THE LA HAGUE VITRIFICATION FACILITIES

Mr S. Merlin
SGN
Saint-Quentin-en-Yvelines, France

ABSTRACT

A brief summary of the continuous vitrification process implemented on an industrial scale in the French vitrification facility at Marcoule (AVM) is given. Advantages specific to this process are enumerated as well as practical lessons drawn from 7 years of continuous active operation. A description of the vitrification facilities which are being built at the La Hague reprocessing plant is presented along with their new features with respect to AVM.

INTRODUCTION

In the early 1970s, the decision was taken in France to close the fuel cycle. This includes the treatment and conditioning of high active level waste for final disposal. The organizations involved were COGEMA (responsible for plant operation), CEA (the French Atomic Energy Commission responsible for Research and Development), ANDRA (responsible for long-term waste management) and COGEMA'S subsidiary company SGN as the Architect Engineer responsible for the design and construction of nuclear spent fuel reprocessing and waste treatment facilities.

The process implemented in the first industrial facility AVM (Marcoule vitrification facility) was based on a two-stage continuous process, i.e. calcination in a rotary tube and melting in a metallic pot heated by induction. Since its commissioning in 1978 this facility has been successfully operated and this process has therefore been selected for the new vitrification facilities presently under construction at the La Hague reprocessing facility, i.e. R7 (UP2 800 facility) and T7 (UP3 facility).

DESCRIPTION OF THE AVM PROCESS

The process may be briefly described as follows : fission products in the form of concentrated nitrates, previously analyzed and adjusted, are transferred from stirred tanks into a rotating calciner heated by electrical resistances.

Nitrates are transformed into oxides which are mixed with glass frit adapted to the chemical composition of fission products and dropped into the induction heated preparation furnace.

The glass is prepared and then poured into stainless steel containers, to which a lid is welded and which after decontamination with water are placed into an air-cooled storage.

The calciner is supplied from these tanks at constant flowrate through a pot in which a calcining additive is introduced so as to prevent any scaling of the calciner internal walls and to give the requisite grain size for correct assimilation by the melted glass.

Pouring is triggered every eight hours approximately by heating the pouring nozzle with a specific inductor. The maximum capacity of this melting furnace is around 15 $kg.h^{-1}$ of glass for a maximum evaporation capacity of 40 $l.h^{-1}$.

Off-gas produced during vitrification successively passes through a dust-scruber which retains and dissolves the dust entrained outside the calciner in a boiling nitric acid solution.

This solution is continuously recycled in the calciner in order to avoid any accumulation of activity and insoluble particles in the dust-scrubber.

The off-gas then passes through a condenser, an absorption column and a washing column before being discharged into the ventilation system.

The glass is poured by 50 liter batches in 150 liter containers.

The containers, filled at the rate of one per day are then directed towards a welding machine which seals the lids by means of a plasma torch.

They are then decontaminated with pressurized water and are subject to a non-contamination inspection by passing through an annular smear brush device and are stored in air-cooled shafts contiguous to the facility.

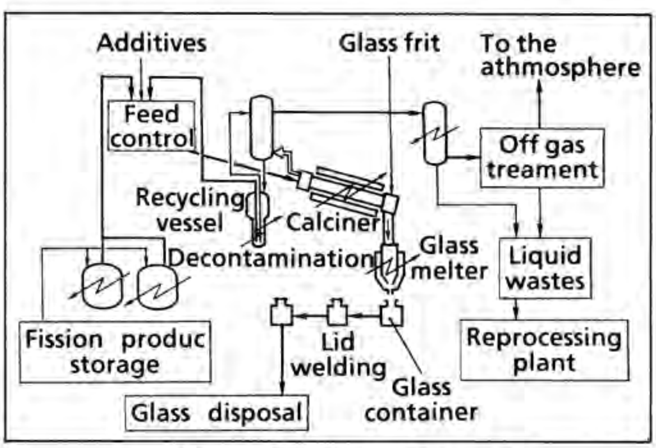

Fig. 1. AVM Process Schematic.

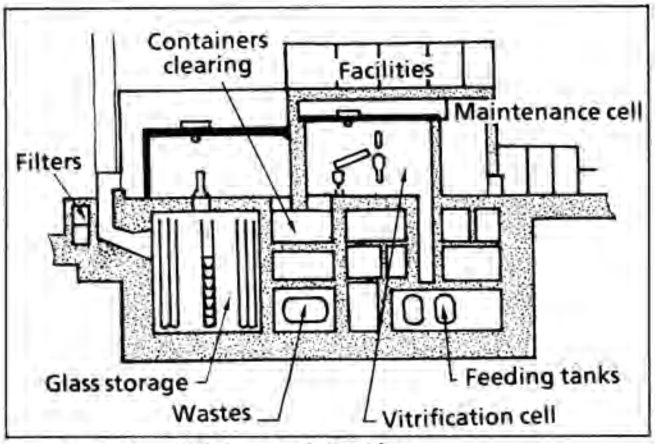

Fig. 2. AVM Vertical Section.

OPERATING RESULTS OF THE AVM FACILITY

Since 1978, the AVM facility, which is at present the only vitrification unit facility in the world operating on an industrial scale, has vitrified more than 995 m3 of fission product solutions (see Table I : Characteristics of French F.P. solutions), thus producing 1,320 glass containers.

This glass production has been obtained in 19 campaigns. The cumulative operating results of the AVM, on December 31, 1985 are :

AVM working period (hours)	33,500
FP volume processed at AVM (m3)	995
Total weight of glass stored (t)	450
Total reduction factor	5.5
Total number of stored glass containers	1,320
Total number of stored waste containers	70

The vitrification capacity of 150 m3 of liquid HLW per year exceeds the rate at which HLW is produced at the Marcoule reprocessing plant but the intent was to meet the current requirements and also, within a few years, to eliminate the stock of fission product solutions that had built up over the previous 20 years of operation. This will be accomplished in less than 10 years from the date of AVM start-up.

The availability factor was higher than 66% which is an excellent result, considering that most items of mechanical equipment were dismounted by remote operation for scheduled replacing or for inspection, and that these operations were performed slowly at the beginning of start-up in order to test the procedures and to obtain a maximum of data.

Thanks to AVM facility a wide experience has been gained with respect to technology, design, maintenance and safety, and this experience will be useful for the future facilities currently under construction.

The main result of the AVM experience has been the final selection of the two-stage process for large industrial applications, which offers numerous determining advantages, among which :

- the separation between the evaporation calcining, and the vitrification function which enables each function to be controlled individually. The calcination step for reprocessing wastes increases the overall safety of the system.
- the low hold-up rate of the installation
- the use of small size equipment ensuring the good capacity of the installation giving easy maintenance and leading to small volumes of technological wastes
- the rapidity of maintenance operations.

CHARACTERISTICS OF THE LA HAGUE VITRIFICATION FACILITIES

The facilities being built in France form an extrapolation of AVM. Improvements made with respect to AVM mainly concern :

- increase in output
- minimizing of waste and effluent volumes
- maintainability
- reduction of number of items of equipment and of amount of civil work involved
- handling of higher activity solutions with high volatile substance content.

Features of R7 and T7 From an Output Aspect

Two vitrification facilities - R7 and T7 - are under construction at La Hague (France). R7 is to be used for the continuous vitrification of FP solutions from the future UP2 800 plant, as well as to absorb existing stocks of solutions with different origins.

T7 will be the vitrification facility for the UP3 plant. Both these facilities will have a yearly treatment capacity corresponding to 800 t/initial uranium, the reference fuel being light water fuel with a burn-up of 33,000 MWd/t and a 4 year cooling period. These plants produce not only fission product solutions but also insoluble compounds called dissolution fines, which are separated during clarification subsequent to the dissolution of spent fuel. They also produce active, sodium rich solutions coming from solvents following treatment by sodium carbonate or from evaporator rinsing at completion of the concentration cycle.

These effluents form high activity solutions with diverse compositions, all of which have to be integrated in the glass. The CEA therefore developed a glass which met these requirements and which gave the requisite warranties as to long term reliability and stability. In order to reduce the number of processing lines, the vitrification line capacity was increased with respect to AVM. From an evaporation capacity of 40 l/h and an average vitrification capacity of 15 kg/h at AVM, these capacities were increased for R7 and T7 to 60 l/h corresponding to 25 kg/h per line. This last value is not the limit of capacity of the melter which can be easily increased to 30 kg/h.

Resources Implemented For Minimizing Waste Volume

A major headache is minimizing waste and effluents. The example of AVM has demonstrated that most of the liquid wastes come from the decontamination of glass containers after their filling. The source of this contamination was contamination spreading in the vitrification cell essentially caused by the replacement of melting pots and occasionaly other equipment, as well as by the in-cell cutting up of these items of worn equipment before packing.

In order to modify this, a decision was taken to physically separate the functions of vitrification, pouring and dismantling for R7 and T7 (Fig. 3).

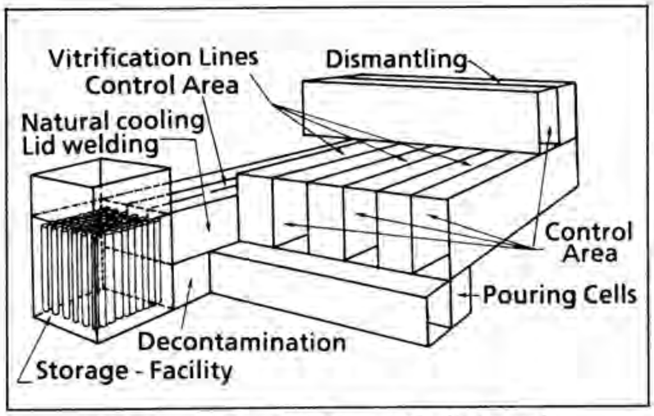

Fig. 3. Layout of R7 and T7 (LaHague).

For this reason, the following mechanical cell arrangement was selected :

- The vitrification lines including the calciner, the melter, the dust-scrubber and the feeding vessels are independent to improve the plant availability and make the maintenance operations easier by grouping remotely dismountable equipment whose life time is considered as being shorter than that of the facility.

- The pouring cell is segregated from the vitrification cells in order to reduce the external contamination of containers to a value compatible with the international transportation rules (10^{-4}Ci/m2).
  When admitted into the pouring cell, the containers are theoretically uncontaminated, as at no moment they are in contact with a contaminated environment. They systematically undergo monitoring of the total external surface, after lid welding, and SGN has developed a dedicated equipment for this operation. If the container is proved to be contaminated, decontamination is performed by pressurized water jets, using a more advanced technique than the one used in the AVM facility, as it decontaminates all points of the container under the same pressure conditions.
  The container is then remonitored after this decontamination using a robot identical to the first one but located in a different cell, with very low contamination hazard. If this second test is negative, the container is placed in a transfer cask and transferred to an interim storage area close to the facility.

  Such a lay-out allows :
  . easier maintenance of all the mechanical equipment located in and downstream from the pouring cell,
  . a minimized volume of liquid waste. In the event of abnormal labile surface contamination, high pressure water decontamination is foreseen,
  . a minimum fracturation in the glass thanks to an optimized cooling down of the glasstemperature only by means of air,
  . an intermediate storage which can be cooled down by natural air convection.

- The pouring cell and the cells located downstream in which container filling and cooling, lid welding and checking of non-contamination of container surface take place are common to the three lines in order to reduce the number of key components.

- A dismantling cell is associated with each facility in order to dismantle worn equipment without modifying the plant availability. The dismantling cell is equipped with master slave manipulators specific tools such as saw or shear and a high pressure decontamination system.

Maintenance

Special efforts were made when designing the facilities to improve both operability and maintainability. These efforts were mainly focused on :

- Interchangeability of the equipment installed in active cells in order to improve the plant availability and reduce the number of spare components to be stored in the facility due to the presence of six vitrification lines on the La Hague site.
  Interchangeability was obtained by the use of remotely handled coupling sleeves specially designed to compensate for the deformations of the associated pipings. The coupling sleeves installed on pipings conveying either gases or liquids which do not incur deposit risks are fitted with bellows. For the pipings that convey liquids entailing deposit or corrosion risks, a piston type coupling sleeve was developed in order to prevent deposits and maintain the required flexibility.

- Optical determination of the x, y and z co-ordinates of all connection points of the remotely dismountable equipment. This method has the advantage of being more accurate and avoids the use of jigs which may suffer deformations during transportation.

This method is currently used to determine the x, y and z co-ordinates of the components prior to their introduction into the cell. Tests are presently performed in order to apply this method to direct incell metrology, which would allow the exact location of the incell piping to be verified.

Besides that, the general maintenance principles implemented in the vitrification plant are those applied to the other La Hague facilities, i.e. :

- Standard dismountable equipment such as jet nozzle, vacuum filter and ventilation filter are removed with a MERC (Mobile Equipment Replacement Cask).

- Modular cranes are used in the active cells.

These maintenance principles not only increase operability but they also reduce sharply the personnel dose rate.

Minimization of the Quantity of Equipment

Cell layout has been designed to minimize the number of equipment and the amount of civil engineering work while retaining a configuration capable of guaranteeing plant operability and safety.

In particular, the pouring, cooling and welding systems of the three lines are grouped in a single cell, like the dismantling equipment for treating radwaste from the entire facility.

Modifications Required By Light Water Solution Treatment

Scaling-up of AVM to R7 and T7 gave rise to no special problem as to the handling of high active fission product solutions with a higher content of volatile substances.

The volatility of considerable quantities of ruthenium in fuel with high burn-up was controlled by the addition of selective reducing agents which act directly at calcining level.

The use of such an agent on R7 and T7, which also acts as a calcining additive, considerably reduces volatility in comparison with AVM and increases ruthenium blocking efficiency in the dust-scrubber.

The performances quoted above and the technological development of equipment were obtained on a scale 1 prototype installed in the nuclear power plant at Marcoule. Its exclusively cold operating enables the performances, the operating conditions and the service life of the constituent parts to be determined.

R and D Program

Scale 1 tests were conducted on all new equipment, even when it differed only slightly from that used in other industrial facilities. The purpose of these tests was to check that the requirements to be met by the equipment were really fulfilled, both under normal operating conditions or during maintenance. They also aimed at defining the acceptable variation range for all the operating parameters.

Some of the most important components are the following :

- The calciner-melter assembly which is identical to the AVM system with minor modifications to facilitate the replacement of parts such as graphite ring-seals between calciner tube and end-fittings.

- The welding machine : the tightness of the weld is obtained by monitoring the welding parameters whose variation range was determined during factory tests and verified under the facility operating conditions on scale 1 containers filled with glass.

- The robot, for controlling the non-contamination of the containers.

Tests were conducted to determine the nature of the smear brush material so that it resists the container temperature. They also aimed at defining the value of operating parameters such as rotational speed of the container, pressure of the smear brush on the container, contamination transfer coefficient between the container and the smear brush, using radioactivetracers. The test results were checked on scale 1 containers.

All the R and D programs are now completed. Satisfactory results were obtained and comply with the requirements to be met for the qualification of the equipment prior to its installation in an industrial facility.

Product Quality

The final product quality (i.e the glass quality, see Table II) is ensured by monitoring of the operating parameters. From the point of view of the design, several stages were necessary for the preparation of the glass Quality Control Plan, namely :

- identification of the parameters having an influence on glass quality,

- definition of the acceptable glass composition variation range on the basis of sensitivity tests performed in the laboratory on each glass component. Limits could therefore be set and verified on the scale 1 prototype,

- parameters failure analysis in order to assess the time needed for failure detection as a function of the detection means, along with its possible influence on glass composition. In order to prevent the glass composition from varying beyond the above-mentioned limits, alarm thresholds which automatically stop the production of glass were defined.

- feasibility study of the data processing systems used in the plant.

DESIGN AND CONSTRUCTION PERFORMED BY SGN IN THE VITRIFICATION FIELD

To complete this demonstration of the commercial aspect of vitrification in France, some information are given concerning the different studies carried out by SGN within the framework of vitrification and on the construction deadlines scheduled for R7 and T7.

The conceptual studies for R7 and T7 were initiated in 1980 and 1982 respectively.

Construction of the R7 vitrification facility is being completed now, cold testing is in progress and the active start-up of the R7 facility is scheduled for 1987. On the other hand, the T7 facility will be in hot operation in 1989.

CONCLUSION

To conclude, it should be pointed out that :

- AVM is the only vitrification facility in commercial operation within a reprocessing plant,

- operating results were most satisfactory from capacity, maintenance and safety aspects, and this has enabled the process to be extended to larger scale facilities which will enter into operation in the near future,

- SGN, in its capacity as an engineering company, has gained a strong experience enabling it to deliver turn-key facilities since, by 1989, it will have built 9 active vitrification lines and, in project form, studied several other lines, each adapted to specific operating conditions,

- this technology advancement was possible due to the close collaboration between CEA, COGEMA and SGN, and this continued collaboration is a warranty for future success.

TABLE I

Characteristics of French F. P. solutions

REACTOR SYSTEM	FUEL TYPE	BURN-UP	CONCENTRATION RATE	ACIDITY	CHEMICAL COMPOSITION ($g\,l^{-1}$)							
					AL	Na	Mg	Fe	Ni	Cr	F	FISSION PRODUCT URANIUM AND ACTINIDES
MTR	UAl/PuAl	500 $MWj.\,kg^{-1}$	12 $m^3\,t.^{-1}$	-1.8	81	2-3		1-2			10-12	LOW
GG	SICRAL	4000 $MWj\,.\,t^{-1}$	100 $l\,.\,t^{-1}$	1.0-1.5	10-12	2-5	3	8	1	1	5	37-42
PWR	UO_2	33000 $MWj\,.\,t^{-1}$	300 $l\,.\,t^{-1}$	1.5		32		20	3	3-4		92
FBR	UO_2 / PuO_2	60000 $MWj\,.\,t^{-1}$	1200 $l\,.\,t^{-1}$	1.0-1.5		20		15-20	1-3	2-3		25-28

TABLE II

Examples of glass compositions

REACTOR SYSTEM	COMPOSITION (IN WEIGHT %)									
	SiO_2	Na_2O	B_2O_3	Al_2O_3	Fe_2O_3	MgO	CaO	NiO + Cr_2O_3	FP Oxides and actinides	F
GG	38.4	17.1	17.3	11.0	3.2	5.1		0.8	5.6	1.4
MTR	37.0	19.4	15.4	23.2	1.7			0.2	1.3	1.8
PWR	47.5	12.0	15.0	3.0	5.0		4.0	0.5	13.0	
FBR	40.7	18.2	18.2	13.9	0.9			0.3	7.8	