KfK 2633
Mai 1978

Treatment of Low and Intermediate Level Wastes

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Kernforschungszentrum Karlsruhe GmbH
ISSN 0303-4003

Behandlung von schwach- und mittelaktiven Abfällen

Zusammenfassung

Die beschriebenen Verfahren zur Behandlung schwach- und mittelaktiver Abfälle basieren ausschließlich auf der Betriebserfahrung mit den Anlagen des KfK zur Entsorgung der Wiederaufarbeitungsanlage Karlsruhe (WAK), der Brennelementfabrikationsanlage ALKEM, der Reaktoren MZFR, KNK und FR 2 sowie des Kernforschungszentrums Karlsruhe und der Landessammelstelle Baden-Württemberg.

Verarbeitungskapazitäten und technischer Stand entsprechen denen des Jahres 1976. Bei einem Jahresdurchsatz von 10 000 m^3 festen und flüssigen Rohabfällen, einer Gesamtaktivität von 85 000 Ci, 500 kg U und 2 kg Pu wurden 500 m^3 Endabfall produziert, die in das Salzbergwerk ASSE II eingelagert wurden.

Abstract

The methods described of low and intermediate level waste treatment are based exclusively on operating experience gathered with the KfK facilities for waste management, the Karlsruhe Reprocessing Plant (WAK), the ALKEM fuel element fabrication plant, the MZFR, KNK and FR 2 reactors as well as at the Karlsruhe Nuclear Research Center and at the state collecting depot of Baden-Württemberg.

The processing capacities and technical status are similar to that in 1976. With an annual throughput of 10 000 m^3 of solid and liquid raw wastes, an aggregate activity of 85 000 Ci, 500 kg of U and 2 kg of Pu,final waste in the amount of 500 m^3 was produced which was stored in the ASSE II salt mine.

Contents

1. Introduction

Radioactive waste is treated so as to minimize its volume, keep the necessary storage volume small, and transfer it into a form capable of ultimate storage so that, under suitable storage conditions, re-entry of radioactive contaminants into the biosphere is excluded.

Compulsory collection and disposal of radioactive waste is required under the law in Germany, in this case under Section 9a of the German Atomic Energy Act [1]. Section 4, Para. 4 of the German Radiation Protection Ordinance [2] of October 13, 1976 quantifies the borderline between radioactive waste and conventional waste. The Gesellschaft für Strahlen- und Umweltforschung mbH (GSF), Munich, stores low level and intermediate level wastes in the Asse salt mine at Remlingen within the framework of a technical experiment. The conditions to be observed with respect to the type and quality of conditioned waste are laid down in the storage rules [3,4].

When classifying all types of waste, a distinction is made between crude waste, which must still be conditioned so as to be fit for ultimate storage, and ultimate waste capable of storage.

Crude waste (Table 1) is reasonably classified by

- the state of aggregation,
- the decisive properties as far as conditioning is concerned (burnable, crushable, baleable, capable of concentration and fixation),
- the specific α- and β-activities, which are proportional to the dose rate and the radiotoxicity.

Specific activities break down into

low level activity	$< 10^{-1}$ Ci/m^3
intermediate level activity	$< 10^3$ Ci/m^3
without α-activity	$< 5 \times 10^{-3}$ Ci/m^3
with α-activity	$< 10^2$ Ci/m^3.

The categories of waste represented in Table 1 ultimately constitute a matrix of basic waste conditioning steps (such as baling, concentration) and the required measures of radiation protection and safety as a function of the activity categories involved. Since both the process technology and the measures of radiation protection and safety have a direct bearing on the costs of construction, operation and ultimate storage, each waste category can be assigned an unequivocal economy parameter (DM/m^3, DM/cell hour). Further subdivision into tritium and uranium-235 is required under the "Storage Conditions for Low and Intermediate Level Wastes in the Asse Salt Mine."

The type of packaging, shielding and solidification of radioactive waste is determined by the geological conditions and the technical equipment of the storage facility. Accordingly, the classification of waste for ultimate storage must be adapted to the "Terms and Conditions of Storage" applicable in each case (Table 2).

The description of the type and quantity of radioactive waste accumulating from nuclear power plants, fuel reprocessing plants, fuel fabrication plants, and experimental facilities is restricted to the most important data. A detailed overview is offered by the "Systems Study on Radioactive Waste in the Federal Republic of Germany" [5].

2. Operating Experience

This report is based on the operating experience accumulated by GfK facilities associated with waste management for the KNK, MZFR, FR2 experimental reactors, the Karlsruhe Reprocessing Plant (WAK), Alkem, the Karlsruhe Nuclear Research Center, and the Baden-Württemberg State Collection Agency. The waste management systems constitute an integrated system in which solid and liquid crude waste is either conditioned so as to be suitable for ultimate storage in the Asse salt mine or, following proper decontamination, to be available for recycling. A major part of the low and intermediate level waste drums stored in the Asse salt mine were conditioned in the facilities of GfK (Table 3). In 1976 some 10,000 m^3 of low and intermediate level crude waste (Table 4) were processed into 500 m^3 (2500 drums) of waste for ultimate storage. The total of drums filled with ultimate waste shipped to the Asse salt mine in 1976 (Table 5) is larger, because contaminated rubble of construction work accumulating as a result of repair activities, scrap and some of the solid burnable waste are reduced for ultimate storage in the unconditioned state.

3. Conditioning Solid Crude Waste

The mechanical reduction in volume of solid low and intermediate level crude wastes consisting of various materials and structural parts is achieved by comminution and baling techniques. These systems must be rugged and require little maintenance. The volume is reduced to not more than one fifth of the initial volume. The capital costs and operating costs of the mechanical part are far below the additional costs caused by buildings and radiation protection.

The incineration of solid low level crude waste reduces the volume to one fiftieth of the initial value. The high operating temperatures and the corrosive, contaminated gaseous effluents loaded with soot and dust make particularly heavy demands upon materials and offgas cleaning systems. Incineration, a process connected with high construction and operating costs, becomes economically competitive with baling only at throughputs above 500 m^3/a and where costs of ultimate storage are high. The crushed or baled crude waste and the ashes are fixed in cement in 200 l drums.

3.1 Comminution

The bulk of low level scrap containing no α-activity consists of ducts, pipes, wood, concrete shielding blocks, and reactor components, such as vessels and heat exchangers. Most of the low level solid waste containing α-activity is composed of gloveboxes, small parts and exhaust air filters.

So far most of the comminution work has been carried out in three large boxes of a design which can be entered by personnel wearing externally vented gas protection suits. The personnel inside the box is monitored from a control room in which all the control and switching functions are carried out for media supply and disposal. The comminution devices used are electric hack saws, plasma cutting torches and manual cutting electrodes as well as compressed air operated hand disk cutters. The annual output is approximately 400 m^3 of solid crude waste with no α-activity and 100 m^3 with α-activity. In order to increase the output and save personnel, the use of remotely operated scrap presses, shears and punches is planned.

Intermediate level solid crude waste with no α-activity is mainly produced in reactors and consists of fuel element guide boxes, inner and outer moderators, and control rods. These components are disassembled either in the fuel element storage pools of nuclear power plants by means of remotely controlled shears and plasma cutting torches, or in separate hot cells, where hack saws are used [6]. Special requirements must be met by the scrap conditioning facilities used to crush reactor components that had been exposed to high neutron fluxes. Fuel element reprocessing plants only produce intermediate level solid crude waste containing α-activity, which is made up of prefilters and scrap from the mechanical process cell, boiler air filters from the offgas cleaning system and the fuel element hulls, and the treatment sludge from the dissolver. Waste from the dissolver and the mechanical cell is directly conditioned in place, whereas pipes and tanks left over after repair work in the chemical cells are disassembled in separate hot cells [6].

3.2 Incineration

Solid burnable crude waste mostly consists of paper, textiles, plastics and cleaning material from nuclear facilities. The calorific value is between 2000 and 10,000 kcal/kg, the packing density is 150 kg per m^3.

3.2.1 Shaft Furnace

The incineration plant schematically shown in Fig. 2 [7] is designed for a throughput of 60 kg/h. The shaft furnace with a height of 6 m consists of a cylindrical steel frame (diameter 2 m), a fourfold brick lining 50 cm thick with the innermost layer made of shaped silicon carbide brick. The furnace is loaded through a slide lock; the ash can be removed through a glovebox and discharged into a drum flanged onto the lock so as to be gastight.

The air volume needed for combustion is fed to the furnace through 3 air inlet openings which are controlled by manual dampers; the uppermost opening is controlled by a thermo-controller.

The furnace is started on easily burnable waste; the normal incineration temperature is between 1000°C and 1200°C. The vacuum in the combustion space is set to 150 mm of water so as to avoid contamination of the work station. The plant is operated in the batch mode in two shifts.

3.2.2 Offgas Treatment

Five filter banks equipped with candle filters are available for afterburning and aerosol retention in the flue gases, two of which are series connected as prefilters and refilters. Two other filter banks can always be shut down for maintenance; a third is available as a standby facility because of the shorter operating period of the prefilter.

The filter housing and the flue gas ducts are made of steel frames with an inner lining of shaped silicon carbide blocks. Above each filter bank there is a box for the installation of new filter candles without any contamination. Spent filter candles are pushed into a glovebox, crushed and loaded into drums. Each filter bank is equipped with 91 candle filters made of silicon carbide (diameter 60 mm, length 900 mm), which are cemented into a perforated plate of high-alloyed steel. The flue gases pass through a plenum chamber and flow through the filter candles from the outside to the inside. The filter housings are connected with the room ventilation system via explosion doors and spark condensing chambers.

The operating temperature of the prefilters is between 800°C and 1000°C, that of the refilters around 600°C to 700°C. The filter resistance is maintained between 200 and 400 mm of water; at higher levels the system is switched to the standby filter bank. The flue gases with temperatures of 500 to 600°C are cooled to 230 or 250°C by adding fresh air downstream of the refilters and forced into the stack alternately by two exhaust fans designed as radial fans with a capacity of 3900 plant cubic meters at a differential pressure of 1.4 m of water.

In 1976 the actual α-activity discharged was 1/5, the discharged β-activity 50% below the permissible levels (Table 6). The retention factor for β-emitters was in excess of 10^2, for α-emitters above 10^4, with approximately 70% of the radioactivity retained remaining in the ash, the balance in the walls of the furnace.

For further reduction to 1% of the present level of the radioactive substances contained inthe exhaust air the offgas cleaning system was added a scrubber with a downstream impingement type separator and an aerosol filter. The system is presently being tested. First of all, water from a circuit is injected at a high pressure into the duct carrying the flue gas; the heat of evaporation of the water extracts heat from the gas. The srubbing water is maintained at 80°C by a cooler, neutralized by means of caustic soda solution and, as soon as a salinity of approx. 20 wt.% has been reached, removed as low level liquid crude waste either continuously or batchwise. The solid particles remaining in the srubber offgas are washed out in the impingement type separator, the liquid effluent is fed to the scrubber. The offgas from the impingement type separator is demisted in an aerosol filter designed as a fiber bed, then heated to 80°C, so as to exceed the dew point and finally forced into the stack through absolute filters together with the exhaust air from the building.

Over an operating period of six years more than 1000 t of solid radioactive waste have been incinerated. This corresponds to an overall throughput of more than 35,000 drums, which is more than half the number of drums filled with low level waste so far stored in the Asse salt mine (see Table 3). The availability of the plant was between 85 and 90%.

3.3 Baling

Most of the baleable solid crude waste is made up of exhaust air filters. In addition there is glass, plastics which are hard to incinerate, and scrap. The filters are put into plastic foils, the other materials into 200 l drums.

In the baling plant (Fig. 3) the drums are first emptied in a series of boxes, and the filters are bagged in and graded. Bulky machine parts are bagged out again in 200 l drums, and so are burnable residues after having been crushed. The baleable waste, after having been crushed, is fed through a temporary storage station into a compression cylinder and baled. After baling with a force of 300 Mp the pellets are stacked for grading in a bunker and then bagged out in 200 l drums.

The rotating column press consists of a pressing table on which a compression cylinder can be displaced in three positions around a central axis. In the first position the compression cylinder is filled, tilted by 120° and then the content is compressed. Subsequently, the compression cylinder is turned by another 120° and the compressed waste is ejected. The system described above is operated in one shift and bales an annual 300 m^3.

3.4 Fixing

Solid crude waste, such as scrap, fuel element hulls, ashes, filter candles or baled waste, is only cemented. In most cases Portland cement with such additives as Eurolan, Zeresit or Tricosal is used. The cement and the additives are homogenized in conventional mixers and pumped into the drum to be fixed either directly or in a bypass line.

4. Conditioning Liquid Crude Waste

The liquid low level crude waste (LAW) consists of a mixture of liquid decontamination, laboratory and sanitary waste or of distillates from the acid rectification step in fuel element reprocessing and the evaporation of intermediate level liquid crude waste (MAW). MAW, which is produced only in fuel reprocessing, is characterized by its high contents of nitric acid and nitrate, respectively, and the presence of an organic phase consisting of a mixture of kerosene and tributyl phosphate (TBP) [9].

Low and intermediate level liquid crude waste is evaporated; the concentrate retains 10^3 - 10^6 times the amount of radioactivity contained in the distillate. The droplets entrained in the evaporation of the water are the activity carriers because they have the same activity as the concentrate remaining in the evaporator. Accordingly, a distillate with a minimum of activity is achieved by reducing the amount of droplets in the water vapor. Technically, this is achieved by

- internals in which the vapors are deflected and the centrifugal forces produced cause the droplets to be separated,

- washer columns,

- double evaporation [8].

Low level liquid waste is concentrated in forced convection evaporators with inner or outer heater bundles. The droplets in the vapors are removed by centrifugal or gravity separation or in packed columns. Vapor compression greatly adds to the economy of the systems.

To reduce leakages and the resultant hazard of contamination in work stations the evaporators for intermediate level liquid waste are designed so as to have external heaters, natural convection and washer columns attached to the system.

The concentrates are fixed in bitumen or with cement. The use of screw evaporators allows the concentrates to be reduced in volume down to 0.5 wt.% of residual water content. The salt can be firmly bound by adding the same amounts, by weight, of bitumen. The advantages of bituminization over cementing are the high resistance to leaching of the end product and an ultimate waste volume about 25 to 30% smaller. These advantages still need to be checked very carefully; especially the lower capital and operating costs of cementing, the sensitivity of screw evaporators to abrasive media, and the non-flammability and higher radiation resistance of the cemented end products must be taken into account. The significance of the leaching resistance of the end products will decrease also as a result of the growing popularity of storage in lost shieldings, because these represent a major safety barrier.

The schematic diagram of the management of low level waste, organic and aqueous intermediate level wastes (Fig. 4) shows the sequence of the different process steps. The specific activities indicated (Ci/m^3) for the product streams are measured averages; in evaporation and bituminization concentration factors of 15 and 2, respectively, were assumed. The specific activities of the bituminized and concreted end products, respectively, correspond to the maximum permissible levels of intermediate level waste capable of storage in the Asse salt mine. Following potential temporary storage (ELMA) organic and aqueous intermediate level wastes are fed through a continuous decanter; the organic phase is split up into kerosene and TBP, kerosene is recycled and TBP is bound to PVC for ultimate storage. The aqueous intermediate level waste is concentrated, the concentrate is bituminized or cemented. The distillates of the intermediate level waste evaporator are passed on to the low level waste facility; the distillates of the screw evaporator are fed to the intermediate level waste evaporator.

4.1 Evaporation of Low Level Aqueous Crude Waste

Low level aqueous crude waste is supplied either through pipelines run on bridge supports or in tank cars and collected in receiving tanks (2 x 150 m^3) (Fig. 5). The two feed tanks (40 m^3) are filled alternately, the pH value is set to 9 or 9.5. The two evaporators with a capacity of 4.5 m^3/h each can be operated either parallel or in series. The solution to be evaporated is preheated in a shell- and-tube heat exchanger heated by the distillate of the evaporator run in a countercurrent flow.

After heating the evaporator by an auxiliary heating register the heat of evaporation proper is generated by vapor compression and subsequent condensation of the vapors in the main heating register as soon as the operating temperature (104°C) has been reached. The distillate is withdrawn continuously, cooled to 30°C through the shell-and-tube heat exchanger and a downstream distillate cooler, pumped into the decanter tank (65 m^3) and collected in the discharge tank (3 x 65 m^3). As soon as a fraction of 25 to 30 wt.% of dry substance has been reached, the concentrate is discharged in the batch mode. In the two evaporators more than 90,000 m^3 of liquid crude waste with an average composition of 0.3 wt.% of dry matter, 5 x 10^{-3} Ci $ß/m^3$ and 2 x 10^{-5} Ci α/m^3 have so far been reduced in volume. The average specific activity of the distillate was 10^{-5} Ci $ß/m^3$ and 2 x 10^{-7} Ci α/m^3.

4.2 Evaporation of Intermediate Level Aqueous Crude Waste

Liquid intermediate level crude waste (Fig. 6) is pumped in batches from a tank car (2 m^3) into an acceptance tank (2.7 m^3) and, after separation of the kerosene-TBP phase, pumped into the feed tank (2 x 3 m^3). The feed tank and the concentrate tank are air sparged, the filling levels in the tank and the evaporator and the density are determined pneumatically. Steam jets are used to feed the liquids.

The vapors of the steam generator, which is vapor heated on the secondary side and has a capacity of 0.8 to 1 m^3/h, enter the column tangentially, with part of the droplets being separated and the balance being retained by seven perforated trays. The vapors are precipitated in the condenser, the distillate discharge cools to 40°C in a downstream cooler and flows into one of the acceptance tanks of the low level waste evaporator stage. In most cases the column works without reflux. The concentrate is discharged batchwise at 70°C. The evaporator is run in a two-shift operation. Since its commissioning it has concentrated 600 m^3 of intermediate level waste; the average decontamination factor has been 10^5.

4.3 Bitumen Fixing of Low and Intermediate Level Evaporator Concentrates

The hot concentrates in a conditioning tank (4 m^3) are given a pH of 9 to 10 and then pumped into a feed tank of the same capacity (Fig. 7). For safety reasons the feed pumps are located above the upper edge of the tank. The tanks are discharged by means of auxiliary suction systems, a centrifugal pump with normal suction driving the liquid jet in the tank which, in turn, delivers into the pump feed tank (0.1 m^3). Out of this cycle the concentrate is continuously forced through a metering valve into the screw evaporator, while bitumen is added from the vapor heated feed tank (20 m^3, 180°C). The evaporation capacity of the dual shaft screw evaporator is 120 l/h. The amounts of concentrate and bitumen to be fed are a function of the solids content of the concentrate. For instance, 135 l of concentrate of the density 1.2 and 25 wt.% of dry matter can be processed with 40 l of bitumen per hour so as to result in 60 l of product fit for ultimate storage.

The maximum operating temperature is 180°C, the maximum driving power of the motor is 60 kW, the screw speed is 300 rpm. The vapors of the five evaporation stages are condensed and the distillate is carried through a tar filter into a collection tank.

The plant has been in operation for more than 10,000 hours; in 1976 200 m^3 of intermediate level evaporator concentrates were transformed into a condition fit for ultimate storage with a plant availability of 85%.

Major breakdowns were experienced as a result of two fires in the discharge cell, each of them preceded by major gas development. After 7500 and 2500 hours of operation the screw shaft evaporator had to be dismantled because of reduced performance and frequent plugging in the extruder part. The reasons were found to be mechanical material abrasion, especially of the screws.

4.4 Cement Fixing of Low Level and Intermediate Level Liquid Wastes

In addition to evaporator concentrates also temperature sensitive ion exchangers and such abrasive media as precoated filters containing kieselguhr are cemented. On the basis of pilot stage experiments a system was built up which went on stream in early 1977 (Fig. 8). The liquid waste is supplied in transport tanks or tank cars and filled into the resin and sludge feed tanks, respectively, by vacuum operation. The circulating flushing water is used to feed the resins. The concentrates and the precoated filters are constantly circulated during the temporary storage phase to prevent solids from settling in the tank.

The waste is cemented in a hot cell onto which 200 l drums are flanged by means of a double lid system. Cement is fed into the drums. The liquid waste and the resins, respectively, are sucked into the metering vessels by means of a vacuum and subsequently drained into the drums. After homogenization by means of a planet mixer the drum is disconnected and moved into the curing rooms. After about 16 hours the density of the cemented product is checked and the drums are bolted closed again.

28 drums each with 100 to 150 l of radioactive material can be fixed per shift. In concentrates and precoated filters the solids fraction may be up to 30 wt.%; resin beads have a residual humidity of 50%. So far 20 m^3 of evaporator concentrates, 50 m^3 of precoated filters and several cubic meters of resin beads have been solidified.

4.5 Conditioning Intermediate Level Kerosene-TBP Mixtures

In reprocessing spent fuel elements 1 to 2 m^3 of intermediate level organic waste solutions are produced per ton of fuel. The waste originates mainly in the kerosene wash of aqueous refined products and product streams. In addition to kerosene the organic phase contains approximately 5 to 15% of TBP, 1 to 10 Ci_α/m^3 and 10 to $100_\beta/m^3$. The principle of separation of TBP from kerosene by adding concentrated phosphoric acid is due to the formation of an adduct of TBP, H_3PO_4 and H_2O which, because of its higher density, settles as a heavier liquid phase and can thus be separated. In a preliminary washing stage with soda a large part of the activity can be washed out of the organic phase; ultimate cleaning of the kerosene is achieved in silicagel columns.

4 m^3 of the kerosene-TBP mixture are sucked into the acceptance vessel (5 m^3) of the existing pilot plant and washed by pumping with 100 l of 5% Na_2CO_3 solution. The soda solution, which extracts 95% of the activity, is removed and reconcentrated in the intermediate level waste evaporator. The kerosene-TBP mixture is sucked in 0.5 m^3 batches into one of the two decanter vessels (0.8 m^3) made of glass and treated in two stages with concentrated phosphoric acid. The concentrated phosphoric acid is used in a countercurrent flow so that 5 kg of concentrated phosphoric acid are consumed per cubic meter of kerosene and percent of TBP. The adduct is decomposed by water and the diluted phosphoric acid is released as a low level solution, while TBP is adsorbed onto the same amounts, by weight, of PVC granulate and reduced to ultimate storage in 200 l drums. The decontamination factor of the adduct

formation is around 10^3, with approximately 0.2 to 0.4 wt.% of TBP remaining in the kerosene. This TBP and the residual activity are adsorbed on silicagel (50 l of silicagel/m^3 of kerosene).

The overall decontamination factor of the process is between 10^7 and 10^8. In the pilot plant so far 40 m^3 of kerosene have been processed and made available to WAK for reuse.

4.6 Incineration of Low Level Liquid Crude Waste

Burnable liquid crude waste consists of contaminated oils, organic solvents, suchas ketones and alcohols, and extraction solvents. In the past few years the scintillator solutions contaminated with tritium and ^{14}C and consisting of a mixture of dioxane-toluene emulsifiers and water were added to this kind of waste. The annual quantity accumulating in the Federal Republic of Germany is 100 m^3.

In the incineration plant described under 3.2 approximately 100 m^3 of liquid crude waste have been incinerated so far. For economic disposal of this waste an incineration chamber is presently being tested with a highly refractory lining, compressed air atomizer and a throughput of 20 l/h.

5. Conclusions

The many years of positive experience in the management of low level and intermediate level wastes have shown that the problems at hand have been solved by the techniques and the machines available. The planning and construction of a fuel reprocessing plant of 1500 t/a with a plutonium recycle element fabrication facility attached to it does not pose any basically new problems of waste management technology. However, because of the larger amounts of waste and the higher specific activities, present techniques will have to be supplemented or expanded. This refers in particular to

- the incineration of solid α-bearing waste,
- the treatment of tritium bearing low level distillates,
- the reduction in salinity of intermediate level liquid crude waste,
- the cementing of intermediate level liquid crude waste,
- the ultimate storage of intermediate level waste in lost shieldings.

Solid α-bearing waste can be incinerated provided that the plants presently existing are adapted to the standards of plutonium technology.

Approximately 500,000 Ci of tritium will annually be generated in a fuel reprocessing plant of 1500 t/a capacity. For radioecological reasons it is not possible to release this amount through a main canal or, as water vapor, through a stack. Three alternatives are at hand:

(1) Enrichment of tritium by retention and recycling of tritium bearing streams in the first cycle of the Purex process, and enrichment of tritium in waste streams by rectification, respectively. The highly tritium enriched water (10^3 - 10^4 Ci/m^3) would have to be fixed in cement for ultimate storage.

(2) Electrolytic dissociation of tritium bearing liquid effluents and stack release of the HT. HT diffuses into the troposphere and will be oxidized there with a half-life of more than 1 year. This prevents the local enrichment of tritium.

(3) Forcing tritium bearing liquid effluents into porous rock of deep underground strata.

The salinity of intermediate level solutions acidified with nitric acid can be reduced by chemical or electrochemical denitration. Non-radioactive pilot stage experiments have already been completed.

The cementation of aqueous intermediate level waste together with the storage in large volume ultimate storage facilities offers a tremendous development potential, especially because of the inherent simplicity of the technique and the radiation resistance of the end products. The acquisition of additional operating experience and the thorough examination of the chemical and mechanical stability of cemented waste is necessary, however.

In the past few years GfK has stored more than three times the amount of intermediate level waste drums in lost concrete shields in the Asse salt mine than the amounts stored unshielded in chamber 8a (Table 7). The advantages of this storage technique are the simple loading of the shielding tanks, the possibility of stacking the tanks in the ultimate storage place, the additional safety barrier, and the low cost of storage. The use of gray cast iron allows the radiation resistance of cemented waste (20 to 50 Ci/l) to be fully utilized.

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Legends of Figures

No.

	ACTIVITY / TYPE	$\alpha <$ 5mCi/m3		α up to 20 Ci/m3	
		Low level	Intermediate level	Low level	Intermediate level
		β : <100mCi/m^3 ODL : <500 mrem/h	< 1000 Ci/m^3 < 5000 rem/h	< 100 mCi/m^3 < 500 mrem/h	< 1000 Ci/m^3 < 5000 rem/h
SOLID	Crushable	H-3 : < 50mCi/m^3 U-235: < 75 g/m^3	< 50 Ci/m^3 < 1000 g/m^3	< 50 mCi/m^3 < 75 g/m^3	< 50mCi/m^3 < 1000 g/m^3
	Burnable	H-3 : < 10 Ci/m^3 U-235: < 1,5 g/m^3	▨	▨	▨
	Baleable	H-3 : < 10mCi/m^3 U-235: < 15 g/m^3	▨	▨	▨
	Capable of fixation	H-3 : < 50mCi/m^3 U-235: < 75 g/m^3	< 50mCi/m^3 < 1000 g/m^3	< 50 mCi/m^3 < 75 g/m^3	< 50mCi/m^3 < 1000 g/m^3
LIQUID	Burnable	H-3 : < 20 Ci/m^3 U-235: < 1,5 g/m^3	▨	▨	▨
	Capable of concentration	H-3 : < 3 Ci/m^3 U-235: < 1.5 g/m^3	< 3 Ci/m^3 < 15 g/m^3	< 3 Ci/m^3 < 1,5 g/m^3	< 3 Ci/m^3 < 15 g/m^3
	Capable of fixation	H-3 : <100mCi/m^3 U-235: <150 g/m^3	< 100mCi/m^3 < 2000 g/m^3	< 100 mCi/m^3 < 150 g/m^3	< 100mCi/m^3 < 2000 g/m^3

TABLE 1: **CATEGORIES OF CRUDE WASTE**

ADB/-/001/77

Waste category	Volume of roll hoop drum (L)	Shielding	Type of conditioning					
			Unfixed		Concreted		Bituminized	
			c_α/drum	c_β/drum	c_α/drum	c_β/drum	c_α/drum	c_β/drum
Low level	200		0,001	0,1	2	5	2	5
Low level	400		0,001	0,1	4	10	4	10
Low level	200	Concreted in 400 l drum	0,01	1	4	10	4	10
Intermediate level	200	Lost shielding	0,02	2	10	25	10	25
Intermediate level	200	Steel on shipment			1	100	2,5	50

TABLE 2: Major waste categories for ultimate storage

Waste category	Stored in Asse	Supplied by GfK
Low level drums*	67.000	38.438
Intermediate level drums	1250	1192

[*] Including intermediate level drums in lost concrete shields

TABLE 3: Total number of drums stored in the Asse salt mine by late 1976

ADB CRUDE WASTE CATEGORIES		WITHOUT α - ACTIVITY		WITH α - ACTIVITY	
		LOW LEVEL	INTERMEDIATE L.	LOW LEVEL	INTERMEDIATE L.
SOLID	CRUSHABLE	115 M^3	10 M^3	90 M^3	
	BURNABLE	890 M^3			
	BALEABLE	290 M^3			
	CAPABLE OF FIXATION		17 M^3		
LIQUID	BURNABLE	4 M^3			
	CAPABLE OF CONCENTR.	6350 M^3		3200 M^3	440 M^3
	CAPABLE OF FIXATION	10 M^3	50 M^3	5 M^3	0,1 M^3

TABLE 4: CRUDE WASTE PROCESSED IN THE WASTE MANAGEMENT FACILITIES OF GFK IN 1976 ADB/-/006/77

WASTE CATEGORY	VOLUME OF ROLL HOOP DRUM (L)	SHIELDING	TYPE OF CONDITIONING			SUM TOTAL OF DRUMS
			UNFIXED	CONCRETED	BITUMINIZED	
LOW LEVEL	200	-	6258	13		6521
LOW LEVEL	400	-	22	117		139
LOW LEVEL	200	CONCRETED IN 400 L DRUM		243		243
INTERMEDIATE LEVEL	200	LOST CONCRETE SHIELDING		485	763	1248
"	200	STEEL ON SHIPMENT		627		627
						8778

TABLE 5: WASTE FOR ULTIMATE STORAGE SHIPPED BY GFK TO THE ASSE SALT MINE IN 1976

	CI/YEAR
α -ACTIVITY	2×10^{-3}
β -ACTIVITY	0,4
TRITIUM	1000
131 J -EQUIVALENT	10^{-2}

TABLE 6: LICENSED LEVELS OF RADIOACTIVE SUBSTANCES IN THE GASEOUS EFFLUENTS OF THE INCINERATION PLANT

	LOST CONCRETE SHIELDINGS		CHAMBER 8 A, UNSHIELDED
	ORDINARY CONCRETE	HIGH DENISTY CONCRETE	
1973	696	-	175
1974	785	336	115
1975	754	78	275
1976	1134	114	627
	3369	528	1192

TABLE 7: INTERMEDIATE LEVEL DRUMS STORED BY GFK IN THE ASSE SALT MINE ADB/-/009/77

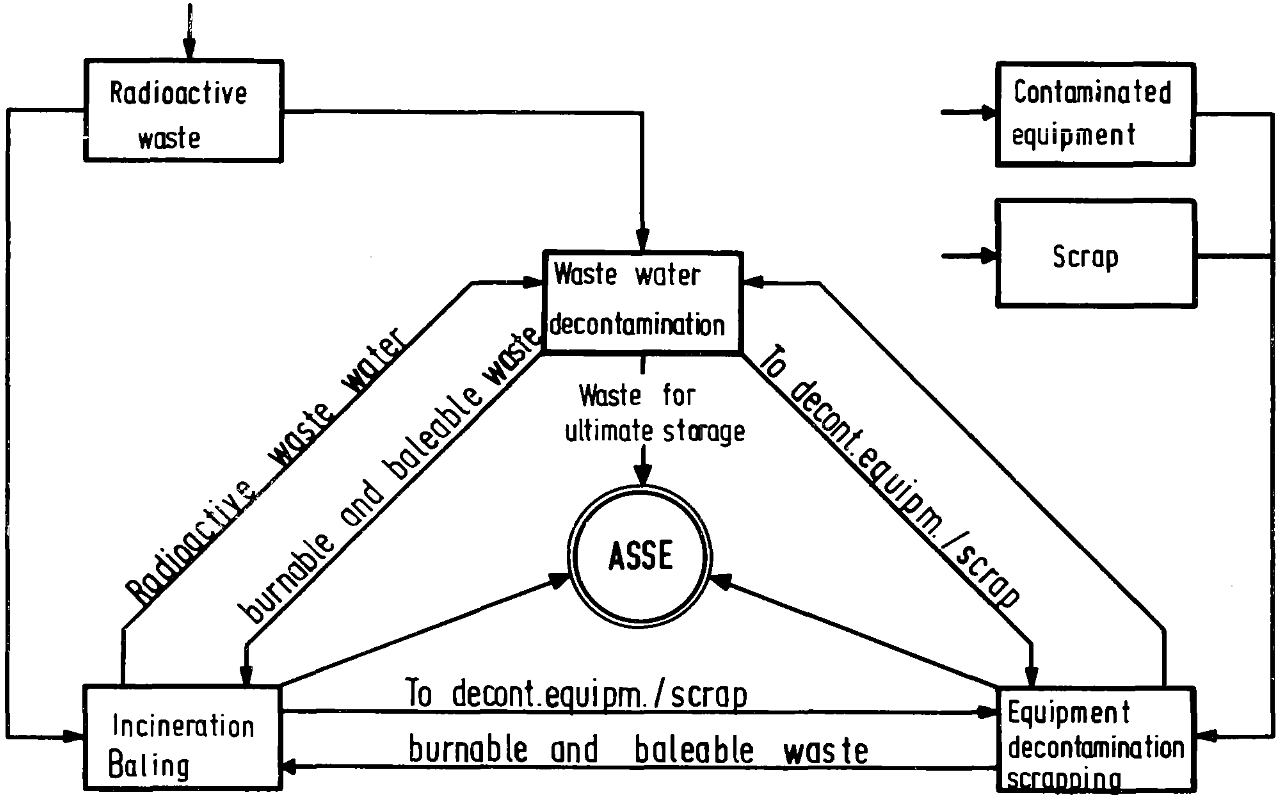
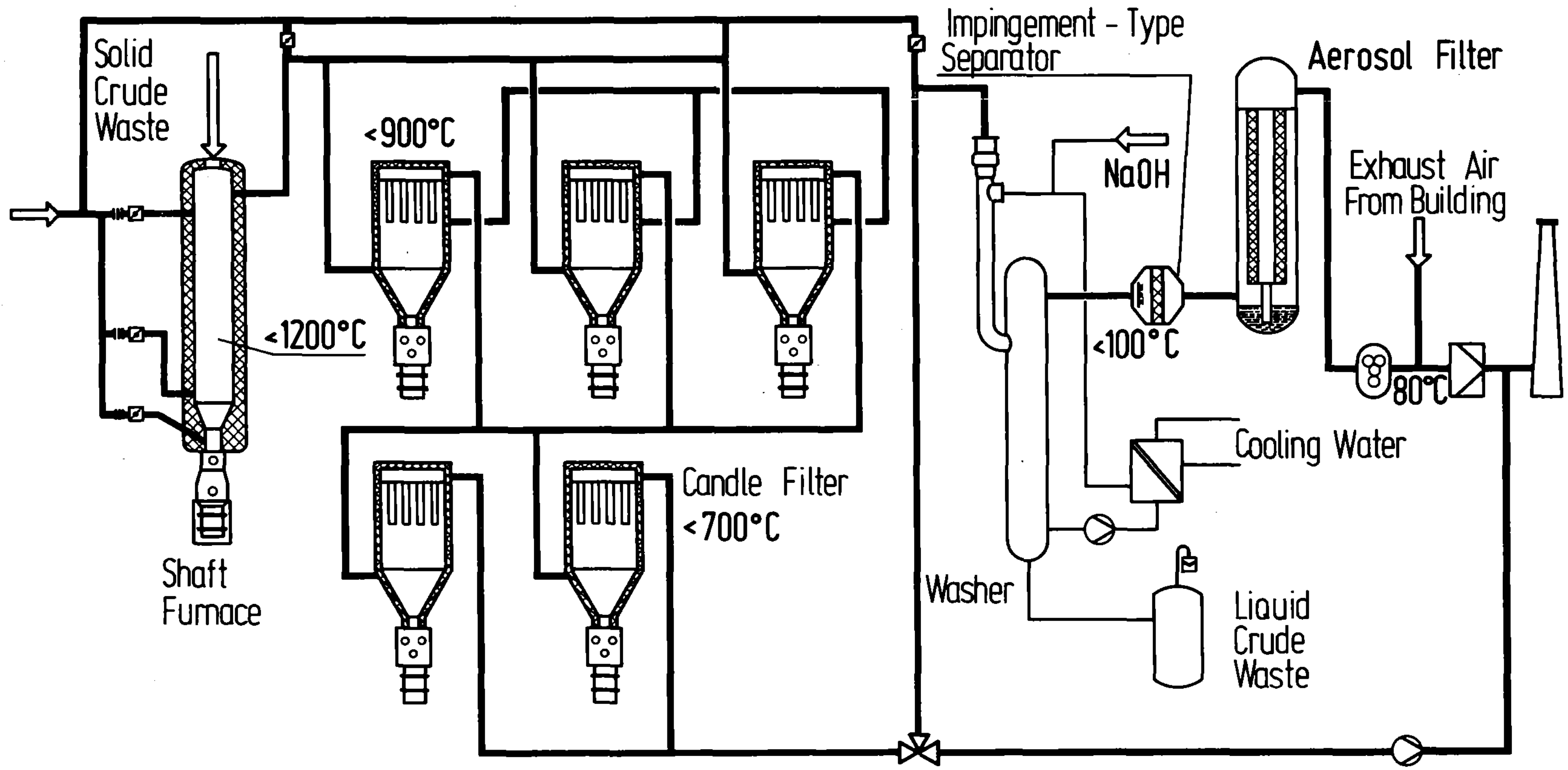


FIG. 1: INTEGRATED WASTE MANAGEMENT SYSTEM



GfK

FIG. 2: INCINERATION PLANT

ADB/V/002/77

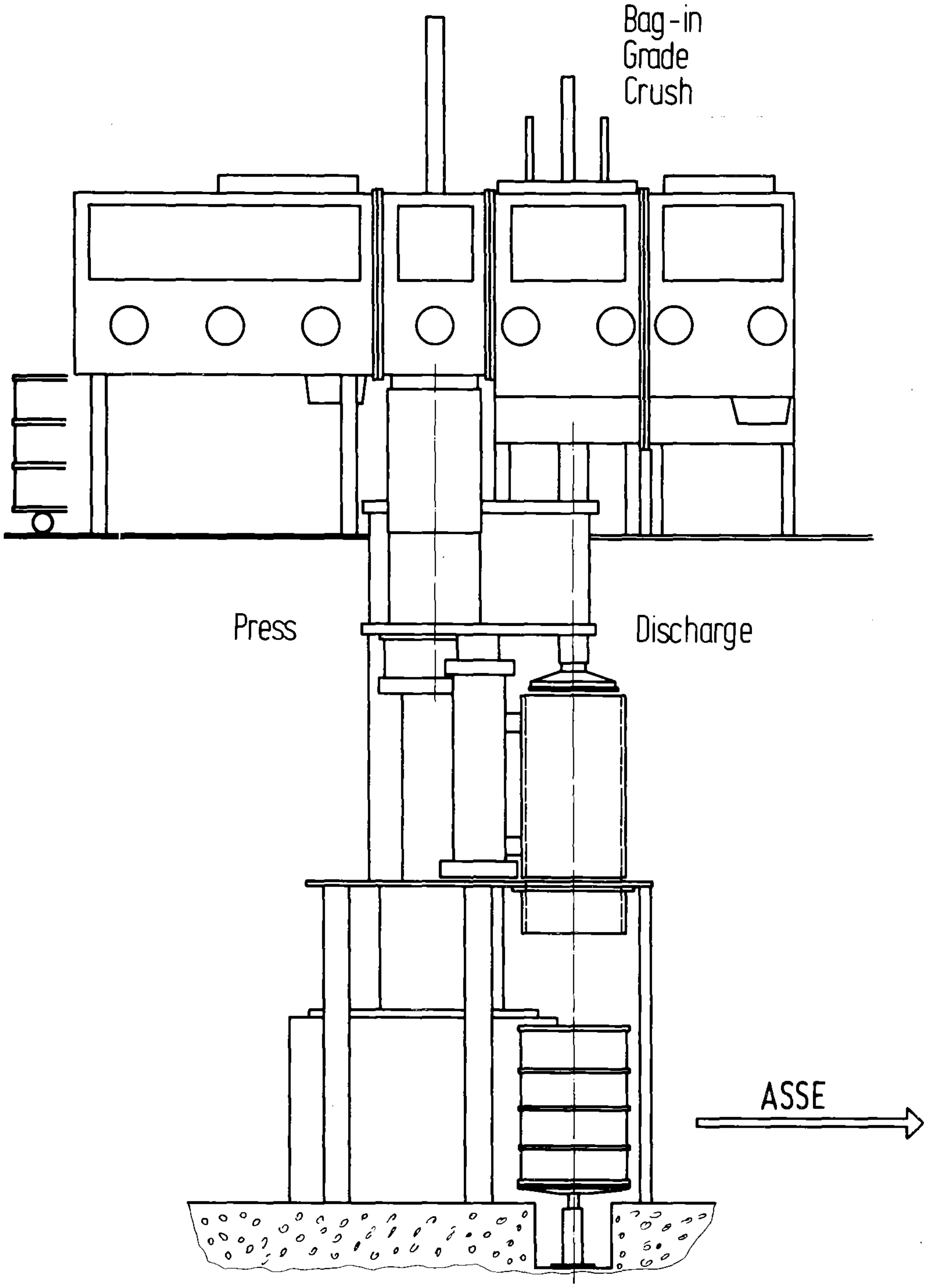


FIG. 3: BALING SYSTEM ADB/P/002/77

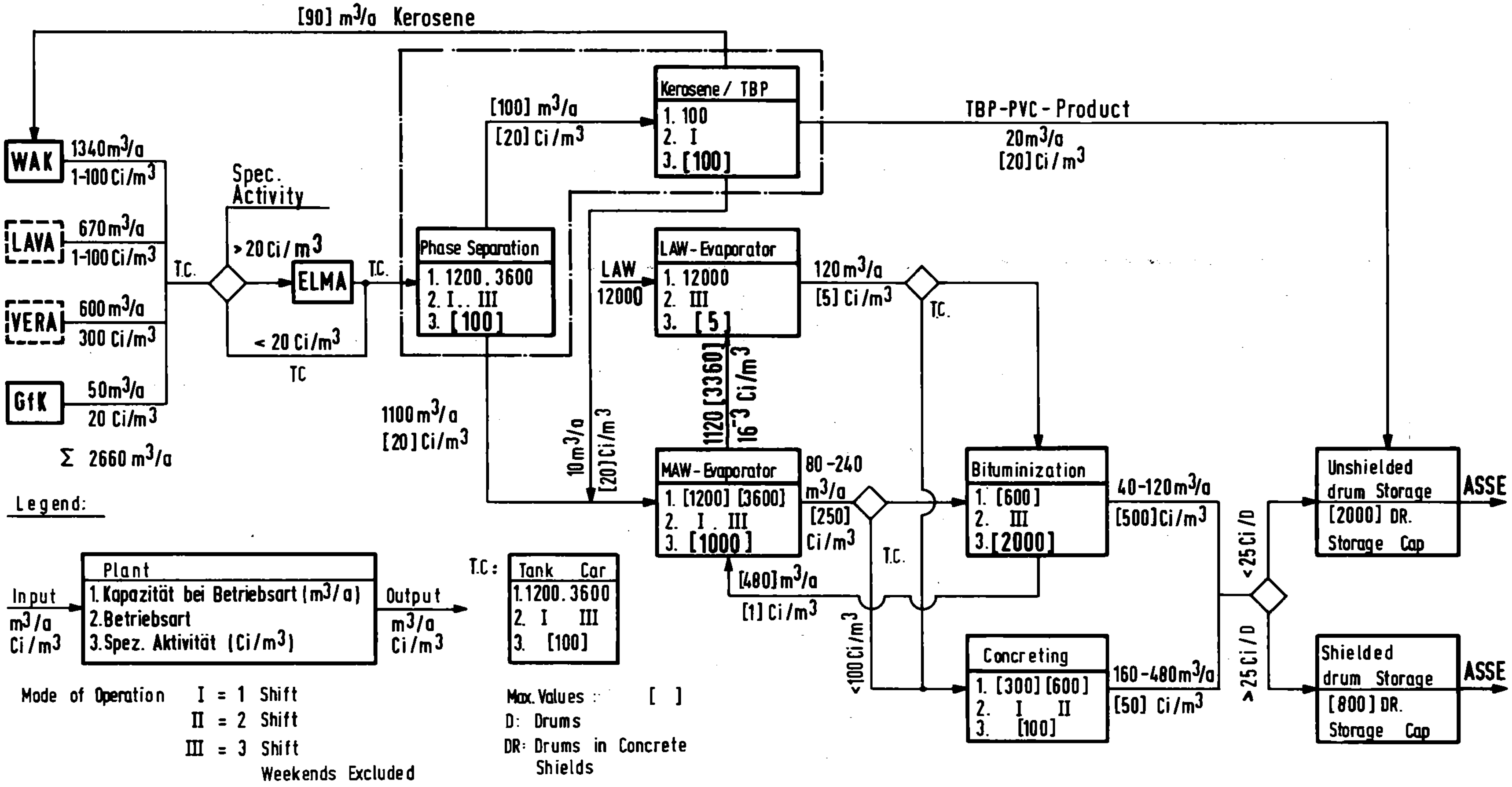
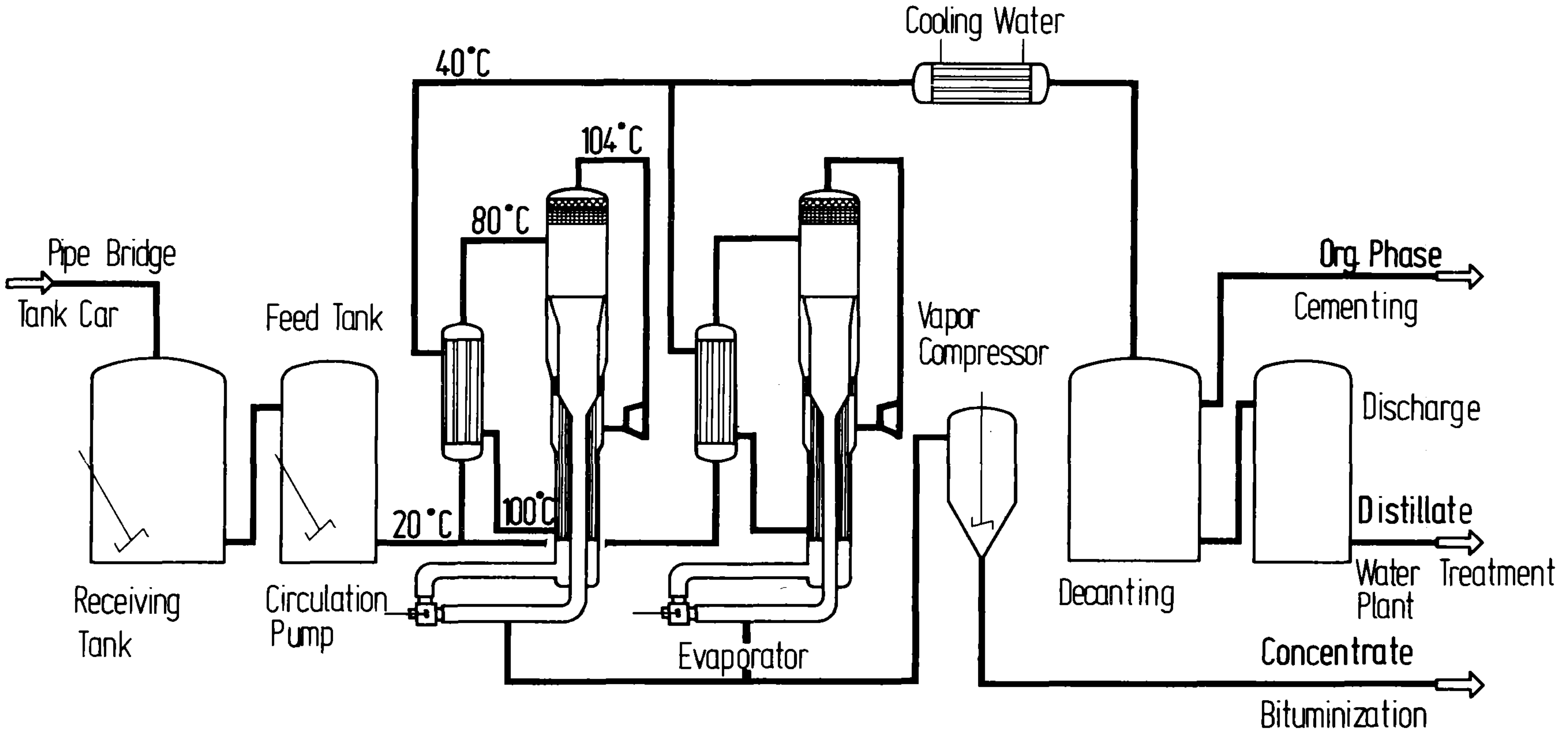


FIG. 4: GWK AND GFK WASTE MANAGEMENT IN ADB PLANTS OF INTERMEDIATE LEVEL ORGANIC AND AQUEOUS SOLUTIONS.

ADB /-/ 003/77



GfK

FIG. 5: LAW-EVAPORATION

ADB/A/002/77

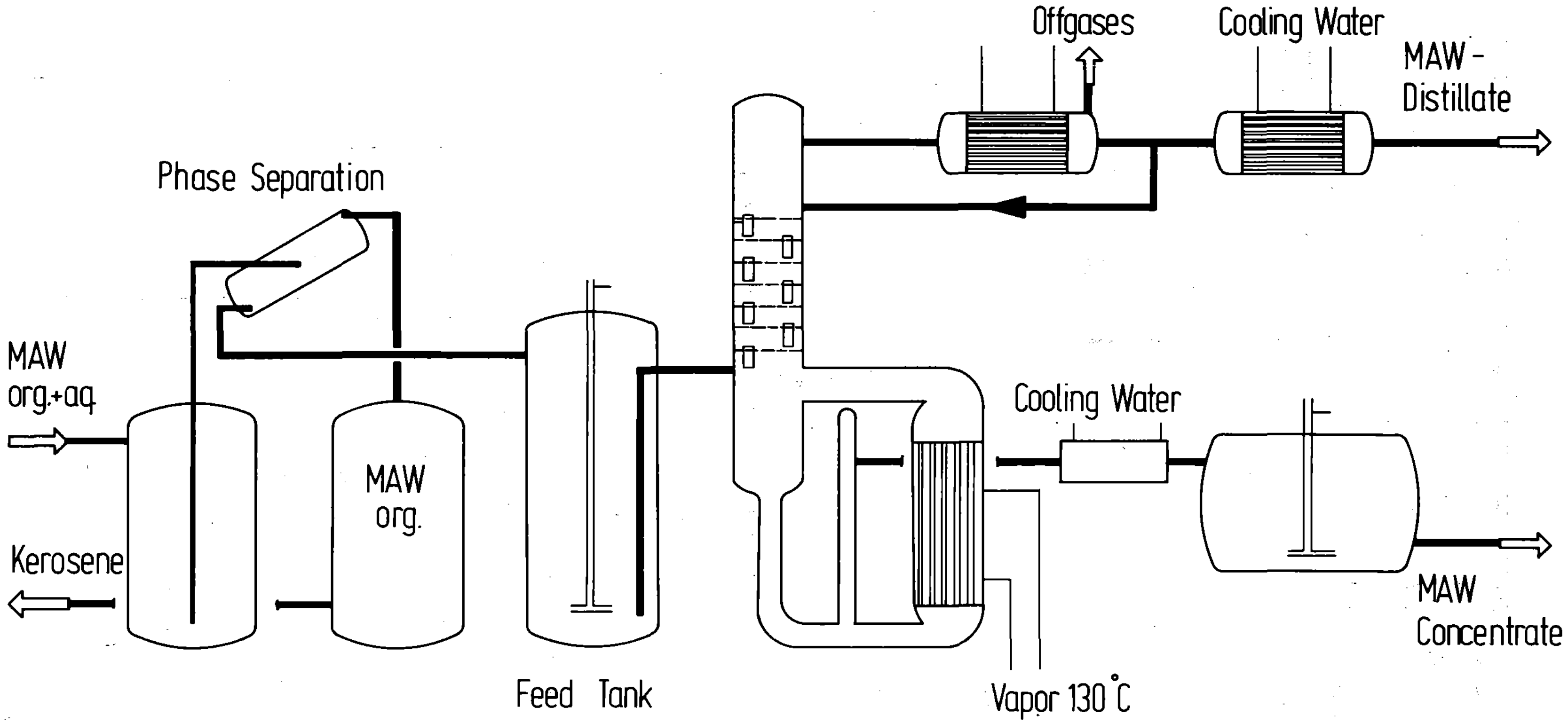


FIG. 6: MAW - EVAPORATION

ADB /B/002/77

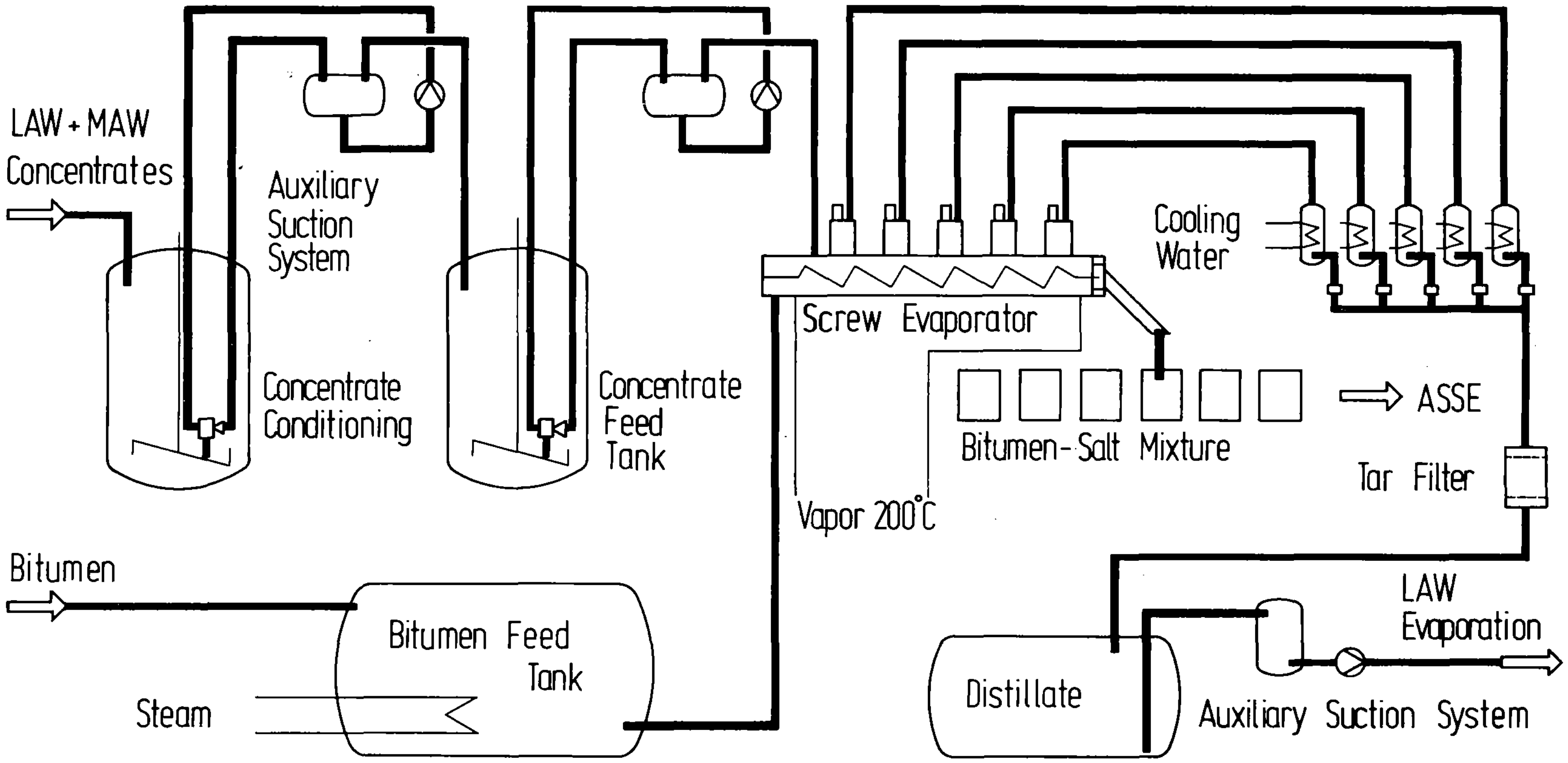


FIG. 7: BITUMINIZING PLANT

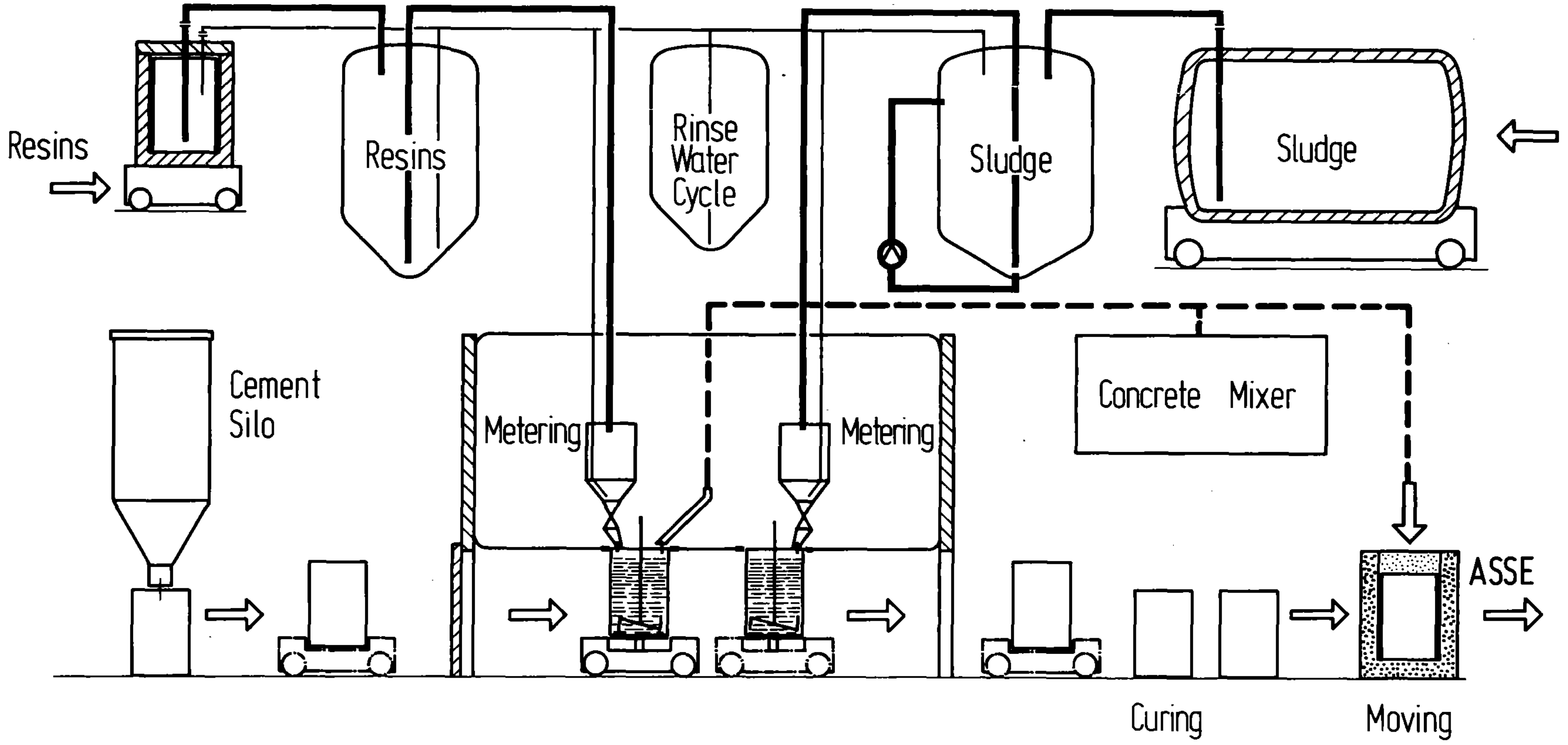


FIG. 8: CEMENTATION SYSTEM

ADB/Z/002/77