BITUMINIZATION OF LOW-LEVEL WASTES

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INTRODUCTION

Today, volume reductivity has become one of the most important factor for evaluation of radwaste solidification technologies. Solidification processes substantially vary according to whether cement, bitumen or plastics is to be used as a solidifying matrix.

Solidification of low-level radwaste with bitumen has a number of favorable features and was originally developed in Europe. In Japan, JGC Corporation focused its attention on the radioactive waste volume reduction method using a bituminization process and has developed the process and constructed the first plant in 1973. The major equipment of the plant is a batch type horizontal mixer names DRUM MIXER.

This paper gives general features of the DRUM MIXER PROCESS together with comparison of solidification processes using abovementioned matrixes.

COMPARISON AMONG CEMENT, BITUMEN AND PLASTICS

Comparison among solidification technologies using cement, bitumen and plastics is shown in Table I. At present, bitumen solidification greatly surpasses conventional cement solidification in volume reductivity, and also seems to be advantageous in experience and economy when compared with plastic solidification.

Of the various methods of bitumen solidification, the DRUM MIXER PROCESS has been developed by JGC giving its priority to simplicity of the batch operation. Consequently, the PROCESS can be considered to be superior in respect of reliability and economy.

TABLE I. COMPARISON OF VARIOUS SOLIDIFICATION PROCESSES

Item	Cement	Bitumen	Plastics*1
BINDER	Portland cement Slag cement	Straight bitumen Blown bitumen	Unsaturated polyester
TYPE OF WASTE	Evaporator concentrates Spent resins	Evaporator concentrates Spent resins	Evaporator concentrates Spent resins
PROCESS	Batchwise or continuous	Batchwise or continuous	Drying; continuous Solidification; batchwise
MAIN EQUIPMENT	Mixer (Out-drum mixer, In-drum mixer, In-line mixer)	Mixing evaporator (DRUM MIXER, Extruder, Thin film evaporator)	Thin film dryer/Mixer
FEATURES	o No heating is required, resulting in a simple plant construction and operation.	o The use of heating sources requires temperature control system. o Direct volume reduction system	o Dewatering and/or drying process are necessary

TABLE I (Cont'd)

	Item	Cement	Bitumen	Plastics
ECONOMICS	PLANT COST	Low	Comparatively high	High
	OPERATION COST	High	Low	Comparatively low
	DISPOSAL COST	High	Low	Low
VOLUME REDUCTIVITY *2	CONCENTRATES	10 drums	1 drums	1 drums
	RESINS	15 drums	4 drums	4 drums
PRODUCT PROPERTIES	DENSITY			
	CONCENTRATES	1.8	1.3	1.8
	RESINS	1.6	1.1	1.2
	LEACHING RATE	$10^{-1} - 10^{-2}$ g/cm^2.day	$10^{-3} - 10^{-5}$ g/cm^2.day	$10^{-4} - 10^{-7}$ g/cm^2.day
	COMPRESSIVE STRENGTH	150 - 300 kg/cm^2	Viscoelasticity	500 - 1,500 kg/cm^2
	RADIATION STABILITY	Excellent	10^8 rad	10^9 rad
	FIRE RESISTIVITY	Incombustible	Flash point: 280°C or higher	Flame resistant (not easily burnable)

*1: JGC-CEA/ECOPOL Process
*2: Number of 200 l (55 gal) drums resulting from 1 m^3 of PWR wastes

DRUM MIXER PROCESS

The DRUM MIXER PROCESS has the following features:

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

(2) It is capable of treating many sorts of wastes ranging from solution through sludge to powder; for instance, PWR and BWR evaporator concentrates, spent ion exchange resins, incinerator ashes, etc.

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

(4) Decontamination of the equipment can be easily carried out by means of hot water and/or non-flammable organic solvent washing.

The basic flow diagram of the DRUM MIXER PROCESS is as shown in Fig. 1.

The operation of the DRUM MIXER PROCESS is explained below.

One batch amount of bitumen is fed to the DRUM MIXER which is the major equipment of this PROCESS. The radwaste is supplied to the DRUM MIXER in which the bitumen is 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 present cummulative amount of the waste has been fed and evaporated, the mixture of fine solid radwaste and bitumen is discharged from the DRUM MIXER and directly poured into a 200 l drum. Thus, the radwaste can be solidified into highly volume-reduced products after cooling.

PROPERTIES OF PRODUCT

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

(1) Specific gravity

The following values are obtained:

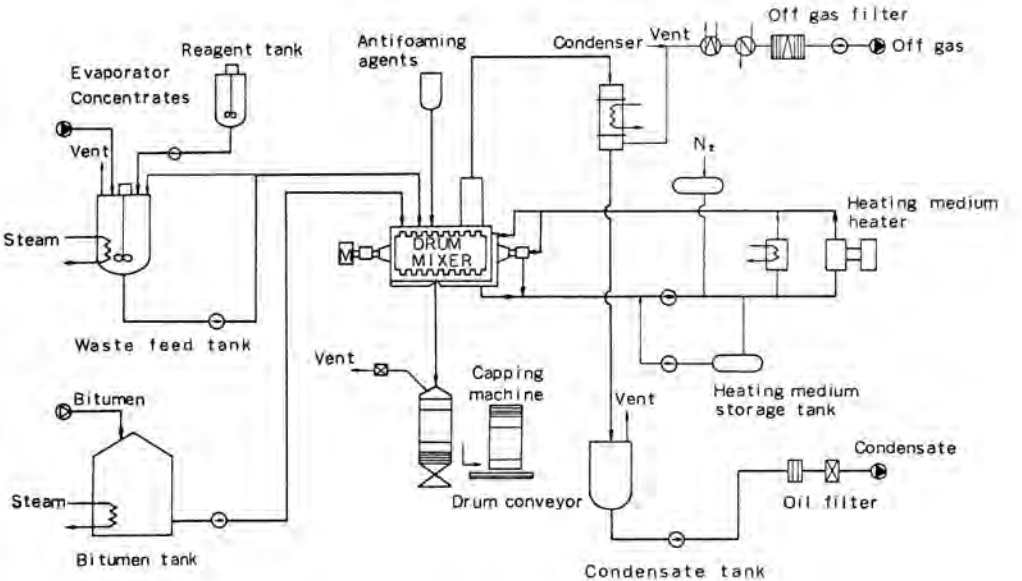

Fig. 1 DRUM MIXER PROCESS

Waste	Mixing Ratio (Solid/Bitumen)	Specific Gravity
PWR concentrates	50/50	1.37
BWR concentrates	50/50	1.48
Spent resins	40/60	1.10
Incinerator Ashes	50/50	1.50

(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 80°C. Higher softening points is attained using blown asphalt.

(3) Flash point

To assess fire hazard, flash point is one of the key factors. Flash points of 330°C or higher is obtained when using straight 40/60 asphalt. Slightly lower flash points are observed with blown asphalt.

(4) Residual water content

Residual water of 1.0% or lower is easily attainable.

(5) Swelling and leaching in water

No swelling has been observed with sodium borate/bitumen= 40/60 product during 200 days immersion in water.

The leaching rate of 10^{-3} to 10^{-5} g/cm^2 day is obtained and considered to be better than those of cement products by a factor of some 10 to 100.

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

OPERATING EXPERIENCE

In Japan, JGC Corporation constructed the first unit for the Japan Atomic Energy Research Institute (JAERI) at Oharai in 1973. In addition to the first unit, three plants for Kyushu Electric Power Company., Shikoku Electric Power Company, and JAERI at Tokai have been in hot operation. Three other units are under construction. Data of these hot operations are shown in Table III.

TABLE II. 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	40/60
Mixing temperature (°C)	170	180	150
Mixer rotation rate (rpm)	120	120	60
Product properties			
Specific gravity	1.48	1.37	1.10
Penetration (0.1 mm)	27	11	34
Softening point (°C)	70.5	81.0	66.0
Residual water content (wt%)	0.05	0.02	0.68
Leaching rate* ($g/cm^2 \cdot day$)	2×10^{-3}	1.3×10^{-3}	-

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

TABLE III. HOT OPERATING EXPERIENCE (As of Dec., 1981)

UNIT	A	B	C	D
EVAPORATION RATE (kg/hr)	140	140	70	80
WASTE	o Evaporator concentrates	o Evaporator concentrates	o Chemical sludges o Evaporator concentrates o Incinerator ashes	o Chemical o Sludges o Evaporator concentrates
TOTAL VOLUME OF WASTE TREATED (m^3)	262	24	142	4
SOLID CONTENTS (wt%)	Up to 11.4	Up to 10	Up to 6	5 to 20
ACTIVITY OF WASTES (Ci/m^3)	10^{-1}	Co-58 4×10^{-3} Cr-51 3×10^{-3} Fe-59 1×10^{-3}	Co-60 10^{-3} Cs-137 10^{-3}	Not available
DATE OF HOT OPERATION	April, 1980	August, 1981	December, 1973	June, 1981
NUMBER OF PRODUCTS (200 l steel drum)	163	16	142 (5 cm concrete inner liner)	13 (5 cm concrete inner liner)
OVER ALL VOLUME REDUCTION RATIO	8	7.5	5	1.5

CONCLUSION

The DRUM MIXER PROCESS is easy to operate and widely applicable to the treatment of many kinds of wastes, because of its simplicity and flexibility of the batch process.

The results of the hot operation can be summarized as follows.

(1) Operation is proceeding smoothly without any signficant troubles.

(2) Volume reductivity is fairly good.

(3) Maintainability is good and there is little accumulation of radioactivity.

(4) Regarding condensate, DF = 10^3 is being obtained, and 1 ppm or less of oil.