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INCINERATION PLANT FOR RADIOACTIVE WASTE AT THE NUCLEAR RESEARCH CENTER KARLSRUHE

by

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Die Verbrennungsanlage für radioaktive Abfälle des Kernforschungszentrums Karlsruhe

Zusammenfassung

Im Frühjahr 1971 wurde im Kernforschungszentrum Karlsruhe eine Verbrennungsanlage für radioaktive Abfälle in Betrieb genommen. In dieser Anlage werden heute routinemäßig bis zu 100 kg brennbare radioaktive Festabfälle bzw. 40 l kontaminierte organische Lösungsmittel und Öle pro Stunde verbrannt.

Für diese Verbrennungsanlage wurde ein trockenes Abgasreinigungssystem entwickelt, bei dem die Rauchgase durch keramische Filterkerzen gereinigt werden. Nach der Filterung und Abkühlung der Rauchgase können diese direkt über einen Kamin abgeleitet werden. Die Aktivitätskonzentration in den Rauchgasen wird durch eine kontinuierlich arbeitende Meßanlage überwacht.

Die bei der Verbrennung anfallende Asche wird mit Zementbrei vermischt und in 200 l Fässer abgefüllt. Auf diese Weise entsteht aus 100 Fässern brennbaren Abfalls etwa ein Faß in Zement fixierte Asche.

In den ersten vier Betriebsjahren wurden in der Anlage mehr als 4000 m^3 brennbare Festabfälle und über 60 m^3 organische Lösungsmittel verbrannt. Über die Betriebserfahrungen wird berichtet.

Incineration Plant for Radioactive Waste at the Nuclear Research Center Karlsruhe

Abstract

In 1971 a large incineration plant started operation in the Nuclear Research Center Karlsruhe. This plant is serving for routine incineration of up to 100 kg of combustible radioactive solids or 40 l of contaminated organic liquids and oils per hour.

A dry off-gas cleaning system has been developed for this installation in which the flue gases are cleaned by ceramic filter candles. After passing the filtering system and cooling the off-gas is discharged directly through a stack.

The activity concentration in the off-gas is measured by a continuous monitoring system. The ashes arising from the incineration are mixed with cement grout and filled into 200 l-drums. By this way approximately one drum of fixed ashes results from 100 drums of combustible wastes.

During the first four years of operation, more than 4000 m^3 of combustible solids and about 60 m^3 organic solvents have been incinerated in the plant. The operating experiences are presented.

1. Introduction

In 1971 an installation for treatment of solid radioactive wastes (Ferab-plant) was started up at the Nuclear Research Center Karlsruhe. The main objective of this installation is the volume reduction of solid rad wastes and the conversion of radwaste into a condition suitable for final storage.

The Ferab-plant is divided into a section for treatment and storage of solid medium-active and a section for treatment of low-active waste. The first section is a hot-cell-block with a large storage cell, a loading cell and a treatment cell. In this area medium to highly active solid waste materials can be sorted, crushed, filled into drums, concreted, stored and packed for shipment.

The second area houses the incineration installation for combustible low-activity solid wastes and organic solvents. A baling press for non-combustible low-activity solid wastes, a filter crushing device as well as a drum cleaning installation are also provided in the incineration facility. Fig. 1 shows the Ferab-plant shortly before completion.

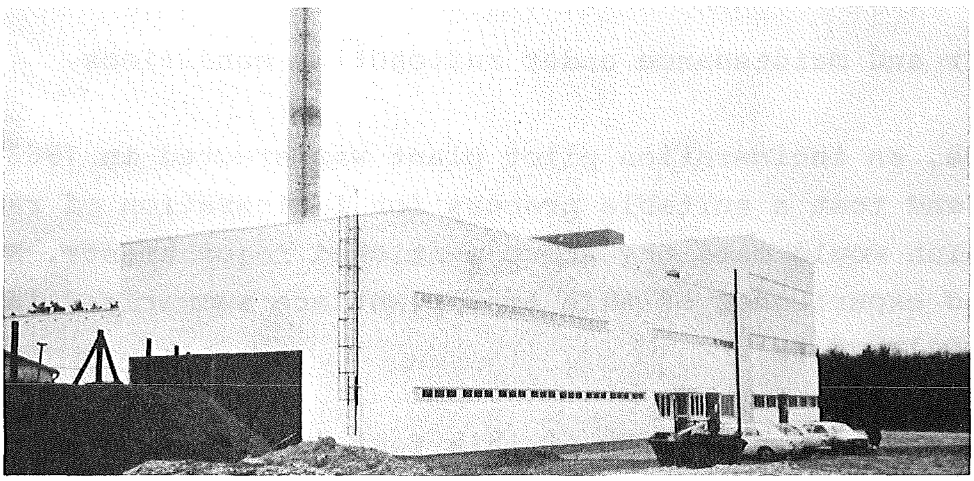


Fig. 1: Ferab-plant prior to start-up

2. Incineration of Combustible Solid Radioactive Waste

2.1 General

A dual objective exists to employ the process of incinerating combustible radioactive waste; i.e. volume reduction and the conversion of residues into a condition suitable for final storage. The first aspect is of special significance where large amounts of radioactive waste are present. In conjunction with the volume reduction, the incineration process generates products well suited for final storage by simply mixing the ashes with cement grout. Naturally, the danger of a fire or decaying process in the waste material is excluded after the incineration; the radionuclides are contained in the concrete/ ash matrix.

In comparison with conventional waste incineration, the incineration of radioactive wastes requires a number of special considerations, such as:

- the necessity to separate the contaminated particles and aerosols from the flue-gas
- totally contamination-free filling of wastes and discharging of ashes
- repair and maintenance under radioactive conditions.

Therefore, an incineration pilot plant was erected in 1963 to develop and test a suitable process for incineration of radwaste which would meet the above mentioned requirements. Results and experiences of this test plant are summarized in reports {1} and {2}.

On the basis of the results of this test installation a large plant was constructed and commissioned in 1971. This report summarizes the experiences of the four years of operation of this plant. The large plant was also urgently needed because of the increasing amounts of combustible waste accumulating at the center. Figure 2 shows the amount of combustible waste generated by the Karlsruhe Nuclear Research Center between 1966 and 1974. The composition of the combustible waste varies greatly as a result of the numerous research and development activities of the Nuclear Research Center, including test reactors and a pilot scale reprocessing plant. Most of the solid waste is composed of paper, wood,filter material, plastics, rubber from gloves and overshoes, textiles, carcasses, ion exchangers and organic solvents.

Operation of the incinerator clearly showed that 99% of the combustible waste was of the low level category; the maximum dose rates at the surface of the waste collection and transport drums were around 200 mR/h.

2.2 Spatial Arrangement of the Facility

The floor space of the building section required for the incineration facility is 10 x 10 m. The ground floor accomodates the feed storage, ash discharge, a storage for organic liquid wastes, and a facility for scrubbing the empty drums. The first floor accommodates the auxiliary facilities of incineration such as filters, fans, air heaters, and the flue gas scrubbers. The service platform is located on the second floor. The facility is loaded and controlled from this floor.

2.3 Incineration Installation Layout

Figure 3 shows the flow and instrument diagram of the incineration plant. The incinerator, the "heart" of the installation is 6 m high, extending up three floors, having an O.D. of 2 m.

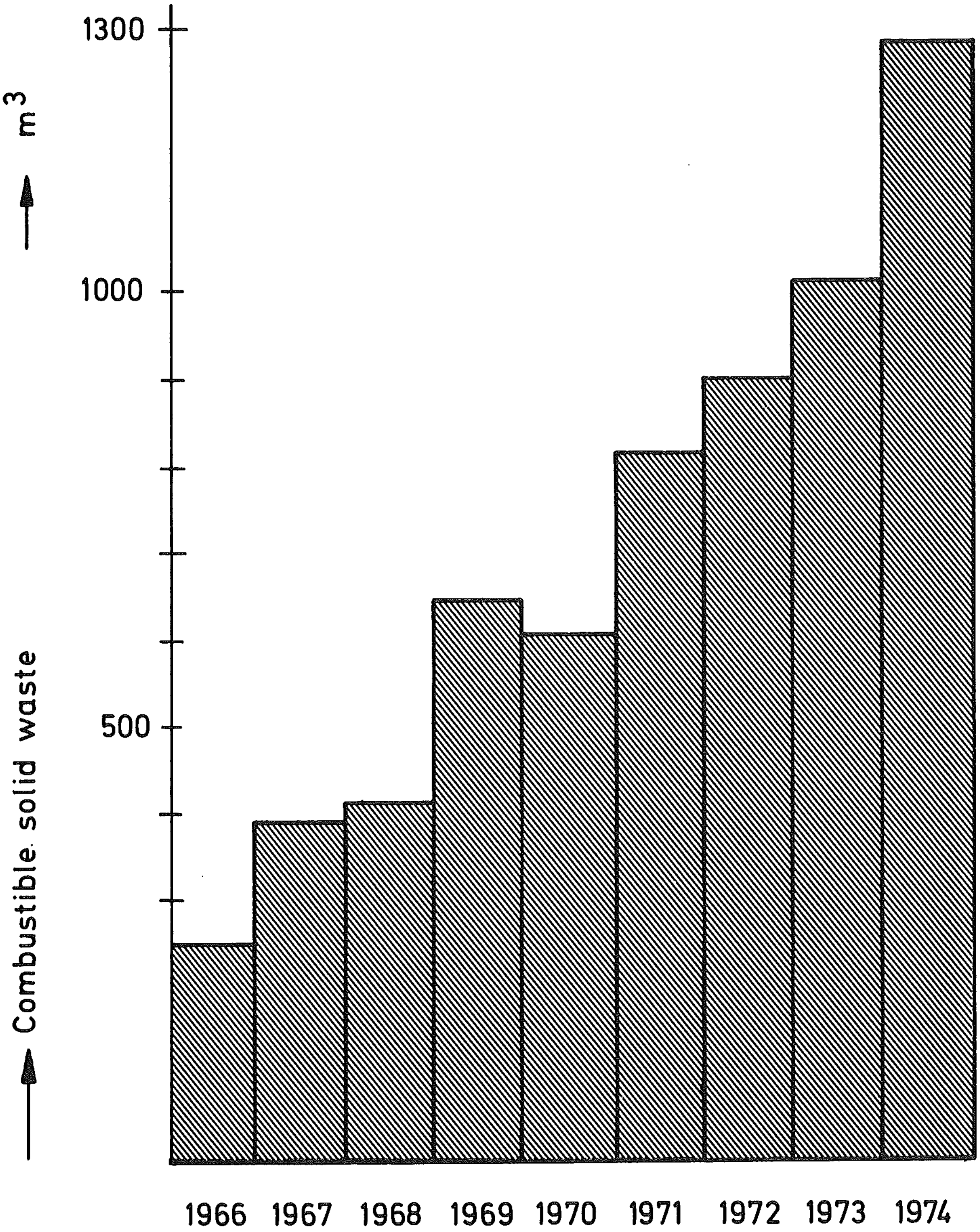


Fig. 2: Amount of combustible radioactive solid wastes generated by the Nuclear Research Center Karlsruhe

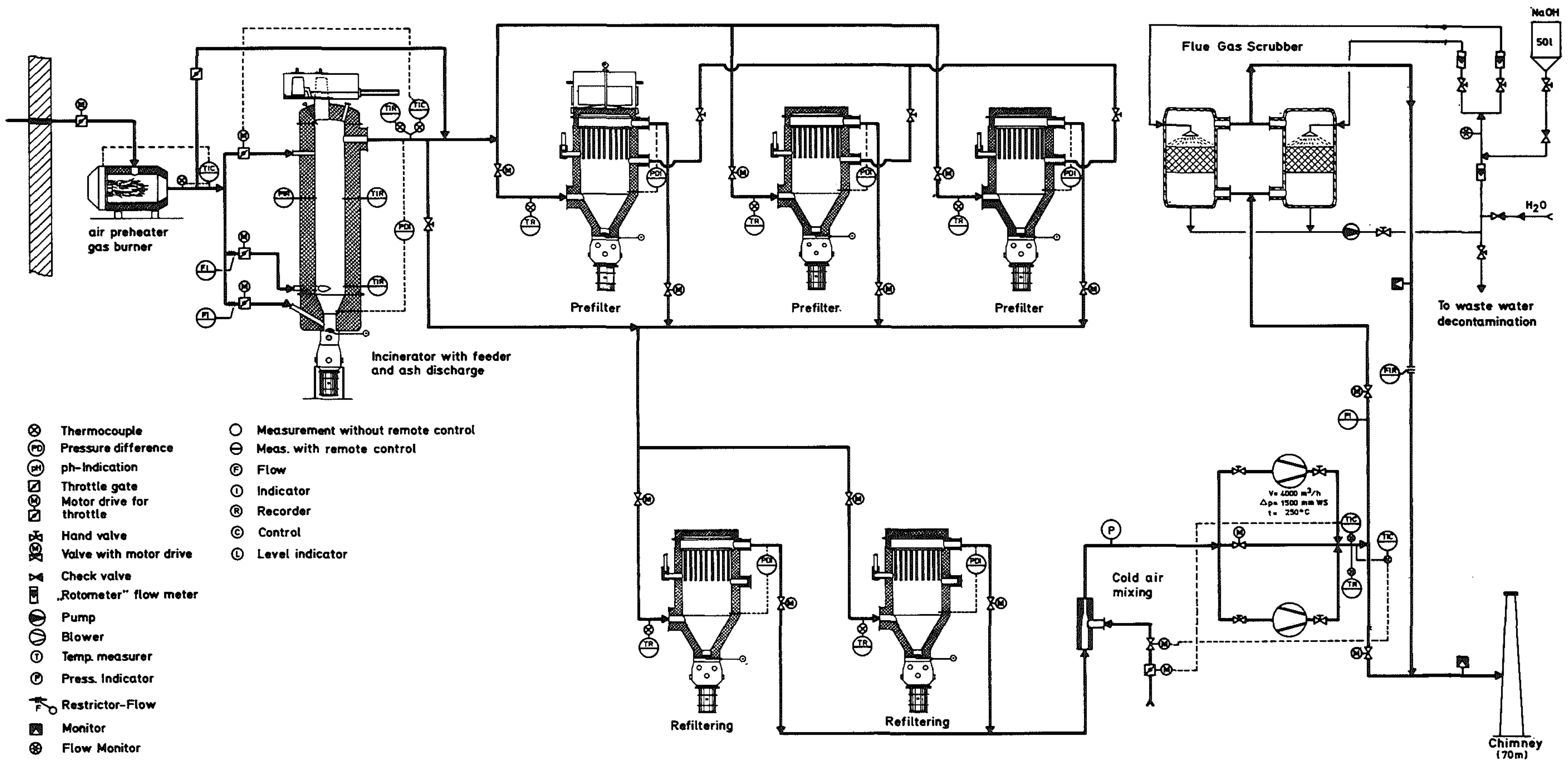


Fig. 3 Incineration Installation at the Nuclear Research Center Karlsruhe

The outer cylindrical steel frame is divided into three separate sections connected by flanges. The inside of the incinerator is lined with a 4-layer fireproof ceramic casing. The internal cylindrical part has an I.D. of approximately 1 m and tapers off into a conical section and continues into another cylindrical part of approx. 40 cm diameter. At the bottom, the incinerator is closed by a spherical gate, which is operated by a weight-loaded handle. A subsequent section is equipped with a 2-part gate connected to a glove box. A drum can be flanged on underneath the glove box for discharging ashes. The ash drum is shielded with 50 mm of lead. (Figure 4).

A feeding device is mounted on top of the incinerator. A flue gas exhaust is provided directly underneath the incinerator cover. Air inlets are provided in 3 places, i.e. above the lower gate, in the area of the conical section, as well as near the flue gas exhaust under the incinerator top.

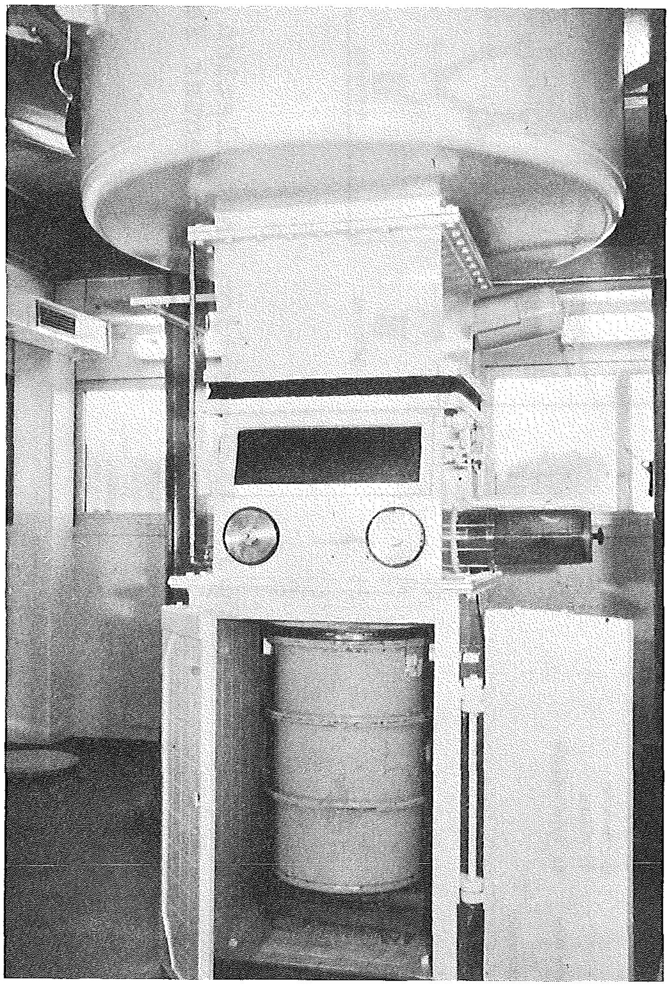


Figure 4: Ash Discharge with Drum and Lead Shield

The incinerator is connected to 3 parallel pre-filters by fireproof lined piping with 200 mm I.D. (Fig. 5)

The filter housings consist of a steel frame of approx. 1.8 m diameter and are 3 m high. They have a fireproof lining as well and have a conical bottom.

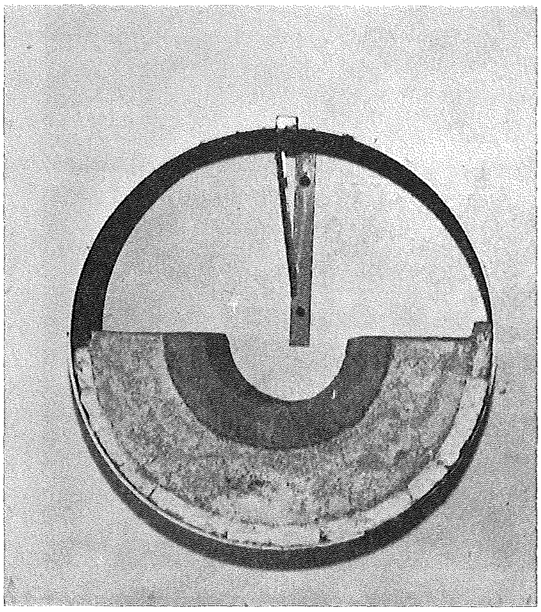


Figure 5:

Cross section of the fire-proof ceramic lined piping

The lining of the incinerator piping as well as the lining of the filter housings, are heatproof up to 1600°C.

All filter housings are equipped with removable covers (Figure 6).

The filter is equipped with a steel plate of 1.2 m diameter positioned on a ledge in the masonary lining, about 300 mm below the filter cover. Ninety-one orifices in the steel plate contain 91 hanging ceramic filter elements of 60 mm diameter and 1000 mm length (Figure 7).

A fireproof sealer is used to install the filter elements in the orifices of the steel plate. The flue gas inlet into the filter housings is located above the lower cone. The flue gases flow through the filter elements from the outside to the inside. At the bottom of the filters, a conical gate connects to a glove box. The glove box is rigidly connected to the filter chamber and is used to extract defective filter

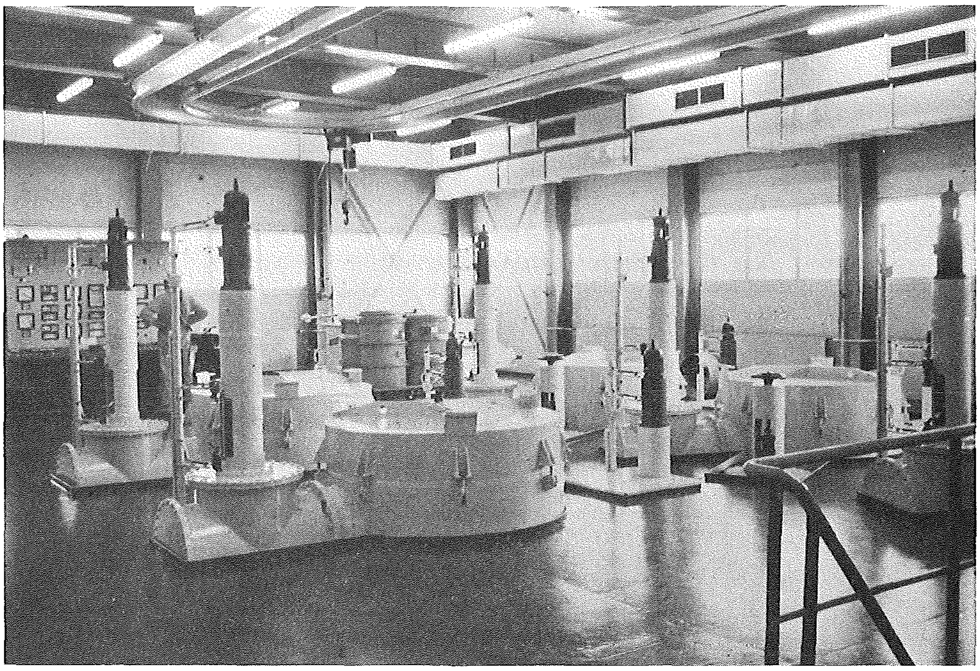


Figure 6: View of the top floor of the incineration plant showing filter housings.

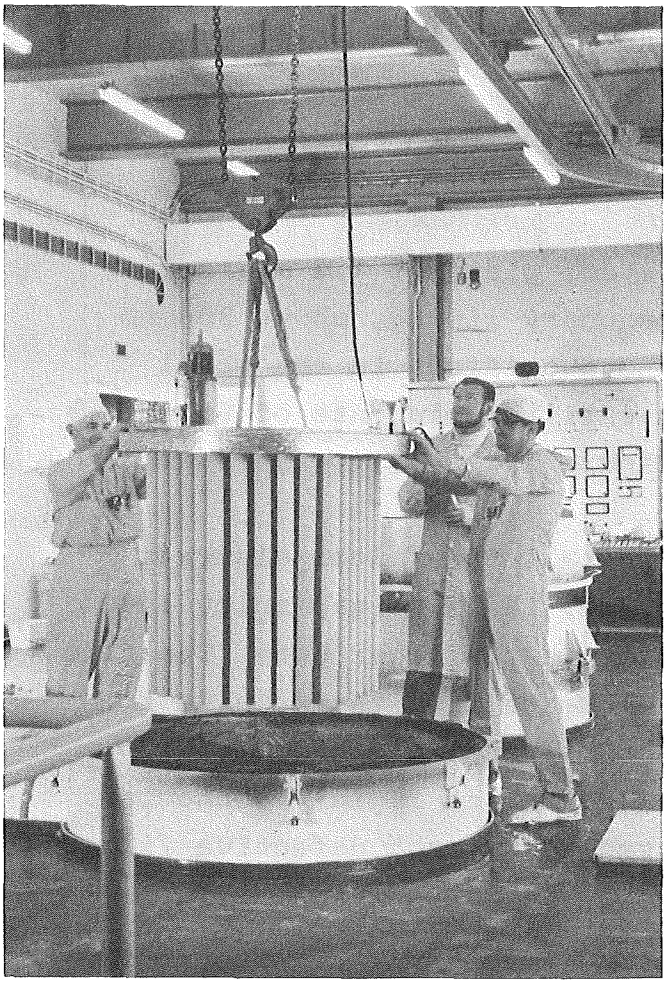


Figure 7:

Insertion of steel plate with ceramic filter elements into the filter housing.

elements, which can be discarded into a 200 l iron-hooped drum, flanged to the underside of the glove box (Figure 8).

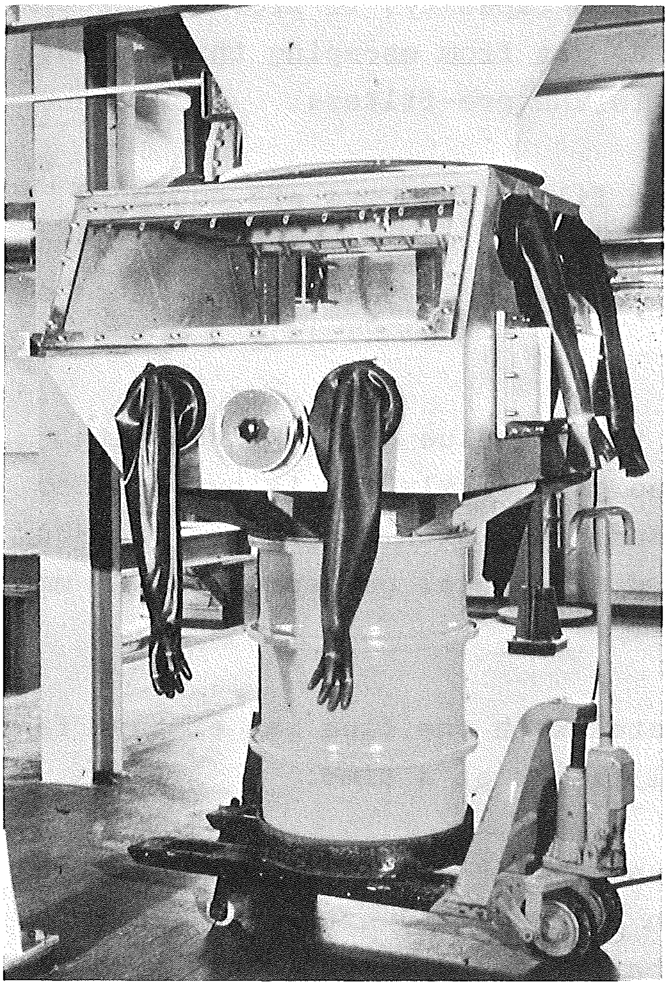


Figure 8

Filter chamber with glove box and flanged-on drum.

By-pass pipes lined with a fireproof material and installed underneath the filter plate, connect all 3 filters, so that the incinerator itself can be by-passed for direct pre-heating of the filters and, in addition, pre-heating of another filter is possible during operation.

The incinerator as well as the prefilters are equipped with explosion relief valves, which have to react in case of explosions. Two, also parallel connected, fine filters are connected to the pre-filters. Their main function is, in addition to increasing the overall filter capacity, to provide safety by preventing radioactive flue gas from escaping through the chimney, in case of defects in the pre-filters.

All inlets and outlets of the filter chambers are equipped with electro-hydraulically controlled valves. The valve cones are designed to ensure tight seal of the valve seats in case of contamination.

Following the fine filters, the hot flue gas is mixed with fresh air. The resulting flue gas-air mixture is pushed into the chimney by 2 radial exhaust fans with a capacity of 3900 operating cubic meters at a differential pressure of 1400 mm water column.

The incineration plant operates with one flue gas exhaust fan, one pre-filter and one final filter at a time.

All other units serve as stand-by, or can be repaired at that time. Also, the flue gas can be by-passed after the exhaust fans into an optional scrubber. This scrubber consists of 2 parallel connected glass columns, filled with Raschig rings.

A demister is installed above the water inlet for droplet separation.

The chimney of the incineration plant has a ceramic liner, its total height is 70 m.

2.4 Operation

Start-up of the incineration plant is initiated by pre-heating the incinerator to 400-500°C via electrical air heaters (Fig. 9).

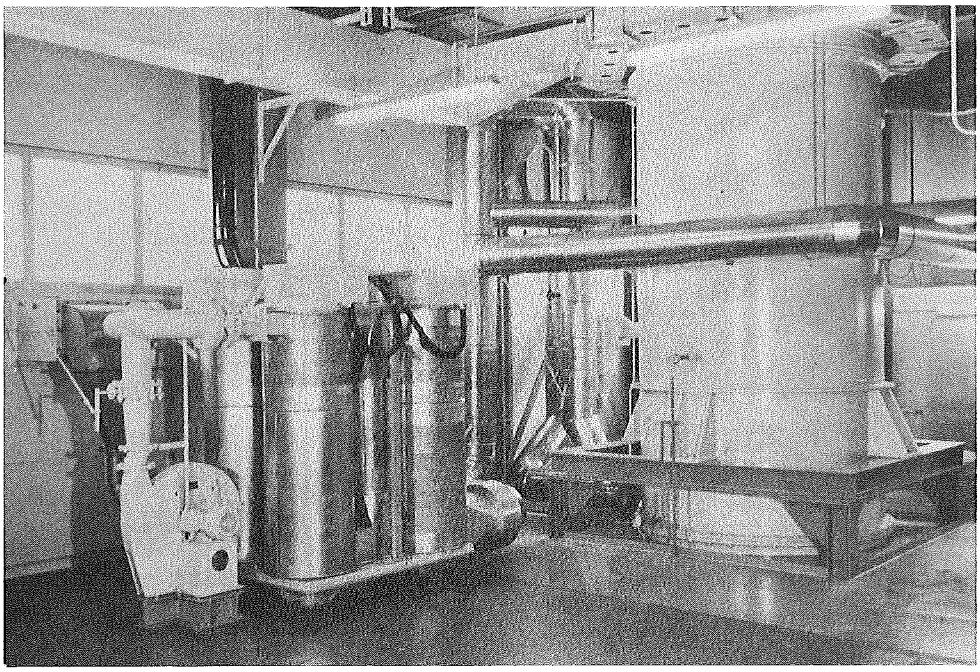


Figure 9: Electrical Air Heaters

By adding easily burnable waste material, the temperature levels of the incinerator and pre-filters are slowly increased to the required operating level of 1000-1200°C (incinerator) and 800-900°C (pre-filter). The temperature of the fine filter adjusts itself to approximately 600°C. At these temperature levels optimal operating conditions are attained and feeding of radwastes may commence.

During operation, the plant does not require any additional fuel or external energy supply. Radwaste is fed into the incinerator in batches through the feeder gate (Figure 10), which is operated by compressed air. The feeding cycle is determined by observation of the combustion chamber and/or control of the filter

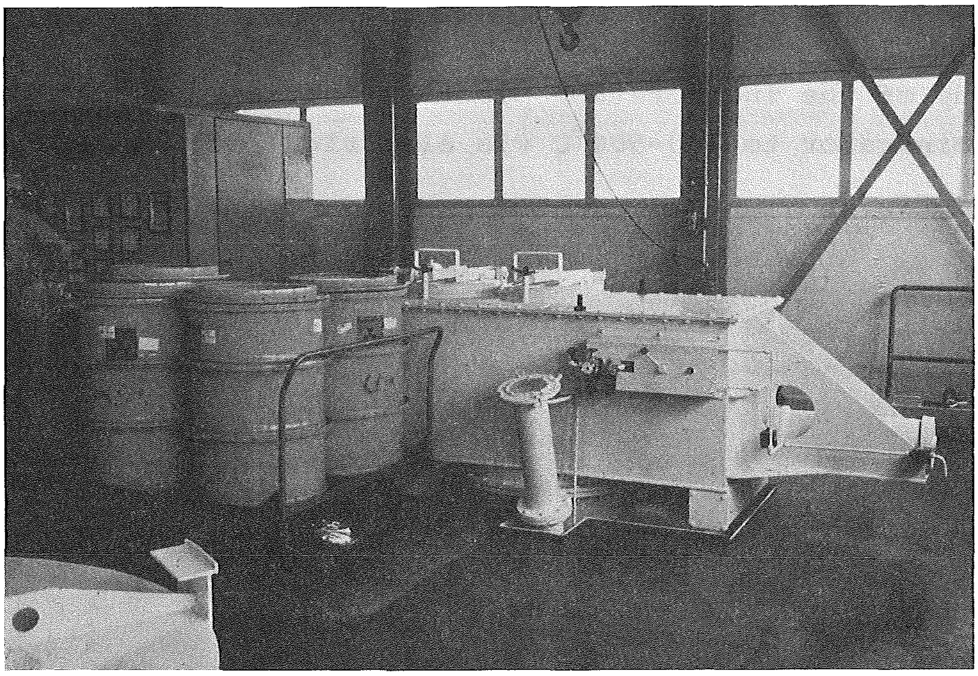


Figure 10: Feeding Unit of Incinerator

resistance. A vacuum of 100-150 mm water column is maintained in the entire system by vacuum blowers. Control of air flow, respectively the distribution of air on the individual wind inlets, is achieved by manually operated throttles, with the exception of the upper wind inlet which is controlled by thermocouple.

Calorific values of the radwastes to be incinerated are at 2000 to 10000 kcal/kg. At times, the combustion in the incinerator is incomplete, and the flue gases exhausted from the incinerator are charged with incompletely burned components, which precipitate on the filter candles increasing the filter resistance by up to 200 mm water column.

The normal filter resistance is between 200 and 400 mm water column.

At operating temperatures of above 700°C and sufficient oxygen supply, the unburned components will burn on the filter surfaces. The ashes generated are collected in the lower conical part of the filter housing. After a short period of time, the filter resistance returns to normal, and the incinerator may be charged again. In addition to their basic function as filters, the filter candles also serve as afterburning elements. After more than 1000 operating hours, an increase in the filter elements resistance may be observed. In case of breakage or other defects on one of the filter candles, the differential pressure immediately drops. Filtering then is assumed by the final filter until the defective pre-filter is replaced.

The air exhausted from the incinerator at temperature levels of 500 - 600°C is cooled down to approximately 230-250°C by mixing with fresh air. After cooling,the air is pushed into the chimney where it is mixed with exhausted building air and discharged into the environment at a velocity of 11.5 m/sec.

All data essential for control of the operation of the incineration plant are being recorded on the central control panel (Fig. 11). From this point also the control of the valves and motors is performed.

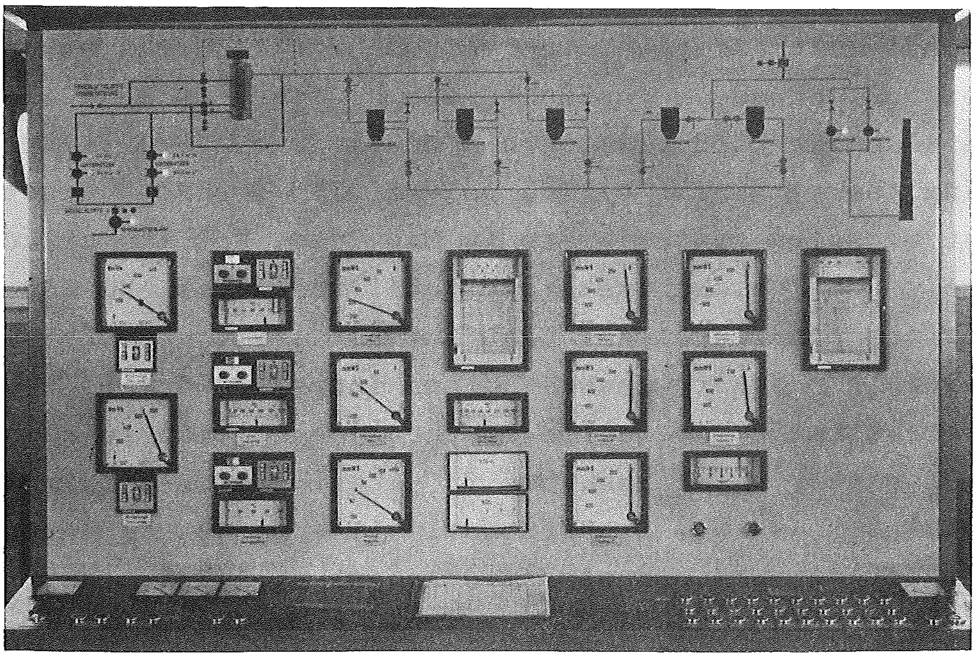


Figure 11: Central Control Panel of the Incineration Plant

2.5 Operating Experience

Since start-up of the incineration plant in 1971, the available capacity of the plant has increased year after year, as indicated in the following table.

TABLE 1

OPERATING DATA

Year	Throughput Rate		Volume Reduction +	Capacity kg/h	Available Capacity % ++
	Solid Waste Tons	Liquid Waste m^3			
1971	113,38	18	1:103	59,3	76,5
1972	109,22	18	1:80	55,0	82,2
1973	115,21	8,7	1:72	54,8	85,8
1974	152,48	11,0	1:55	69,2	91,5

\+ Based on solid waste ++ Actual Operating Hours / Calculated Operating Hours

The increase in available capacity ("ON" time) is due to the gradual elimination of initial operating difficulties. The table also shows that the volume reduction decreased since 1971. This has several reasons. The density in the combustible radwaste barrels increased significantly. In addition, the method of fixing the ashes has been improved. Nowadays the ashes are collected in a 140 l perforated sheet metal basket and placed in a 200 l drum. (See figure 12)
By filling the remaining barrel volume with concrete grout, an excellent encasing of the ashes is provided. For the calculation of volume reduction, however, the total volume of the 200 l barrel is taken into consideration. Last but not least, the total amount of combustible radwaste generated has increased during recent years, necessitating operation of the installation at higher throughput rates, which resulted in deterioration and impairment of the final combustion. Significantly, the weight reduction of the installation remained almost constant at 1:14.

FIXATION OF INCINERATOR ASHES

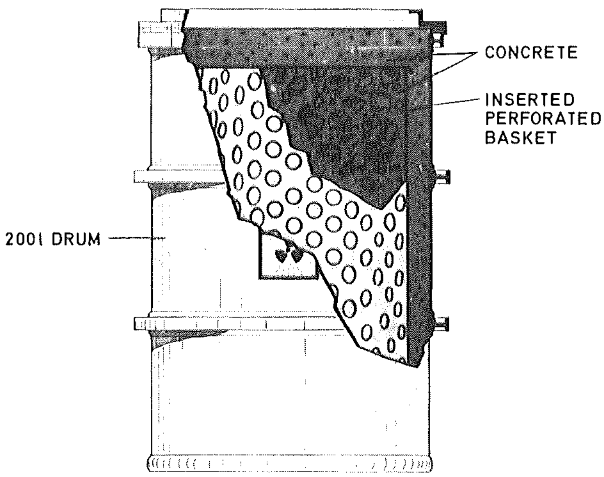


Fig. 12

2.6 Components

The following will report the experiences with the individual components of the installation during the past 4 years of operation.

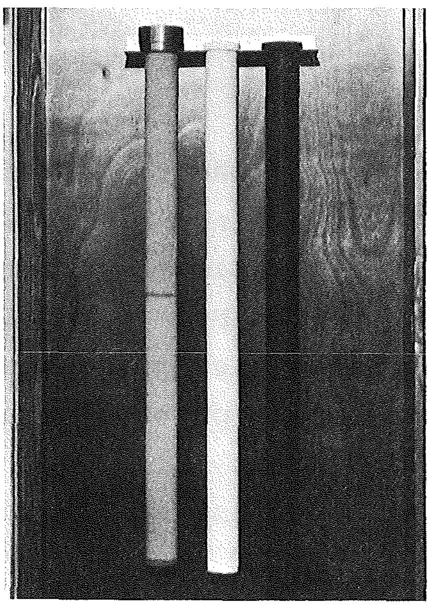
2.6.1 Flue Gas Blowers

After the first year of operation the blower had to be replaced due to excessive mechanical wear. In the beginning of 1974, two new vacuum blowers were installed, which gave improved performance in regard to capacity and service life. Normal steel was selected as material of construction, since high-grade steel would have resulted in higher cost. Essential parts of the blowers were designed to be "disposable" parts, i.e. wear parts could easily be replaced, repairs were made fast at low cost.

This procedure has proved to be very successful. Changing a blower rotor and cleaning of blower housing does not take longe than 2 shifts. During this period the installation can be operated with the second blower.

2.6.2 Ceramic Cilter Candles (Fig. 13)

Essentially, the development of the ceramic filter candles contributed to the high "ON-Time" of the installation. Initially, the installation was equipped with fire-clay filter candles, which had a service life of only about 150 operating hours in the pre-filters. The service life was lower than that of the same candles used in the pilot plant. Modifications of the flow pattern in the filter housings were the cause for the low service life. Square filter housings were used in the pilot plant, giving a larger plenum chamber under the filter candles. The round filter elements installed in the operating installation did not result in a desired degree of stabilization of the flue gases. Minor modifications in the filter chambers, however, corrected the flow patterns of the flue gases onto the filter candles, enlarging the plenum chamber.



a. b. c.

Fig. 13:
Different types of filter candles

a. fire-clay filter candle
b. porcelain filter candle
c. silicon carbide filter candle

Tests were conducted with other filter materials. Porcelain filters showed excellent service life, but had to be disregarded because of very high filter resistance. Filter candles of silicon carbide showed a definite improvement, increasing the service life of the pre-filters to approximately 400 hours and that of the final filters to 1500 operating hours. These improvements also lowered the operating cost. The previously installed fire-clay filter candles showed longitudinal cracks, whereas the presently installed silicon carbide filter candles occasionally break below the filter support plate, caused possibly by continuous vibration load on the candles.

After a certain time, the filter support plates, made of heat-proof steel, do suffer deformations due to continuous temperature fluctuations. The deformation becomes obvious in a distinct warping of the support plates, i.e., the filter candles no longer hang perpendicular to the bores and break off, due to unilateral load under the collars.

These disadvantages could be largely eliminated by using highly heat-proof materials for the filter support plate. Experience shows that the wastes contain approximately 10% PVC, so that an average of 3-4 kg hydrochloric acid per hour is generated during combustion. Hydrochloric acid did not produce any corrosive effects on the ceramic lining or the filter candles. Combustion of organic solvents, however, created difficulties.

Table 1 shows that, in addition to solid radwastes, large amounts of contaminated liquids of various chemical compositions are generated by the Nuclear Research Center, such as contaminated oils, organic solvents, e.g., ketones, alcohols, hydrocarbons and extraction solvents such as amines, tributylphosphate (TBP), etc. The liquids are mixed and incinerated in special batches. The difficulties in incinerating these liquids are mainly due to the presence of TBP. At temperatures above 1000°C TBP is subject to pyrolytic decomposition. The P_2O_5 created reacts with the ceramic liners of the installation, resulting in a glass-like layer on the surface.

Sublimates on the filter candles result in total clogging of filters after a short time (See Fig. 14). These obstructions were observed 5 times during the 4 years of operation. Therefore, incineration of TBP-solvents has been stopped.

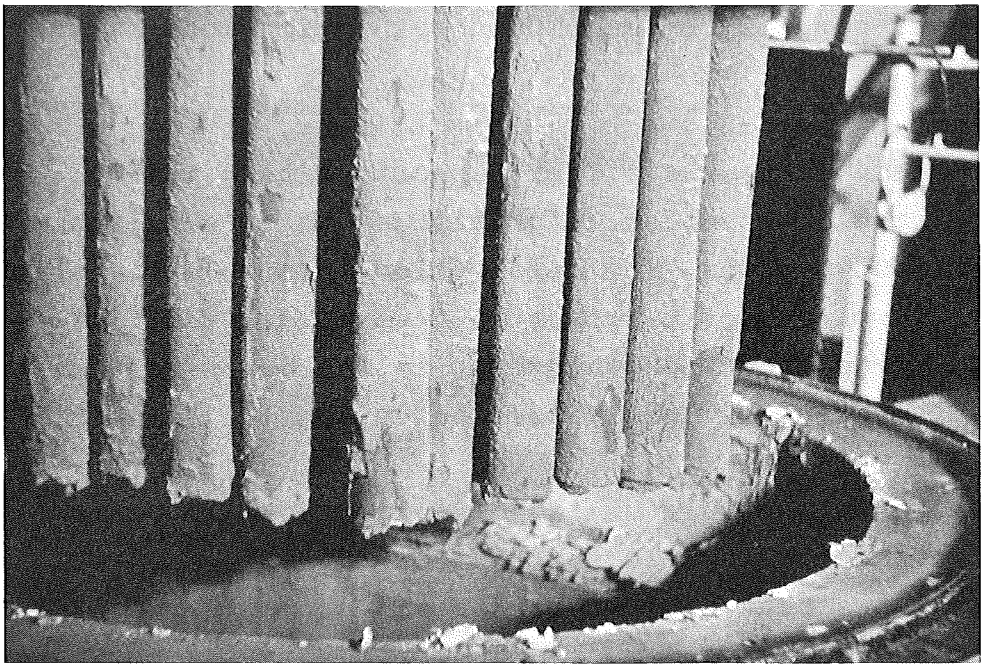


Fig. 14: Encrusted Filter Elements caused by incineration TBP-containing solvents

2.6.3 Ceramic Liners

During the first two years of operation the actual wear part of the incinerator, i.e. the cone in the lower part, had to be replaced yearly. In order to increase the service life of this part of the incinerator the initial lining was replaced by profilated bricks of silicon carbide, which are significantly harder and more heat resistant. Their performance to date indicates that the service intervals may be extended significantly.

The lining of the upper part of the incinerator was replaced after 4 years. In the future, the entire incinerator lining will be made of silicon carbide. The incinerator is designed so that by removing the ash discharge the lower part of the incinerator can be lowered into the ash discharge room. The ash discharge room allows access to the lower part of the incinerator for disassembly and repair. Repairs on the incinerator only take a relatively short time. The only repair necessary on the pipe linings had to be made at the incinerator discharge; 6 m of pipe had to be replaced.

2.6.4 Air Heater

The originally installed electrical air heaters did not give a satisfactory performance. Air temperatures of 500^{o}C, required to pre-heat the installation, result in extremely high wall temperatures of the electrical heating elements, and consequently in defects. The electrical air heaters will be replaced by propane gas burners.

2.6.5 Valve

At the end of four years of operation it appears that the support of the flue gas valve must be replaced. It is intended to make repairs step by step without restricting the operation.

2.7 Flue Gas Scrubbing and Emission of Radioactivity

The most important factor in the operation of an incineration plant is to minimize the emission of radioactive components into the environment. In order to illustrate the function of the plant and to illustrate the effectiveness of the filters, various tests and radioactivity measurements were conducted.

Test results showed that approximately 70% of the radioactivity is contained in the ashes. Radioactivity measurements in the ashes were performed for a certain time, which showed that the radwaste incinerated in the plant show an average of β and γ-activity of approximately 160 mCi/ton and an α-activity of approximately 45 mCi/ton. Based on these tests, the yearly total radioactivity of the radwaste incinerated may be estimated by extrapolation. (See Table 2).

Table 2: Yearly Doses of α- and β-Activity in Combustible Radioactive Solid Waste

YEAR	THROUGHPUT		α-ACTIVITY	ß-ACTIVITY
	m^3	t	Ci	Ci
1971	851,3	113,4	5,4	18
1972	735,3	109,2	5	17,4
1973	811,0	115,2	5,5	18,5
1974	989,6	152,5	7,5	25

t = 1000 kg

Very rigid standards for the emission of radioactivity into the environment are a prerequisite for the operations at the Nuclear Research Center in Karlsruhe. The exhausts of the incineration plant may contain no more than a total of 0.001 Ci of α- and 0.4 Ci of ß-activity, and no more than 500 Ci of tritium per year. Maximum permissible monthly emission amounts to 1/10 of the yearly emission and accordingly 1/10 of the maximum permissible monthly emission as a daily permissible emission.
As shown in Table 3, twice since the start-up of the plant the permissible yearly level of α-activity was exceeded, which is insignificant as the total activity discharged by the Research Center was well below the permissible exhaust levels.

TABLE 3

YEAR	α-Activity mCi/a		β-Activity mCi/a		H_3-Activity Ci/a		Emission of β-Activity per Ton of Throughput
	Emitted	Permissible	Emitted	Permissible	Emitted	Permissible	
1971	1,2	0,8	32	400	-	800	0,274
1972	1,7	1	170	400	-	10	1,560
1973	0,27	1	100	400	159	500	0,870
1974	0,21	1	230	400	179	500	1,503

Presently, the actual emitted α-activity is below the permissible level by a factor of 5, and the emitted ß-activity is below the permissible level by a factor of 2.

Occasionally, difficulties were experienced in meeting the requirements for the daily permissible emission levels. By installation of treshold values into the emission measuring installation, the daily permissible levels are not exceeded.

Table 3 shows, starting in 1972 an increase in specific ß-activity in the flue gas, based on the throughput rate of radwaste products, despite the fact that the filter effectiveness has been improved since start-up of the installation. This increase is due to the presence of large amounts of volatile radionuclides in the radwaste material, which are generated since start-up of a pilot reprocessing plant. Radwastes generated by this plant contain fission products such as ruthenium and cesium. The oxides of these products are volatile at high temperatures, as present during incineration, and, therefore, increase the ß-activity of the exhaust.

Spectro-scopic tests showed that the exhaust activity is composed of 95% Ru^{106}, and approximately 5% of Cs^{134}, Cs^{137}

Based on the data obtained during a period of 4 months of testing, the following separation degree of the plant can be calculated (Table 4).

Table 4: Calculation of Separation degree for α and β activities by the Ceramic Filter

TEST PERIOD	THROUGHPUT t	α-Activity (mCi) in Waste	α-Activity (mCi) in Exhaust	β-Activity (mCi) in Waste	β-Activity (mCi) in Exhaust
1. Month	12,48	165	0,010	1217	7,92
2. Month	7,30	430	0,007	1290	11,34
3. Month	15,53	149	0,0053	2910	16,20
4. Month	20,18	1945	0,0464	3470	31,90
	55,49	2689	0,0688	8887	67,36

Separation degree for α and β-activities:

$$\mu_\alpha = 100 - \frac{0,0688 \cdot 10^2}{2689} = 99,997$$

$$\mu_\beta = 100 - \frac{67,36 \cdot 10^2}{8887} = 99,25$$

The installation of a scrubber after vacuum blowers further reduced the emission of radioactive components into the environment.

The following results were obtained after a 6 - week operation of the scrubber, (see Table 5).

Table 5: Calculation of separation degree for ß-activity by employing a scrubber

Week	Throughput t	Waste Water Amount in Scrubber m^3	Activity in Waste Water (mCi)		ß-Activity in Chimney (mCi)
			ß	H_3	
37	1,74	226	2,7	880	0,10
38	2,62	304	1,6	40	1,00
39	0,82	128	2,5	1000	0,13
40	3,72	448	2,8	120	0,15
41	4,07	685	5,5	700	0,46
42	2,78	300	1,3	190	0,03

Total-ß-activity in fluegas before scrubber = 18,27 mCi

Total-ß-activity in fluegas after scrubber = 1,87 mCi

Total-ß-activity in waste water of scrubber = 16,40 mCi

Separation degree of scrubber for ß-activity

$$\mu_{\beta} = 100 - \frac{16,4 \cdot 10^2}{18,3} \sim 10$$

2.8 Drum Scrubbing Facility

Before reuse, the empty 200 l reinforced drums must be cleaned and decontaminated. Previously cleaning was effected manually. In order to automate this process, a drum scrubbing machine was installed in the FERAB facility allowing to clean 12 drums per hour (Fig. 15). The purification process passes four steps with two positions.

In the first position the drums are cleaned with rotating brushes and a scrubber solution of 70°C (standard detergent). This scrubbing step is followed by hot water flushing. Before the drum gets into the second position, most of the water attached is blown off by air. In the second position the drum is dried by hot air. The drums are subjected to wiping tests to ensure that they leave the facility and are cleared for internal transportation.

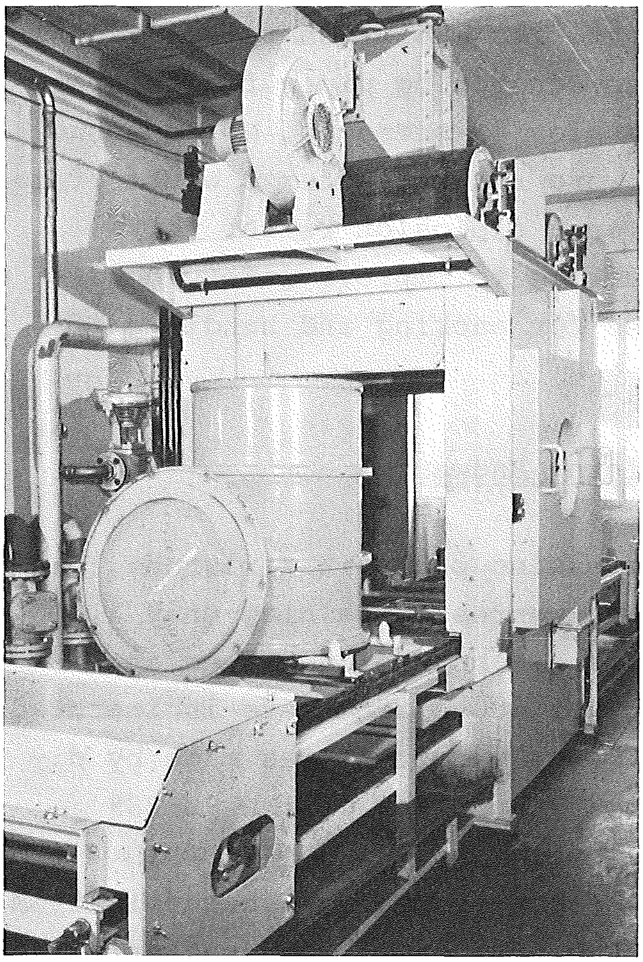


Fig. 15:

Drum scrubbing machine

3. Operating Interferences

During the four years of operation only 2 minor malfunctions occurred. In both cases explosions took place in the ash discharge unit. Both explosions were caused by combustion of flammable, incompletely burned gas in contact with hot ashes. These gases were produced during start-up of the plant and had collected in the ash discharge box. By improving venting conditions in the discharge box further explosions were prevented. In addition, the ash discharge box was also equipped with explosion-relief valves. Both incidents did not result in personnel injuries or damage, and operations could be resumed after a brief down-period. A larger scale explosion occurred in 1973 in the feeding device. This incident was caused by improper delivery of organic solvents. A 10-l glass bottle containing highly flammable solvent was delivered in a carton, improperly marked. During charging of the incinerator a violent explosion took place, resulting in deformation of the cover for the ash discharge unit. The explosion relief valves acted immediately, however, the connecting pipes to the spark arrester were damaged by the explosion pressure. No personnel injuries occurred. Operations were resumed after 2 weeks of decontamination work. A large area explosion relief valve was installed at the feeding device to improve safety conditions. In addition, regulations for packing and handling of combustibles were tightened.

3.1 Incineration of α-containing Radwaste

Prior to start-up of the reprocessing plant in Karlsruhe, distinction was easily made between wastes containing only α,β and γ contaminants. At that time, α-containing wastes at levels between 10 and 20 mg Pu per 200-l drum were incinerated in the plant. Determination of the Pu-content was made by direct measurement of the 50 and 380 KeV-line of the Pu-239 with a special drum measuring device (Fig. 16). By accepting also combustible waste from the reprocessing plant, a determination of the plutonium content with the previously used measuring device was no longer possible because of the fission products contained therein. Since the incineration plant was not designed for α-containing wastes, occasionally plutonium contaminations occurred where wastes from the reprocessing plant were incinerated. In order to avoid similar contaminations, only reprocessing wastes containing less than 20 mg/200-l drum were processed. By modification of individual installation components, such as filter housings or feeding device for α-application, the installation will certainly give improved performance in respect to incineration of wastes with higher Pu-levels

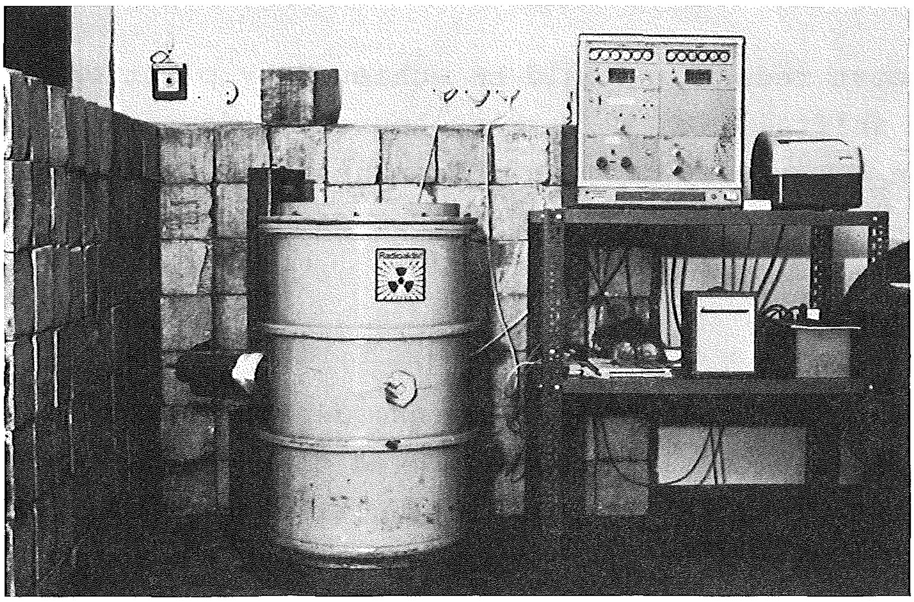


Fig. 16: Drum measuring device for Plutonium waste

4. Operating Costs

The volume reduction plant for low level solid radioactive waste was built at a total expenditure of approximately $ 1.2 million.

Table 6 shows that the total operating cost of the incineration plant has roughly doubled between 1971 and 1974, while the throughput of the plant has risen by only some 20%. At a level of 180 tons of throughput per annum the combustion plant has reached the upper limit of its capacity; this figure is based on an average output of 65 kg/h, two-shift operation over a daily working period of 14 hours, and 200 working days a year.

The percentage breakdown of the total cost shows that overhead represents a major factor. Thus, in 1974, $ 3.69 had to be paid for the combustion of 1 kg burnable waste, of which $ 1.60 were due to the infrastructure of the Karlsruhe Nuclear Research Center. A plant running under commercial conditions would certainly be able work at lower cost.

Further cost reduction could be achieved by plant operation in three shifts, with 19 working hours per day and 250 days of operation . The cost of 1 kg of combustible waste in that case would drop to $ 3.10, as can be seen from the table.

5. Conclusion

Twelve years of experience, from the design to the operation of an incineration plant, have proved that the combustion of radioactive waste entails no difficulties whatsoever. This is true, above all, of burnable waste from nuclear power stations whose composition is more homogeneous and which rarely contains any plutonium or fission products. This makes incineration an ideal process to reduce the volume of burnable radioactive waste.

Only because of the high capital and operating costs, incineration plants for radioactive wastes are mostly set up in places where large quantities of combustible wastes are generated. If a satisfactory solution is to be found for the future, probably the centralized use of larger economical plants will be desirable.

Table 6: Operating Costs

YEAR	THROUGHPUT TONS	TOTAL COSTS $	BREAKDOWN OF TOTAL COSTS IN PERCENT MATERIAL %	PERSONNEL %	OVERHEAD %	DEPRECIATION %	COST OF COMBUSTIBLE WASTE($/kg)
1971 +	150	364,000	14.0	27.9	33.3	24.8	2.41
1972 +	144	510,000	16.6	19.9	36.2	27.3	3.54
1973 +	133	435,000	15.1	20.7	38.6	25.6	3.24
1974 +	175	650,000	14.5	20.4	43.5	21.6	3.69
++ 3 SHIFT BASIS	310	980,000	21.1	19.2	42.0	17.7	3.12

	OPERATING TIME/DAY	WORKING DAYS/YEAR	AVERAGE THROUGHPUT/HOUR
+	14 HOURS (2 SHIFTS)	200	65 kg
++ ESTIMATE	19 HOURS (3 SHIFTS)	250	65 kg

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