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High temperature treatment of waste: From laboratories to the industrial stage

Rodolphe POIROUX* - Marianne ROLLIN**

*EDF R&D Division, Les Renardières Research Center, 77250 Moret sur Loing France
**INERTAM, 6 rue Ampère, 93600 Saint Denis

Abstract
The French legislation drawn by European directives requires that any waste producer is responsible for elimination of its own wastes and this should not generate additional harmful effects on the environment.
To answer this regulation enforcement, high temperature treatment using a plasma torch or an electrical arc is a very interesting solution for toxic wastes elimination.
EDF started several actions in this field at industrial or quasi industrial scale to treat asbestos and fly ash.

ASBESTOS WASTE PROCESS

During the last decades, asbestos has been widely used in buildings for its good protection against fire. Numerous medical surveys have proved that the very thin fibers of this mineral compound can lead, through inhalation, to serious pulmonary diseases.
INERTAM is a joint venture including EDF (majority shareholder) and PROMETHEE. It has been created in 1992 to build and operate a movable asbestos waste treatment facility, and to sell services based on this equipment.
The process based on the vitrification with a high temperature plasma torch, enables the transformation of rubbles polluted with asbestos to get an inert and non leachable product.
This installation which has been set on the EDF site of Arjuzanx is now in operation since the end of 1994. 1500 tons of asbestos wastes coming from the dismantling of the Arjuzanx plant and from others EDF power plants have been processed.

INSTALLATION MAIN FEATURES

The installation does not require any selection of asbestos wastes which are more often made of a mixture of rubbles and metallic beams polluted by asbestos rather than made of pure asbestos.Most containers used for transportation and storage of asbestos wastes are accepted. Nevertheless, the experience acquired in this field lead us to prefer type 2301 hooped metallic drums and 500 l big bags, loaded 2 by 2 in the furnace.
The installation is movable using 17 vehicles ; the mounting-dismounting time is around 10 days ; the capacity is 1ton/hour and the operation is continuous 24h a day.

The processing line includes 5 main units (fig. 1):

- The automatic loading mechanism
To ensure the loading into the furnace at a regular cadence of 1ton/hour, taking into account the possible heterogeneity of the product, the system is equipped with a weighing table, a gauge control and several belt conveyors. An automatic system manages the packages according to their weight and supply regularly the elevator feeding the lock chamber. An hydraulic ram introduces the load into the furnace as soon as it receives the enabling signal.
The conveyors start from a temporary store integrated in the movable platform which enables the operator to have about 48 hours of treatment available in advance.

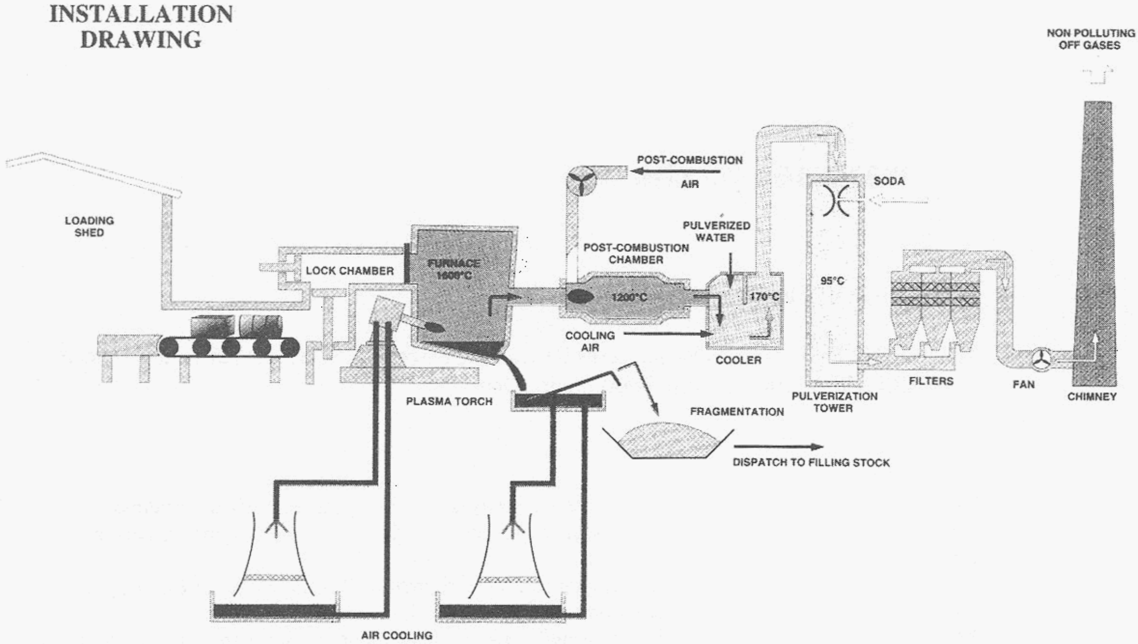

figure 1: schematic diagram of the plant

- The furnace with the post-combustion chamber

The vitrification of asbestos wastes takes place in a cylindrical furnace in which the temperature is maintained at 1 600°C by the plasma torch.

The wastes are introduced in front of the torch nozzle and are submitted to the plasma jet. The 4 000°C jet ensures a perfect vitrification of the products and the stirring ensures the bath homogeneity.

The furnace includes a tapping hole opening and closing automatically so the vitrified product can be discharged toward an ingot system.

The pyrolysis gas of the wastes fuel elements are exhausted by depression toward the post-combustion chamber where it is fully oxidised. The combustion is made at a temperature of 1 200°C and the retention time exceeds 2 seconds. The post combustion chamber is equipped with an auxiliary burner which maintains the desired temperature in the phases where the wastes does not contain any fuel products.

-The plasma system

The electric power of the plasma torch is 1 750 kW that is to say a thermal effective power of 1 435 kW.The plasma gas used is the ambient air.

The cooling of the electrodes is made by a demineralised water circuit flowing in closed loop. The use of a plate exchanger and an air cooling system limit the water consumption to 3 m3/h.

- The fumes discharge treatment unit

At the post combustion chamber outlet the gas is led toward a cooler in which pressurised water is pulverised. The temperature is lowered down to 200 °C to garantee dry fumes.

The fumes are then introduced into the soda evaporation chamber where a soda solution is pulverised to neutralised the high acidity of the fumes. The temperature at the depression outlet is such that we remain above saturation and we keep dry. Salts obtained by neutralisation reactions crystallise.

After passing through an electrofilter and a high performance filter which catches most of the dust, which are recovered and introduced in the furnace. The fumes are exhausted into the atmosphere using a 15 m high chimney

Analysers continuously check the dust level, the hydrochloric acid concentration as well as CO, CO_2 and O_2 analyses.

Gaseous rejection levels are below European Standard. There is no humid emission.

- The monitoring-control panel

Every unit is equipped with its own controller which ensures the good operation of every phase in the acceptable range. Operators work with a data computing supervisor which enables to communicate with every controller, to trigger the start and stop phases, to set the different operation phases and to get information on the system condition, especially when an operational fault appears.

Three persons are enough to pilot the installation, including the loading of the furnace and the removal of the vitrified product.

MAIN RESULTS

A feedback has been carried out on the furnace operating tests.

Some very positive aspects have been pointed out, especially the very good thermal insulation of the furnace and the homogeneity of the wall range of temperature (except for the impact area facing the plasma jet).

This behaviour has been partly observed by a series of 3D digital modelisations carried out at the EDF National Hydraulics Laboratory (see fig. 2)

To take into account the production requirements, the furnace has been slightly modified in 1994 (volume and inclination of the loading chamber, length of the plasma jet, introduction and conditioning of the wastes, structure of the refractory walls ...) to reduce the furnace wear on the area facing the plasma jet impact.

The aim for the materials life time is 1 000 hours in continuous operation.

To increase the efficiency of the furnace, it is necessary to optimise the asbestos bath-plasma thermal transfer. The height of the bath is calibrated according to the melting duration (around half an hour per loading cycle). The temperature level is adjusted at 1 600 °C for the different asbestos types. The thermal transfer is optimised thanks to the vortex created above the bath and due to the plasma flow, which ensures mixing between the melted wastes and the wastes still in solid state

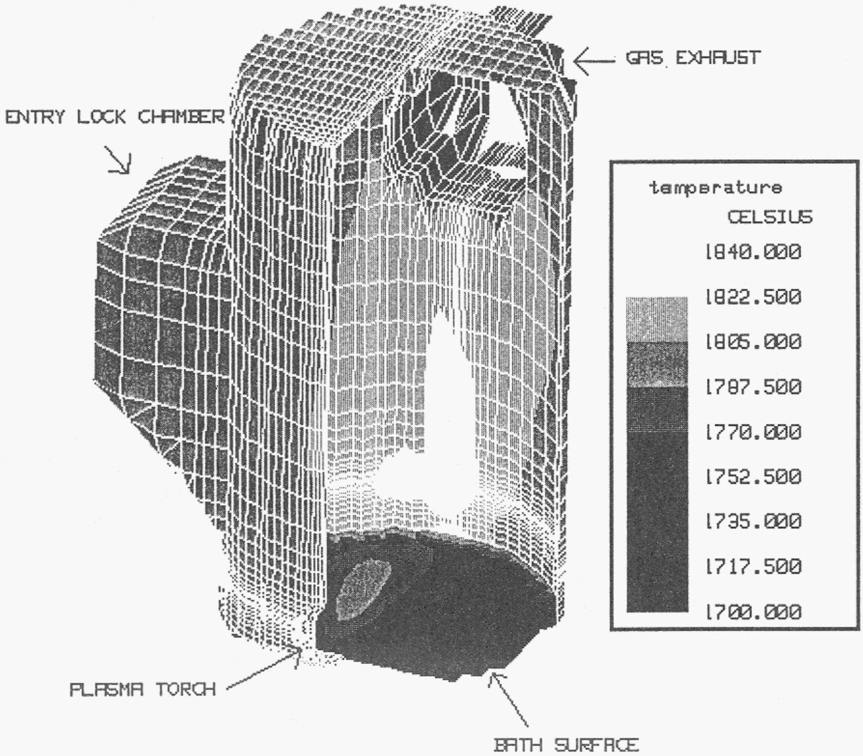

figure 2: results of the modelling of the furnace chamber

The vitrified product obtained is non leachable and fiberfree. Its long time stability is at the present time estimated to be superior to 2 000 years without any modification of its crystalline structure. The product is marketable, with a volume of waste reduced to 1/20th its original volume, and is used as landfill material for road technics.

After having processed in Arjuzanx the asbestos coming from the dismantling of EDF power plants, INERTAM will move the platform near Arzujanx on a site where two types of vitrification services can be proposed:
- treatment on the customer site, moving the installation.
- treatment on the Pithiviers site which is a 2 000 tons storage and process centre. Asbestos wastes can come from France and the European Union after agreement from the administrative authorities.

DOMESTIC WASTE INCINERATION FUMES PURIFICATION RESIDUES TREATMENT

The yearly production of domestic waste in France reaches 20 millions tons. One of the techniques to eliminate wastes is incineration followed by a combustion fumes treatment. This fumes purification produces fly ash which are still toxic.
Fly ash include harmful leachable elements, especially lead, mercury, cadmium, tin, nickel, chromium, copper and zinc which concentration can vary from 10 ppm to 1 2000 ppm.
The growing share of incineration to eliminate domestic wastes leads to an increasing quantity of ash from a year to another (400 000 tons today in France).

The overload risks of class 1 dump and the reinforcement of the regulation pressure urge industrialists on to develop processes to decrease the wastes toxicity and to lower elimination costs.
EDF took an interest into vitrification, as a technique using electricity. It consists to heat the fly ash at a temperature of 1 400 °C to produce a low volume inert glass which traps residual polluting elements and to treat the vaporised compounds.
In order to do so, a pilot platform has been built at the R & D Division in 1992.

INSTALLATION MAIN FEATURES

The installation includes (see fig. 3):

- A vitrification furnace lined with high temperature refractory liable to operate continuously at 1 700 °C. The tiltable type furnace is equipped with a central graphite electrode creating an electrical arc. The maximal electrical power can reach 900 kVA (2 000 A, 450 V).
A bottom graphite electrode ensures the return of the arc current.
The furnace has a treatment capacity of 300 kg/h and operates under a slight depression (1 mbar).

- A device including an Archimedean screw to introduce fly ashes into the furnace which creates a pasty front avoiding the particles to fly. At the screw outlet, ashes submitted to the furnace and the arc radiation change of state and progress toward the bath due to the melting effect. An appropriated flow rate is needed to get a constant and renewed pasty front.

- A dry quench device to condense heavy metals in a salt form after filtration : the level of temperature required for vitrification leads to the evaporation of part of heavy metals and chlorides. The water quench device proved to be inefficient to completely trap heavy metals since out standard aerosol type rejection was found at the smokestack outlet. With a dry quench (cooling carried out by injection of cold air followed by an appropriated filtration), the major part of heavy metals is trapped in secondary ashes. The gas purified that way is easier to neutralise in the washing tower.

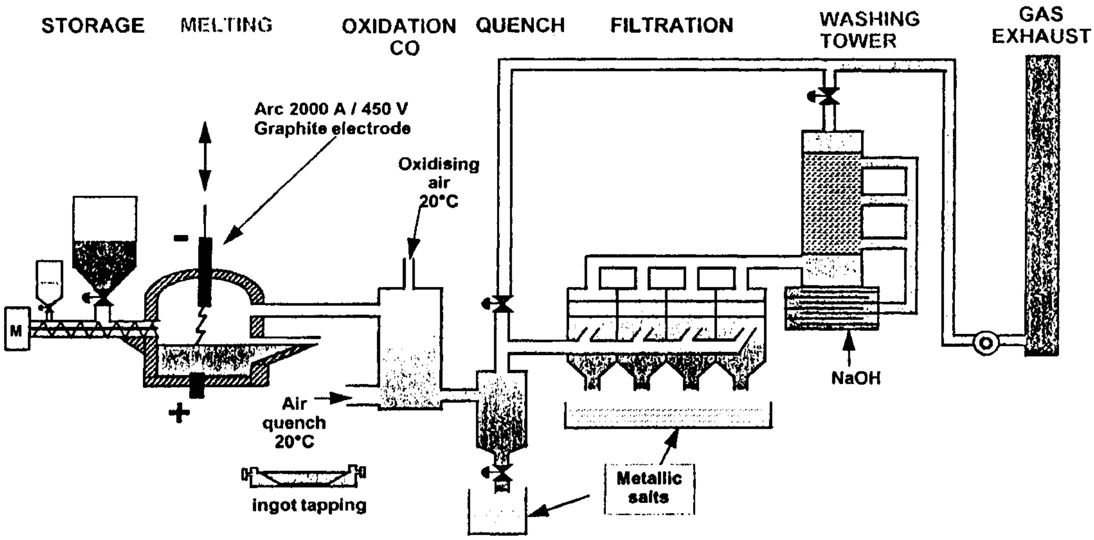

figure 3: schematic diagram of the installation

- A washing tower associated with a soda neutralisation to trap harmful acid gas (S02, HCl) before rejection into the atmosphere. The treatment ends when SO2 stops to be rejected at the furnace outlet.

- An ingot tapping system.

During tests, the treatment was mainly carried out in batch process to better control the retention time, nevertheless some continuous operation tests have been also planned.

MAIN RESULTS

Energetic consumption

Batch process (kWh/kg)	Continuous process (kWh/kg)
1.02	0.92

Values for a continuous flow process are calculated with the actual ash introduction duration ;

on the other hand, with a batch process the treatment must lasts 15 minutes after introduction of the last ash.

Initially the platform was equipped with a transferred arc plasma torch which has been replaced by a graphite electrode for energetic consumption, safety, maintenance and investment costs reasons. The use of the graphite electrode leads to an energetic consumption gain reaching 22% in comparison with the plasma torch.

Mass balance

The first tests were carried out on filtration ash (no lime reagent).

Table 1 - processed ash composition (as %):

Moisture	1.32	PbO	1.25	ZnO	3.27	HgCl2	0.0013
SiO2	20.23	CdO	0.05	NaCl	10.42	BaO	0.06
CaO	20.07	MnO2	0.07	KCl	9.26	SO3	10.10
MgO	3.66	CoO	0.02	CuO	0.18	C	1.10
Al2O3	14.32	SnO2	0.31	NiO	0.10	PO3	2.42
FeO	1.38	AgCl	0.02	CrO3	0.14	N	0.12

The temperature level to obtain a good quality vitrified product is around 1 400 °C. The mass balance of a standard treatment for 100 kg of fly ash is:
- 71 kg of vitrified product
- 28 kg of neutralised salts, heavy metals free
- 1 kg of metallic salts, containing heavy metals mostly, known as ultimate wastes

This ultimate wastes very low level is due to an additional treatment of residues recovered in the dry quench device filters (EDF patent).

Table 2 - vitrified product composition (mg/kg of dry material):

Al	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Sn	Zn	Na	K	Ca	Mg	Hg	AS
82,5	0,07	2	0,47	25	1,45	0,78	2,15	2,75	31	16,7	11,5	147	23,5	0,03	0,005

The following tables show the maximum values (mg per kg of waste) above which wastes must be disposed of in special dump and the values obtained for two samples of vitrified product according to the AFNOR X31.210 french standard (4 mm crushing) leaching tests.

Table 3 - AFNOR Standard

COT	Cr	Pb	Zn	Cd	CN	Ni	As	Hg
<400	/	<30	/	<5		/	<2	<0,3

Table 4 - leaching tests

COT	Cr	Pb	Zn	Cd	CN	Ni	As	Hg
null	0,08	0,4	0,2	0,01	/	0,2	<0,01	<0,01
null	0,04	0,2	0,3	0,01	/	0,1	<0,01	<0,01

Additional tests have been carried out or are planned this year:
- Others fly ash types - dry treatment, filtration cakes
- Replacement of the bottom electrode by a second electrode set on the side of the furnace to resolve operation and maintenance problems
- Continuous flow process
- Determination of operation parameters - temperature, incoming products composition, furnace atmosphere - to get a vitrified product without any toxic element, in case of law enforcement in that direction.

The promising results allow to project an industrial process with the vitrification advantages:
- Reduction of the wastes of 1/6th its original volume

- Very good capacity of resistance to leaching and long time stability (long terms behaviour) of vitrified products, forecasting a classification as a harmless waste.

EDF in association with engineering companies is studying the implementation of a 2 t/h industrial furnace. This furnace will be designed with the latest modifications made on the prototype furnace.

The geometry conception of the furnace will be redesigned in order to comply with higher capacities and continuous flow process.

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