adjusted to between 10 and 11.5. Is this done as part of the process control and what are the operator actions if this pH cannot be obtained?

ANSWER

This is part of the PCP. The operator must repeat the pretreatment of wastes if this pH cannot be obtained.

Q17. SEC. 4.1.1 CONDITIONS OF FEED WASTE: SOLID CONCENTRATION (1)

Is the value of 15 - 20% salt content of evaporator concentrate a limiting range outside of which waste will not be processed? Discuss this including what are the limiting ranges and what the procedure is if the waste lies outside the process control range.

ANSWER

In the DRUM MIXER PROCESS, the required salt/bitumen ratio is maintained by controlling the integrate volume of feed liquid waste according to its salt content (as described in the Answer to Q15).

Therefore, from the standpoint of operability, the range of salt content is not restricted.

However, from the standpoint of the salt precipitation, the maximum content is restricted as follows.

- o BWR Waste: Below 25%-Na_2SO_4
- o PWR Waste: Below 21,000 ppm-B

Q18. SEC. 4.1.1 CONDITIONS OF FEED WASTE: SPENT RESIN (2)

Is this maintained at 50 - 60% water by the process control program? What is done if the water content is greater or less than this?

ANSWER

The process places no limit on the water content of dewatered resin.

Q19. SEC. 4.1.2 MIXING RATIO

The values of mixing ratio are stated to be "recommended". What variation from these is allowed by the process and how is the ratio controlled procedurally? Discuss this.

ANSWER

The mixing ratio should be controlled so as not to exceed the designed value from the viewpoint of operability and product properties.

The procedures for controlling the value are described in revised Sec. 4.1.2 in Reference 1. Please refer to the answer to Q15.

Q20. TABLE 4-1 PROPERTIES OF BITUMEN

Define the factors used in the column headings. Define penetration and the units as used in this table.

ANSWER

(1) Column heading

Usually, the asphalt is broadly classified into straight and blown types depending on the manufacturing method, and is finely classified depending on the extent of softness (extent of penetration). Straight 40/60 means that the penetration is in the range of 40 to 60 for straight asphalt. (With regard to the unit of penetration, refer to (2). JGC regards straight 40/60 as standard asphalt.

(2) Penetration (0.1 mm)

Penetration means the penetration depth of a needle in the case where a fixed load (100 g) is applied to the sample asphalt for a unit time (5 seconds) at a fixed temperature (25°C), expressed in units of 0.1 mm. Therefore, the deeper the penetration of the needle, the softer the asphalt is.

(3) Softening point (°C)

The softening point denotes the temperature at which the asphalt attains a predetermined consistency under fixed conditions.

(4) Specific gravity (25/25°C)

The specific gravity is expressed by the ratio of the density of asphalt at 25°C to the density of water of the same volume at 25°C. Usually, the specific gravity is found by using a water substitution method.

(5) Evaporation loss (163°C x 5 hrs, wt%)

In order to determine the change in the properties of asphalt during the heating and melting operation, the difference the evaporated portion of asphalt and the degree of penetration thereof is used as an index. The evaporation loss shows the volume reduction of the sample (wt%) after it is kept at 163°C for five hours.

(6) Penetration after evaporation (%)

This shows the change in the penetration value (%) after the above test.

(7) Viscosity (cSt)

Viscosity is one of the important properties of asphalt. The behavior of asphalt and its mixtures thereof is attributed to its viscosity. The viscosity of asphalt in relation to temperature is indicated in Centi Stokes.

Q21. TABLE 4-2 PROPERTIES OF BUTUMINIZED PRODUCTS

What does the ratio 40/60 under "Straight" mean? Define penetration and the units used. Please discuss the leach rate tests, and the units used. State the procedure used or reference it (e.g., IAEA, ANSI, etc.). What does a leak rate of 2×10^{-3} g/cm^2.day mean? Is this 2×10^{-3} g of Na^+ leached per cm^2 of the entire surface area of a drum-sized monolith of bitumen? Describe in more detail. How does the quoted leach rate compare with published values? Discuss to what extent the Na^+ leach rate is applicable to the nuclides given in Table 2-2 and 2-3. If any leach tests using radioactive nuclides have been done as part of JGC's R & D, please discuss them.

ANSWER

(1) Refer to Q20's answer regarding the meaning of straight 40/60.

(2) Refer to Q20's answer regarding the explanation of penetration.

(3) Leach test

This test is conducted according to the immersion test method suggested by IAEA in 1968 (Reference 2) and in 1971 (Reference 3).

- Size of solid : ø 50 mm x H50 mm
- Leach water : Type - ion exchange water
Volume - 750 ml
Temperature - 25°C or 5°C

- Replacement frequency of leach water: Once a day during the first one week

  Once a week during the subsequent 8 weeks

  Once a month during the subsequent 6 months

  Subsequently once per 6 months

  (The water should be measured each time it is replaced.)

- Method for calculating the leaching rate

$$Rn = \frac{(a/Ao)}{(S/W)} \times \frac{1}{t_n - t_{n-1}} \ (g/cm^2.day)$$

t_n, t_{n-1}: n, n-1th replacement time

a : Volume of Na^+ leached during the n, n-1th replacement time

Ao : Total volume of Na^+ in sample

S : Surface area of sample

W : Weight of sample

Alternatively, the leaching ratio will be obtained from the following formula.

$$Rn' = \frac{(a/Ao)}{(S/V)} \times \frac{1}{t_n - t_{n-1}} \ (cm^3/cm^2.day)$$

Where,

V: Volume of sample

(4) Comparison with published data

Because the leach test data are affected by the types of radwastes and nuclides, mixing ratio of radwastes, testing and data calculation methods, and leaching conditions (leaching water, temperature, and size of sample), it is difficult to compare the leaching rate data with the published data. According to the IAEA publications (References 4 and 5), the leaching rate of asphalt solids is in the range of 10^{-3} - 10^{-6} g/cm^2.day.

JGC has obtained this data as per Table 2-1, based on the change in the conditions of the type of radwaste and mixing ratio, etc. Further, this data coincides with that in the published literature.

(5) Leaching rate of radionuclides

Fig. 3-1 shows data on the leaching rate of radionuclides of sodium borate products (mixing ratio: 40/60).

The data shows that the leaching rates of Co - 60 and Cs - 137 are 10^{-5} g/cm^2.day and are almost the same as the Na leaching rate of cold products made under the same conditions as those of sodium borate products (mixing ratio 40/60) shown in Fig. 3-1.

Oak Ridge National Laboratory has reported that the leaching rates (10 weeks) of Na and Cs - 137 are 2 x 10^{-4} g/cm^2.day and 3 x 10^{-4} g/cm^2.day respectively, and that it is satisfactory to express the leaching rate of soluble nuclides in terms of Na (Reference 4).

Table 3-1 Asphalt Solidification Products under Various Conditions (JGC Test Data)

Waste	Mixing Ratio (Waste/ Bitumen)	Size of Sample	Leaching Ratio (g/cm .day)	Tracer
Sodium Borate	40/60	IAEA	$5x10^{-5}$	Na^{+}
Sodium Borate	40/60	200 1	$2x10^{-5}$	Na^{+}
Sodium Borate	50/50	IAEA	$1x10^{-3}$	Na^{+}
Sodium Borate	40/60	IAEA	$6x10^{-5}$	Cs-137
Sodium Borate	40/60	IAEA	$2x10^{-5}$	Co-60
Sodium Borate	30/70	IAEA	$5x10^{-4}$	Na^{+}
Sodium Borate	50/50	IAEA	$2x10^{-3}$	Na^{+}

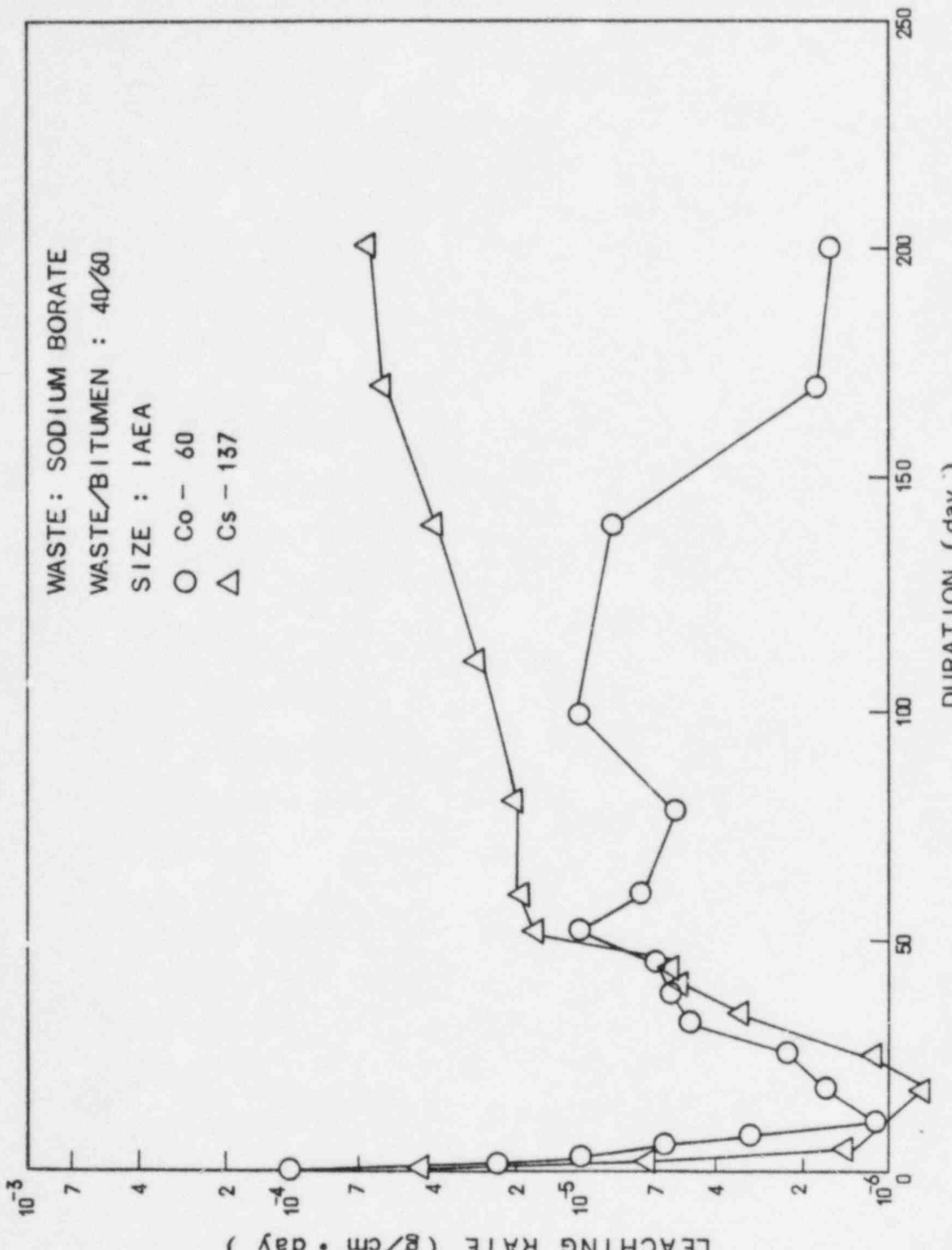


Fig. 3-1 Leaching Rate of Co-60 and Cs-137

Q22. FIG. 4-4 SWELLING AND LEACHING TENDENCIES IN WATER

The meaning of the ordinate is not clear. Does the oridinate mean the percent increase in mass of an original mass due to uptake of water? Please clarify.

ANSWER

As pointed out, the vertical ordinate denotes the percent increase in mass of an original mass due to the up-take of water, so the vertical ordinate is changed to "Change in Weight". The testing method conformed to IAEA Recommendation (refer to Q21).

- Size of sample	:	ø50 mm x H50 mm
- Leach water	:	Type - ion exchange water
		Volume - 750 ml
		Temperature - 25°C or 5°C
- Replacement frequency of leach water	:	Once a day during the first one week
		Once a week during the subsequent 8 weeks
		Once a month during the subsequent 6 months
		Subsequently once per 6 months
		(The water should be measured each time it is replaced.)

- Calculation method

$$\text{Change in weight} = \frac{Wn - Wo}{Wo} \times 100 \text{ (wt\%)}$$

Where,

Wn: Weight of sample on the nth day (g)

Wo: Weight of sample before leaching (g)

Q23. FIG. 4-5 LEACHING RATE OF Na^+ IN WATER

The meaning of the ordinate and its units are not clear. Please discuss.

ANSWER

The vertical ordinates shows the leaching rates. As shown in Q21's answer, the leaching rate of Na^+ in water has been obtained using the following formula.

$$Rn' = \frac{(a/Ao)}{(S/V)} \times \frac{1}{t_n - t_{n-1}} \ (cm^3/cm^2.day)$$

Accordingly, the leaching rate has been indicated in terms of $(cm^3/cm^2.day)$.

The above leaching rate, if multiplied by the specific gravity of the sample, can be converted to $g/cm^2.day$, i.e. $Rn = 1.3\ Rn'$ $(g/cm^2.day)$.

ARTICLE 4. ANSWERS TO QUESTIONS ON CHAPTER 5 EQUIPMENT DESCRIPTION

Q24. TABLE 5-1 EQUIPMENT LIST

Table 5-1 does not list the control system or a control panel (Sec. 5-12) as being supplied by JGC. If JGC normally supplies this, it should be listed. If it is an option that JGC or some other source can supply, then its functions should be included in the process control program and its requirements should be included as part of the plant interface. Please discuss this.

ANSWER

JGC supplies the control system and control panel, and revises the list as shown in Table 3-1.

Table 4-1 Equipment List

Waste Feed System

Item No.	Equipment Name
T-1	Liquid Waste Feed Tank
P-1	Liquid Waste Feed Pump
T-8	Ash Hopper
P-8	Ash Feeder
M-9	Resin Slurry Dewaterizer
P-9	Resin Feeder

Bitumen Feed System

Item No.	Equipment Name
T-3	Bitumen Tank
P-3	Bitumen Feed Pump

Evaporating Mixing System

Item No.	Equipment Name
M-8	DRUM MIXER
M-1	Condenser
T-7	Antifoaming Tank
P-7	Antifoaming Feed Pump

Distillate Recovery System

Item No.	Equipment Name
T-4	Distillate
P-4	Distillate Pump
M-5	Oil Separator Unit

Table 4-1 Equipment List (Continue)

Heating Medium System

Item No.	Equipment Name
T-5	Heating Medium Storage Tank
T-6	Heating Medium Surge Tank
P-5	Heating Medium Feed Pump
P-6	Heating Medium Circulation Pump
M-2	Heating Medium Heater
M-3	Heating Medium Cooler

Off-gas System

M-4	Off-gas Heater
M-13	Off-gas Cooler
M-14	Off-gas Filter
P-13	Off-gas Fan

Drum Handling System

M-7	Drum Handling System

Decontamination System

T-10	Solvent Tank
P-11	Solvent Feed Pump

Instrumentation

	Control Panel
	Instruments
	Radiation Monitors
	Control Systems

Q25. SEC. 5.2.6 ANTIFORMING TANK

Please discuss what effect, if any, the anti-foaming agent has on the bitumen mix, as well as what quantities are typical and whether any restriction cn quantity of type is needed for the process control program.

ANSWER

The information on this page is proprietary.

(2) The above matters are described in the PCP.

The information on this page is proprietary.

Fig. 4-1 Effect of Antifoaming Reagent on Asphalt

Q26. SEC. 5.3.1 RESIN SLURRY DEWATERIZER AND RESIN FEEDER

Is a centrifuge or other water removal method required as part of the JGC process in addition to the water removal provided by the upward moving screw resin feeder, or is it merely an option that the plant may choose if it desires? Please clarify this. If a centrifuge is used, is its use considered to be subject to and part of the Process Control Program?

ANSWER

In the case that the Resin Slurry Dewaterizer and Resin Feeder are provided, no centrifuge will be required.

Q27. SEC. 5.8 PIPING AND VALVE

Is the bitumen transfer line from tank T-3 to the drum-mixer heat traced? If not, please discuss how solidification in this line is prevented.

ANSWER

The bitumen transfer line from the Bitumen Tank (T-3) to the DRUM MIXER is steam-traced to keep the bitumen in the melted state.

Q28. SEC. 5.12 CONTROL PANEL

Please discuss in more detail the exact functions of the control panel. In particular address what switches, indicators, meters, alarms, interlocks, etc., are on it and their functions. Describe which are manual, which are automatic and which automatic ones have manual bypass modes.

ANSWER

Normal operation can be conducted and monitored at the control panel which consists of the following:

(1) Indicators, interlocks and alarms

The indicators for the instruments shown on Fig. 3-2 (P & I diagram) in Reference 1 are mounted on the panel and their interlocks and alarms also are provided to ensure safe operation.

(2) Switches and lamps

Automatic operation switches and lamps are provided on the control panel.

Also, the auto/manual switches and pilot lamps for the automatic valve and rotary machines are provided on the control panel.

Each batch operation can be automatically conducted by means of a manual start/automatic stop program.

Manual operation can be conducted in preference to automatic operation within the safety limits (within which the equipment can be protected).

Q29. SEC. 5.13 INSTRUMENTATION

(1) Are there any radiation monitors that are associated with the drum mixer instruments?

(2) Are there any indicators that the drum filling process is carried out as designed?

(3) If there is an overflow during drum filling or a breach in the filling piping, is there a procedure to cope with such an accident?

ANSWER

(1) A radiation monitor is provided at the Control Room and at the Smear Survey Unit.

(2) A weight meter is provided at the drum filling position. The drum being filled at the drum filling position is weighed. By this means, it is possible to confirm that the drum has been filled normally.

(3) There can not be an overflow during drum filling, because the volume of product filled per batch is less than the volume of a drum. However, as a precaution, a level detector is provided on the drum (placed in the drum filling position) should the drum be filled to the upper limit (level high), the interlock will function to prevent overflow of the product.

If there is an overflow during drum filling or a breach in the filling piping, manual cleaning with a solvent is necessary.

Q30. SEC. 5.14 SCOPE OF SUPPLY AND INTERFACE

The items listed are presumably the minimum that JGC supplies. Please list any other equipment items that must be supplied in order to have a complete and controllable system and whether it is available from JGC or to be supplied by another source.

ANSWER

The minimum items that JGC Corporation supplies are as follows. (Please refer to Fig. 3-2 P & ID in Reference 1 and Table 4-1 Equipment List.)

(1) Waste feed system

(2) Bitumen feed system

(3) Evaporating/mixing system

(4) Distillate recovery system

(5) Heating medium system

(6) Off-gas system

(7) Drum handling system

(8) Decontamination system

(9) Control panel

(10) Instruments

(11) Control systems

Other equipment items, that must be supplied in order to have a complete system, are as follows.

(1) In the case the Waste Storage Tanks and Pumps are required to be supplied by JGC Corporation, JGC Corporation will supply them as part of the Waste Feed System.

(2) In the case the reagent feed system, to adjust the liquid waste can not be supplied in the Plant, JGC Corporation will supply a Reagent Feed Tank, Pump, Instruments, and Control System.

(3) And JGC Corporation will also supply the following equipments and systems.

- o Utility System (demineralized water, cooling water, steam, etc.)
- o Ventilation System
- o Fire Fighting Equipment

ARTICLE 5. ANSWERS TO QUESTIONS ON CHAPTER 6 EQUIPMENT LAYOUT

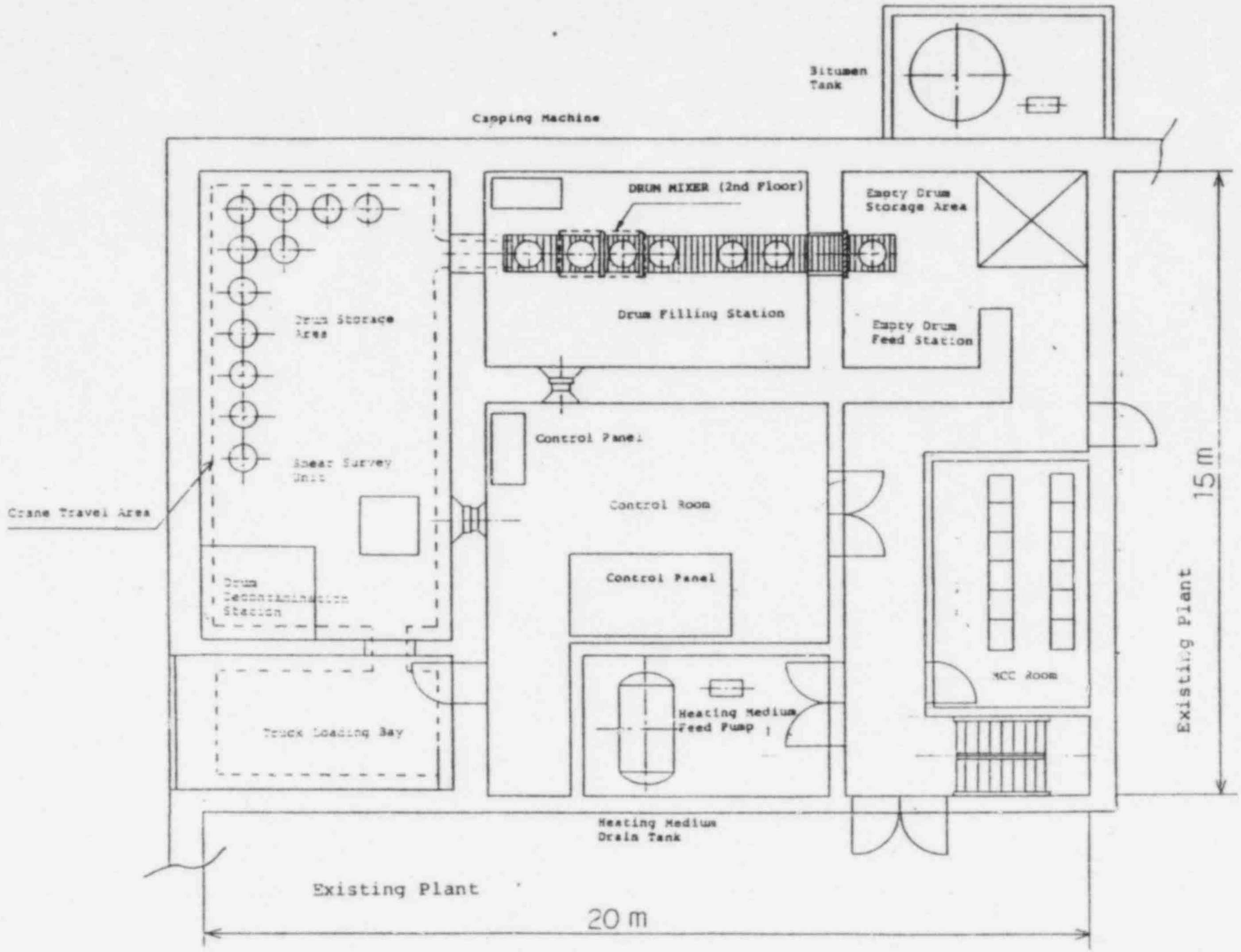
Q31. FIG. 6-1 EQUIPMENT LAYOUT (1)

Indicate location or drum-mixer.

ANSWER

The DRUM MIXER is installed in the 2nd floor and Fig. 6-1 (1) in Reference 1 is the Equipment Layout of the 1st floor. Therefore JGC didn't indicate the DRUM MIXER in Fig. 6-1 (1) in Reference 1.

In accordance with your comment, JGC indicates it in Fig. 6-1 (1) with a dotted line. Please refer to Fig. 5-1.



1st Floor

2/28/1983 0 13-70

NO	DATE	DESCRIPTION	DRWN	CHKD	APPD
◇					
◇					
◇					

REVISIONS

JOB CODE □-□-□-□-□

JGC CORPORATION

Fig. 5-1 Equipment Layout(1)

DATE SCALE
DRW'N CHK'D APP'D

DWG NO. -D ◇ REV

Q32. SEC. 6-4 RADIATION EXPOSURE CONTROL

Please discuss and tabulate the radiation levels expected from the drum mixer, and other major components, as well as from a filled drum for various types of waste.

ANSWER

The radiation levels expected from the DRUM MIXER, and other major components, as well as from a filled drum are shown in Tables 5-1 - 5-8, for various types of wastes which are specified in Table 2-1 in Reference 1. The dose rates are calculated by the Point Kernel Integration method. Table 5-9 presents the gamma-ray energy spectra used in calculating the dose rates.

Radiation levels are expected to be highest in the Drum Storage Area, Drum Filling Station, DRUM MIXER Room and Liquid Waste Feed Tank Room. Next would come the Liquid Waste Feed Pump Room and Distillate Tank Room with radiation levels of less than 1/100 of those in the first group above. These would be followed by the Off-gas Filter Room with a radiation level estimated to be $1/10^4$ that of the Distillate Tank Room.

Table 5-1 Radiation Dose Rates Bead Resin for PWR's (High)*

No.	Equipment Item	Equipment Service	Activity (Ci/m^3)	Dose Rates (mR/hr) At Surface	Dose Rates (mR/hr) At 1 m
1.	M-9	Resin Slurry Dewateriser	650	$5.5x10^5$	$4.2x10^4$
2.	P-9	Resin Feeder	650	$4.7x10^5$	$2.7x10^4$
3.	M-8	DRUM MIXER	780	$4.1x10^5$	$3.3x10^4$
4.	T-4	Distillate Tank	3.22	$3.2x10^3$	$6.4x10^2$
5.	M-14	Off-gas Filter	$2.9x10^{-4}$	0.18	$6.1x10^{-3}$
6.		Filled Drum	780	$5.4x10^5$	$2.6x10^4$

*: The generation volume and radioactivity are specified in Table 2-1 in Reference 1.

Table 5-2 Radiation Dose Rates Bead Resin for BWR with Deep-Bed Condensate Cleanup (Low)*

No.	Equipment Item	Equipment Service	Activity (Ci/m^3)	Dose Rates (mR/hr) At Surface	Dose Rates (mR/hr) At 1 m
1.	M-9	Resin Slurry Dewateriser	1.1	750	57
2.	P-9	Resin Feeder	1.1	640	36
3.	M-8	DRUM MIXER	1.32	560	44
4.	T-4	Distillate Tank	$5.0x10^{-3}$	4.0	0.80
5.	M-14	Off-gas Filter	$4.4x10^{-7}$	$2.2x10^{-4}$	$7.4x10^{-6}$
6.		Filled Drum	1.32	730	36

*: The generation volume and radioactivity are specified in Table 2-1 in Reference 1.

Table 5-3 Radiation Dose Rates Powdered Resin for BWR with Powdered Resin Condensate Cleanup (High)*

No.	Equipment Item	Equipment Service	Activity (Ci/m^3)	Dose Rates (mR/hr) At Surface	Dose Rates (mR/hr) At 1 m
1.	T-1	Liquid Waste Feed Tank	110	9.0×10^4	1.8×10^4
2.	P-1	Liquid Waste Feed Pump	110	1.9×10^4	95
3.	M-8	DRUM MIXER	483	2.0×10^5	1.6×10^4
4.	T-4	Distillate Tank	0.54	440	88
5.	M-14	Off-gas Filter	4.9×10^{-5}	2.5×10^{-2}	8.3×10^{-4}
6.		Filled Drum	483	2.7×10^5	1.3×10^4

*: The generation volume and radioactivity are specified in Table 2-1 in Reference 1.

Table 5-4 Radiation Dose Rates Powdered Resin for PWR with Powdered Resin Condensate Cleanup (Low)*

No.	Equipment		Activity	Dose Rates (mR/hr)	
	Item	Service	(Ci/m^3)	At Surface	At 1 m
1.	T-1	Liquid Waste Feed Tank	0.026	26	5.1
2.	P-1	Liquid Waste Feed Pump	0.026	5.5	0.028
3.	M-8	DRUM MIXER	0.114	60	4.8
4.	T-4	Distillate Tank	1.3×10^{-4}	0.13	0.026
5.	M-14	Off-gas Filter	1.2×10^{-8}	7.3×10^{-6}	2.4×10^{-7}
6.		Filled Drum	0.114	79	3.8

*: The generation volume and radioactivity are specified in Table 2-1 in Reference 1.

Table 5-5 Radiation Dose Rates PWR Evaporator Concentrate (High)*

No.	Equipment Item	Equipment Service	Activity (Ci/m^3)	Dose Rates (mR/hr) At Surface	Dose Rates (mR/hr) At 1 m
1.	T-1	Liquid Waste Feed Tank	0.032	32	6.3
2.	P-1	Liquid Waste Feed Pump	0.032	6.8	0.035
3.	M-8	DRUM MIXER	0.173	91	7.3
4.	T-4	Distillate Tank	$1.6x10^{-4}$	0.16	0.031
5.	M-14	Off-gas Filter	$1.4x10^{-8}$	$9.0x10^{-6}$	$3.0x10^{-7}$
6.		Filled Drum	0.173	120	5.8

*: The generation volume and radioactivity are specified in Table 2-1 in Reference 1.

Table 5-6 Radiation Dose Rates PWR Evaporator Concentrate (Low)*

No.	Equipment Item	Equipment Service	Activity (Ci/m^3)	Dose Rates (mR/hr) At Surface	Dose Rates (mR/hr) At 1 m
1.	T-1	Liquid Waste Feed Tank	0.018	18	3.6
2.	P-1	Liquid Waste Feed Pump	0.018	3.8	0.020
3.	M-8	DRUM MIXER	0.097	51	4.1
4.	T-4	Distillate Tank	8.9×10^{-5}	0.089	0.018
5.	M-14	Off-gas Filter	8.0×10^{-9}	5.0×10^{-6}	2.0×10^{-7}
6.		Filled Drum	0.097	68	3.3

*: The generation volume and radioactivity are specified in Table 2-1 in Reference 1.

Table 5-7 Radiation Dose Rates BWR Evaporator Concentrate (High)*

No.	Equipment Item	Equipment Service	Activity (Ci/m^3)	Dose Rates (mR/hr) At Surface	Dose Rates (mR/hr) At 1 m
1.	T-1	Liquid Waste Feed Tank	7.0	$5.7x10^3$	$1.2x10^3$
2.	P-1	Liquid Waste Feed Pump	7.0	$1.2x10^3$	6.1
3.	M-8	DRUM MIXER	17.5	$7.4x10^3$	$5.9x10^2$
4.	T-4	Distillate Tank	$3.2x10^{-2}$	26	5.1
5.	M-14	Off-gas Filter	$2.8x10^{-6}$	$1.4x10^{-3}$	$4.7x10^{-5}$
6.		Filled Drum	17.5	$9.8x10^3$	$4.7x10^2$

*: The generation volume and radioactivity are specified in Table 2-1 in Reference 1.

Table 5-8 Radiation Dose Rates BWR Evaporator Concentrate (Low)*

No.	Equipment Item	Equipment Service	Activity (Ci/m^3)	Dose Rates (mR/hr) At Surface	Dose Rates (mR/hr) At 1 m
1.	T-1	Liquid Waste Feed Tank	0.018	15	2.9
2.	P-1	Liquid Waste Feed Pump	0.018	3.0	1.6×10^{-2}
3.	M-8	DRUM MIXER	0.045	19	1.5
4.	T-4	Distillate Tank	8.1×10^{-5}	6.6×10^{-2}	1.3×10^{-2}
5.	M-14	Off-gas Filter	7.2×10^{-9}	3.6×10^{-6}	1.2×10^{-7}
6.		Filled Drum	0.045	25	1.2

*: The generation volume and radioactivity are specified in Table 2-1 in Reference 1.

Table 5-9 Gamma-ray Energy Spectra

Waste	Energy (MeV)	Fraction (%)
PWR Waste (Total)*	0.3165	39.29
	0.6776	76.19
	1.1625	6.361
	1.7767	0.283
BWR Waste (Total)**	0.3426	45.50
	0.7329	28.97
	1.2201	6.235
	1.6464	9.324

* : The radioactivity and nuclide composition are specified in Table 2-2 in Reference 1.

**: The radioactivity and nuclide composition are specified in Table 2-3 in Reference 1.

ARTICLE 6. ANSWERS TO QUESTIONS ON CHAPTER 11 POSTULATED ACCIDENT ANALYSIS

Q33. CHAPTER 11 POSTURATED ACCIDENT ANALYSIS

The topical report has addressed two of the most likely accident scenarios: (a) release of radioactive material due to failure of the liquid waste feed tank; (b) fire due to a break in the heating medium subsystem. An additional scenario that should be addressed is fire in a filled drum of waste caused by some external means such as a fire in the drum filling room. Though highly unlikely, one would have a burning radioactive liquid and the consequences should be addressed.

ANSWER

(1) Of fire accidents which have so far occurred at bituminization plants, the largest one may be that which occured at the Nuclear Research Center Karlsruhe in the Federal Republic of Germany in 1974 (Reference 6). The evaporator concentrates of low-and intermediate effluents discharged by the various research institutes and reactors of the Center and by the 40 t/Y reprocessing plant called WAK, are solidified by homogeneous incorporation into bitumen at the waste treatment facilities of the Center. The bituminization equipment is of a screw-extruder type.

The fire accident occurred during the processing of the liquid waste containing $NaNO_3$ discharged by the WAK reprocessing plant. The bitumen product was foaming and abnormal fumes were detected in the filling chamber. Suddenly the fumes caught fire and two filled drums among six placed on the turntable were incinerated.

The fire was easily extinguished with CO_2 and did not spread to any other drum. As a result, no damage was caused in the filling chamber, no person was injured and only very little room contamination was found.

The causes of the fire accident are presumed to be as follows:

(a) Error in pH adjustment of the liquid waste.

(b) Failure to uniformly agitate the liquid waste due to a problem with the agitator in the evaporator concentrate tank.

(c) Generation of a flammable gas from the bitumen product due to the presence of excess organic matter in the liquid waste.

Up to now there have been several cases of fire accidents at bituminization plants in addition to the abovementioned case. All were caused by the ignition of a bitumen product containing $NaNO_3$. In this connection, it is presumed that, should the bitumen product include excess $NaNO_3$, the product will be in danger of ignition due to the oxygen gas and heat generated by some exothermic reactions.

The DRUM MIXER PROCESS has processed approx. 550 drums of PWR concentrator evaporates up to February 1983 and not a single fire accident has occurred. Because LWR wastes contain only a minimal amount of the matter which would cause an exothermic reaction in the bitumen mixture, it is unlikely that the temperature of the bitumen product would increase over its flash point of 330°C from the initial temperature of 180°C (temperature in dumping).

Further, because hardly any combustible material other than the bitumen product exists in the Drum Filling Station and Drum Storage Area, it is inconceivable that the bitumen product would be ignited by a fire occurring in another material. Therefore, it can be said that the outbreak of a fire in a filled drum of bitumen mixture is highly unlikely.

In the event that fire in a filled drum broke out due to some external causes in the Drum Filling Station, the impact to the environment will be restricted as low as practicably by means of the following fire protection systems installed in the station:

(a) Fire extinguisher (Water Spray)

(b) Facility for isolating fires (Fire Damper)

(c) Fire detection and alarm (Smoke Detector)

(d) Interlock instrumentation for fire protection (High Temperature Detector)

By means of the shielding window, TV monitoring system or the above alarm system, the operator will discover the fire within a few minutes after the outbreak of the fire. The water spray type of fire extinguisher will come into action, and the fire dampers will be closed in order to stop the ventilation to and from the Drum Filling Station.

Prior to shutting the fire dampers, it has been continued to ventilate the radioactive aerosol and/or vapor which is dispersed in the Drum Filling Room from the ignition of the bitumen mixture in a filled drum. Of the radioactive aerosol and/or vapor which has been transferred to the plant H&V system, some is trapped by the filters and the remainder is released to the environment from the plant stack.

The following bases were used for estimating the radioactive release to the environment for various types of waste specified Table 2-1 in Reference 1:

(a) One hundred liters bitumen mixture in a filled drum are completely incinerated.

(b) The decontamination factor for the burning bitumer mixture is 1 for iodine, 10 for ruthenium and 10^2 for other particulates (these data are used on burning organic solvent waste in Reference 7).

(c) The decontamination factor for the filters (HEPA & Charcoal) of the plant H & V system is 10.

(d) The 1/2 of the radioactive aerosol and/or vapor which has been dispersed in the Drum Filling Station is transferred to the plant H&V system.

The radioactive release to the environment is expected for each type of waste as shown in Table 6-1.

(2) Judging from authorized data about radioactive liquid wastes generated in LWR plants, it can be said that any radioactive liquid wastes received into the DRUM MIXER PROCESS are not flammable.

Table 6-1 Radioactive Release into the Environment Due to Fire in a Filled Drum

Waste *		Activity of Bitumen Product (Ci/m^3)	Radioactive Release (Ci)
Bead Resin	(High, PWR)	780	1.74
	(Low, BWR)	1.32	2.61×10^{-3}
Powdered Resin	(High, PWR)	483	0.953
	(Low, BWR)	0.114	2.54×10^{-4}
PWR Evaporator	(High)	0.173	3.85×10^{-4}
Concentrate	(Low)	0.097	2.16×10^{-4}
PWR Evaporator	(High)	17.5	3.45×10^{-2}
Concentrate	(Low)	0.045	8.88×10^{-5}

*: The generation volume and radioactivity are specified in Table 2-1 in Reference 1.

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