REVIEW OF THE FRENCH VITRIFICATION PROGRAM

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ABSTRACT

The Vitrification of high-level liquid waste produced from nuclear fuel reprocessing has been carried out industrially for over 25 years by COGEMA, with two main objectives: containment of the long lived fission products and reduction of the final volume of waste.

Research performed by the French Atomic Energy Commission (CEA) in the 1950's led to the selection of borosilicate glass as the most suitable containment matrix for waste from spent nuclear fuel and to the commissioning of the Marcoule Vitrification Facility (AVM) in 1978. In this plant, vitrified waste is obtained by first evaporating and calcining the nitric acid feed solution-containing fission products. The calcinate is then fed together with glass frit into an induction-heated metal melter to have a glass throughput of 15 kg/h. Based on the industrial experience gained in the Marcoule Vitrification Facility, the process was implemented at an even larger scale in the late 1980's in the R7 and T7 facilities of the La Hague reprocessing plant. Both facilities are equipped with three processing lines having a glass production capacity of 25 kg/h each.

Consistent and long-term Research & Development programs associated to industrial feed back from operation have enabled continuous improvement of the process. For instance for R7/T7, the average melter lifetime now exceeds the design basis value by more than a factor of two (5000 hours instead of 2000 hours)

So far, COGEMA's AVM (at Marcoule), R7 and T7 facilities (at la Hague) have produced more than 12750 high-level glass canisters, representing more than 5000 metric tons of glass and 167×10^{6} TBq with high records of safety, reliability and product quality. More than a technical success, in-line Vitrification of HLW produced by operating reprocessing plants has become a commercial reality that led, in 1995, to the first return of glass canisters to COGEMA customers. Moreover AVM is now playing an important role by vitrifying HLW solutions coming from the decommissioning of COGEMA UP1 reprocessing facility.

In this paper, the Vitrification process currently operated in the COGEMA facilities will be described as well as the major milestones of French industrial High Level Waste Vitrification. The potential evolution in technology, process, and glass formulation for liquid waste will also be presented.

INTRODUCTION

Vitrification of high-level liquid waste is now an internationally recognized standard. Many countries such as the USA, United Kingdom, Germany, Belgium, Japan, Russia, have already vitrified high level waste and several more countries are studying application of the vitrification technology.

The first work on vitrification of radioactive waste began in France in 1957 at the Saclay nuclear center with early the selection by CEA (French Atomic Energy Commission) of :

- **Borosilicate glass** as the most suitable containment matrix for waste from spent nuclear fuel.
  By the mid 60s, borosilicate glasses were selected for the vitrification of HLW solutions as the best compromise in terms of containment (leach resistance, thermal stability, resistance to irradiation), technological feasibility, and cost (via the volume reduction factor). The first high-level radioactive glass blocks, weighing 3 kg each and containing some 111 TBq, were fabricated at the Marcoule industrial site in 1965, in graphite crucible.

  Today, borosilicate glasses have become a worldwide standard and have been chosen for nearly all vitrification processes of HLW solutions.

- **Induction-heated vitrification technology**: the metallic melter is joule heated by using electric inductors; the heating system is outside the metallic melter (melting pot) and thus
  - Independent from the melting pot,
  - Not sensitive to the glass melting (no wear, no corrosion, no shorting),
  - Not directly contaminated by High Active Level glass
  - Easy to start (even if the metallic melter is full or empty), to stop, to maintain or to replace.

  Induction technology development was conducted in parallel with glass formulation studies.

The way from preliminary R&D choices to large scale industrial implementation is always the result of a combined approach which involves close links between research, engineering and operating team, and also a judicious build up of results and experience.

As a consequence, COGEMA[i], CEA[ii] and SGN[iii] have integrated a large experience in the vitrification field of high-level waste comming from reprocessing activities through :

- The design and operation of three industrial vitrification facilities with high records of safety, reliability and product quality;
- The design of various glass formulations including those used in the AVM, R7 and T7 facilities;
- Continuous efforts to improve at the same time the technology (from hot to cold crucible) and the associated matrix formulations, with constant emphasis on quality and volume reduction.

FROM R&D TO INDUSTRIAL VITRIFICATION FACILITY

The PIVER Pilot Facility

The first industrial-scale prototype unit in the world intended for vitrification of concentrated fission product solutions began operating in 1968 at Marcoule, in southern France.

As shown in fig. 1, the heart of the process was a tapered cylindrical Inconel vessel 35 cm in diameter and 3 m high, heated by a series of (7) superimposed inductors designed to supply power as necessary according to the level reached by the molten glass inside. It was a batch process capable of a direct vitrification of 200 liters of fission product solution with 100 kg of glass in order to reach 25% loading factor.

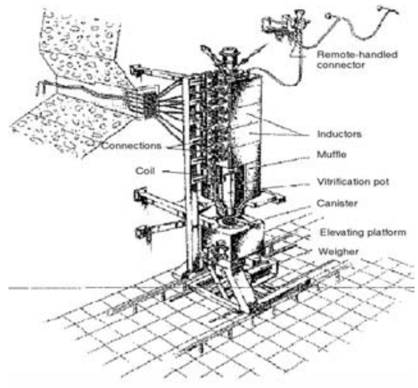

Fig 1 Piver Pilot

The glass melted at 1200°C, was poured into a canister simply by induction heating of a cold glass plug in the metal pouring nozzle.

The entire melter assembly was designed to allow dismantling by means of an overhead crane and a few special tools. The melting pot was designed as a consumable item. The melter itself, consisting of the concrete-lined inductor blocks, was never replaced.

The PIVER pilot vitrification unit operated from 1968 to 1970, during which time it converted 25 m3 of HLW into 12 metric tons of glass poured into 164 canisters containing a total of $1,6x10^5$ TBq.

The facility was restarted in 1972 to vitrify very high-level solutions obtained by reprocessing fuel from the PHENIX fast breeder reactor, and produced another 500 kg of glass containing $4x10^5$ TBq. PIVER was decommissioned in the early 1990s.

Industrial French vitrification design

Learning from the PIVER vitrification experience, the basic principles leading to the choice and design of the French industrial two-step vitrification process with hot induction metallic melter [1] are

- The separation of the functions (calcinations/melting), to have simpler and more compact equipment and to limit the size of the melter, allowing complete in-cell assembly and disassembly with moderate size overhead cranes, master-slave manipulators and remote controlled tools.
- Easy remote maintenance of the process equipment with optimization of solid wastes generated during operation

Thus, in the two step process (Fig. 2), the nitric acid solution containing the concentrated fission products solution coming from reprocessing operation is sent to a rotary calciner which assume evaporating, drying and calcining functions. Aluminum nitrate is added to the feed prior to calcination to avoid sticking in the calciner. Sugar is also added to the feed prior to calcination to reduce some of the nitrates and to limit ruthenium volatility. At the outlet of the calciner, the calcine falls directly into the melting pot along with the glass frit which is fed separately. The melting pot is solid fed continuously and is batch poured. The melting pot is made of base nickel alloys; the glass in the melter is heated to a temperature of 1100°C and is fully oxidized.

Off-gas treatment comprises a hot wet scrubber with tilted baffles, a water vapor condenser, an absorption column, a washing column, a ruthenium filter and three HEPA filters. The most active gas washing solutions are recycled from the wet scrubber to the calciner.

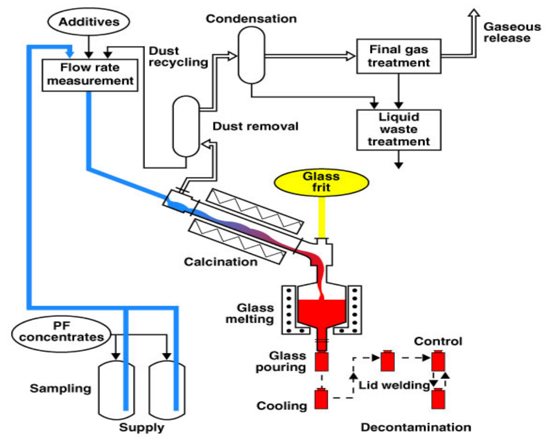

Fig. 2 French industrial two step Vitrification process

FRENCH INDUSTRIAL VITRIFICATION FACILITIES

AVM : The World's First Industrial HLW Vitrification Facility

Process and technology developments performed in the Marcoule pilot facility led to the commissioning of the AVM (Marcoule Vitrification Facility) which was the world's first vitrification facility to operate in-line with a reprocessing plant. The AVM started active operation in June 1978.

AVM design

This facility was designed to have a nominal glass throughput capacity of 15 kg/h to vitrify in line HLW solutions coming from the reprocessing of GCR fuels and research reactor fuels at the UP1 plant.

The evaporative capacity of the calciner is about 40 l/h. The melter is fed continuously and is batch poured. The glass in the melter is heated up to a temperature of 1100°C. The canister, which has a volume of 150 liters, is filled with three glass batches of 125 kg each.

The melter of the AVM facility is made of inconel 601. As shown in Fig. 3, it is cylindrical in shape with a diameter of 0.35 m and an overall height of 1,7 m. The melter is heated by induction.

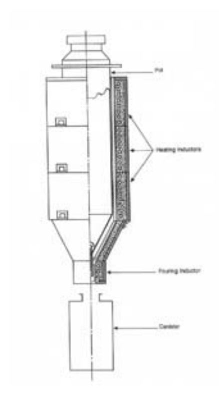

Fig. 3 AVM Melter

The AVM is a compact facility built around the hot vitrification cell containing almost all of the process equipment, including the fission products solution feeding system, the rotary calciner, the hot melter, the pouring station, the glass canister welding equipment, as well as the primary components of the off-gas treatment system (scrubber and condenser). Moreover, solid wastes such as worn components are dismantled in the same cell and packaged into containers of the same size as the glass canisters.

The Control room and interim storage where glass canisters are transferred after an external decontamination are actually adjacent to the vitrification cell.

All mechanical and process equipment subject to wear are designed for remote assembly and disassembly by means of a 20 kN overhead crane and master-slave manipulators.

AVM Records of Operation

The AVM facility's records of operation by the end of October 2003 are given in Table I.

Table I : AVM records of operation

Weight of glass produced since start-up (metric tons)	1075
Number of canisters produced since start-up	3000
Total activity immobilized from start-up (10^6 TBq)	16,8

With an availability of about 70 % with only one vitrification line, AVM has first demonstrated the industrial maturity of the two-step continuous vitrification process.

During these 25 years of operation, no major difficulties leading to long-term shutdowns have been encountered. Nevertheless, all the important maintenance operations planned for the design stage of the facility have been performed : the metallic melter is periodically replaced after more than 7000 hour of operation; the calciner tube, its driving motor, the inductor coils, the scrubber and the condenser have been replaced. All these exceptional in-cell maintenance operations have proved the efficiency of remote maintenance when taken into account in the design of the process equipment as well as the facility's layout.

AVM robustness in ‘non-standard’ operating conditions

The UP1 plant stopped its reprocessing activity in 1999 and has entered a phase of rinsing and decommissioning. During these operations, the AVM facility plays an important role as it vitrifies all the HLW solutions produced by the decontamination of the UP1 equipment

The current strategy applied successfully by COGEMA is to vitrify these decontamination effluents by diluting with in tank fission product solutions, previously stored before the end of UP1 reprocessing activities, and to continue like this to produce specified AVM glass.

The AVM facility will continue operations until 2005.

R7/T7 : COGEMA's Modern Commercial HLW Vitrification Facilities

Based on the industrial experience gained in the Marcoule Vitrification Facility, the AVM vitrification process was implemented at larger scale in the late 1980's in the R7 and T7 facilities in order to operate in line with the La Hague UP2 and UP3 reprocessing plants. Both vitrification facilities are equipped with three vitrification lines having a nominal glass production capacity of 25 kg/h each.

R7/T7 glass Formulation

The glass formulation was adapted to commercial Light Water Reactor fission products solutions, including alkaline liquid waste concentrates as well as platinoid-rich clarification fines. R7/T7 glass formulation was designed to hold, a maximum of 18.5 wt % of radioactive waste oxides (fission products, actinides, noble metals and Zr fines), or equivalently an overall maximum waste-loading ratio of 28 %. This limit was set to avoid excessive heating of the glass during interim storage. The glass product has a high activity (predominantly ^{137}Cs, ^{90}Sr) and significant amounts of noble metals (3 wt% max.). The maximum βγ activity at vitrification time is of 28150 TBq per canister (each canister receiving about 400 kg of glass). The maximum contact dose rate of the canister at the time of production can be greater than 10^5 rad/h

Industrial glass samples coming from R7 and T7 facilities have been characterized [2]. Satisfactory quality of the glass has been demonstrated; glasses were homogeneous with no undissolved feed and their characteristics were in full agreement with the expected values.

The R7/T7 formulation is known worldwide to have an outstanding durability. Normalized releases using a powder test very similar to the 7-day Product Consistency Test are less than 1/10 of the US acceptability criteria.

Table II : AVM and R7/T7 reference glasses *(FP: fission products, Act. : Actinides, MP : Metallic particles)*

wt %	SiO_2	B_2O_3	Al_2O_3	Na_2O	Fe_2O_3	NiO	Cr_2O_3	FP	Act.	MP
AVM	40,0	16,6	10,0	16,5	0,9	0,2	0,4	3,2	0,4	0,7
R7/T7	45,1	13,9	4,9	10	2,9	0,4	0,5	10,4	2,7	1,6

The R7/T7 design

The R7 and T7 facilities were designed on the basis of the industrial experience acquired in the AVM facility. The AVM vitrification process was implemented at a larger scale in order to operate the R7 and T7 facilities in-line with the UP2 and UP3 reprocessing plants. Each facility was designed to have a nominal glass throughput of 50 kg/h. A three line design was selected, each line being capable of producing 25 kg/h of glass. With two lines in service and one line on stand-by, each vitrification facilities could meet the production requirements with sufficient flexibility of operation.

The calciner was scaled-up (by a factor of about 2). The shape of the hot induction melter was also modified as shown in Fig 4. Its base was made oval-shaped (long axis 1m; short axis 0,35 m; total height 1,4 m; weight around 400 kg) to optimize the resistance to heat transfer from the walls of the melter to the glass melt; is made of base nickel alloys.

The glass is heated up to a temperature of 1100°C and is batch poured. Each canister is filled with two batches of 200 kg.
The off gas treatment (the wet scrubber, the condenser and the NOx column) has been also redesigned in order to be compliant with the waste treatment capacity of a vitrification line.

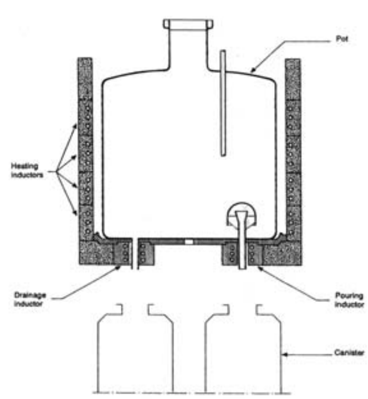

Fig. 4 R7/T7 melter

The decontamination factor after the wet scrubbers is greater than 10^6 and the total decontamination factor for off-gas treatment is about 10^{10}.

Maintenance operations are fully integrated into the process design and method of operations, which is of utmost importance to minimize downtime and to increase availability for production. Thus, the process equipment of each vitrification line are located in a separate cell, while pouring and cooling cells are common to the three lines. All of these cells are equipped with cranes, master slaves manipulators and shielded windows for remote maintenance. Pieces of equipment and sub-components considered to be the least reliable are designed to be modular and compact to be replace remotely. The volume of secondary waste generated by maintenance operations is thus minimized.

R7/T7 record of operation

R7 Start-Up

R7 entered active service in June 1989 and began to treat 1200 m^3 of the backlog HLW solutions that had been accumulated since the start of the first La Hague reprocessing plant, UP2. The challenge for the R7 start-up was to rapidly reach nominal capacity.

From this point of view, the start-up was a complete success even though the operators had to cope with two significant problems :

- The melter lifetime was lower than the design basis value (2000 hours) thus requiring frequent replacements;
- The containment at the bellows assembly located between the pouring nozzle and the canister was not sufficient during the pouring stage thus leading to an increase of the activity in the cell ventilation filters.

In spite of these problems, fission products stock resorption and production goals were met thanks to the ease of maintenance.

T7 Start Up

The T7 facility is dedicated to the treatment of the HLW solutions produced by UP3 reprocessing plant. It entered in active service in July 1992, 3 years after its twin facility R7.

The design of T7 took into account the feedback from R7 operations through :

- Implementation of a new connecting device between the pouring nozzle and the canister, associated with an improved off-gas system ;
- Addition of a washable in-cell pre-filtering device on the ventilation line of the main hot cells (vitrification, pouring, dismantling) in order to protect HEPA filters from contamination ;
- Modification of the cranes to improve the reliability of sub-components and to reduce maintenance;
- Improvement of the canister decontamination device

Moreover, T7 operators had the unique opportunity to train on R7 before T7 active start-up. As a consequence, T7 was able to quickly reach its production goals, and the improvements mentioned previously proved to be beneficial in terms of reduction of operating costs, reduction of the volume of waste, reduction of doses to personnel, and availability. For instance, the use of washable metallic pre-filters led to a reduction, by a factor of about 10, of the number of HEPA filter replacements.

R7 Upgrading

At the beginning of 1994, it was decided to interrupt operations and to upgrade the R7 facility to the same level as the T7 facility, by implementing all of the major improvements that T7 had benefited before its start-up in 1992.

The work was conducted in two steps. During the first step, from February to June 1994, only one line was stopped, while the other vitrification lines continued to be operated. During the second step, from July 1994 to March 1995, all the lines were stopped.

All of the goals set at the start of the project were achieved : the doses to the personnel were 10 % lower than those estimated, waste volumes generated by the modifications as well as costs were very close to those projected, and R7 resumed operation in March l995, 10 days earlier than planned.

Major On-Line Developments

Since the start of operations, the R7 and T7 facilities have demonstrated the industrial maturity of the French two step vitrification process. Nevertheless, COGEMA and the CEA have been continuously improving its performance through consistent and long term R&D programs.

The plant's layout and maintenance concepts, already described previously, have played an important role in meeting these different objectives. The fact that each facility has three lines in parallel has enabled testing of most major developments before deployment on all the vitrification lines.

As one of the major on-line developments undertaken, the melter's lifetime is now exceeding by factor 2,5 the initial design basis values with an average melter lifetime of 5000 hours or 150 glass canisters corresponding to one melting pot per vitrification line and per year.

Another major development was the implementation, in 1996, of mechanical stirring in the melter in order to increase the noble metals content in the glass from an initial 1.6 wt. % to 3 wt. %, and to maintain at the same time throughput capacity of vitrification lines by avoiding settling or accumulation phenomena in the melter.

2004 marks the 26th anniversary since the start of HLW vitrification in COGEMA's commercial reprocessing plants. Over this period of time, outstanding records of operation have been established by the R7 and T7 facilities. These are given in Table III below.

Table III : R7/T7 records of operation (End of October 2003)

Number of canisters produced since start-up	9770
Weight of glass produced since start-up (metric tons)	3910
Total activity immobilized since start-up (10^6 TBq)	150,6

R7 and T7 are mature vitrification facilities which vitrify in line fission products and fines coming from UP2 and UP3 reprocessing plants.

FROM HOT INDUCTION MELTER TO COLD CRUCIBLE INDUCTION MELTER

To improve flexibility in term of waste to be treated, in volume of glass to be produced by developing new high waste loading glass matrix, in glass throughput, to increase availability, and to reduce still more the secondary waste generated during operation, COGEMA has developed with the CEA and its engineering subsidiary SGN the Cold Crucible Induction Melter (CCIM) technology.

Basic Principles of the Cold Crucible Induction Melter

The Cold Crucible Induction Melter (See CCIM in Fig. 5) is a water-cooled induction melter in which the glass frit and the waste are melted by direct high frequency induction. The cooling of the equipment produces a solidified glass layer which acts as a protection against corrosion and high temperature damage along the melter inner wall.

In addition , mechanical stirring of the melt, directly derived from those used in the presently operating La Hague facilities, guarantees homogeneity of temperature and composition and enables high throughputs.

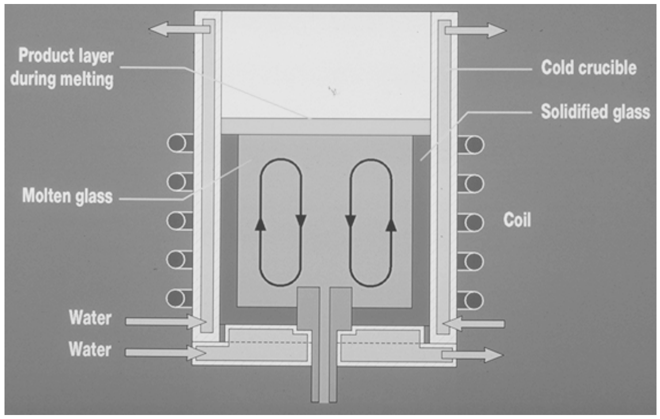

Fig 5 Cold Crucible Melter

This technology developed by CEA and COGEMA since the 1980s, benefits from HLW French industrial vitrification experience and ensures a compact design, a long equipment service life, and extensive flexibility in dealing with different types of waste. Indeed, the introduction of this technology has opened new perspectives in term of waste formulation and enabled the CEA to design a totally new range of matrices for very various applications [3].

The UMo Project

COGEMA is committed to condition some hard-to-process legacy solutions, coming from the reprocessing in the seventies of spent Mo-Sn-Al fuel (used in gas cooled reactor), which are still stored in La Hague [4]. The main features of these High Level Liquid Wastes called « UMo solutions » are to have high molybdenum and phosphorus contents (about 90 g/l in MoO_3 and 15 g/l in P_2O_5), and to be less radioactive than the current fission products coming from actual reprocessing activities.

Because high amounts of molybdenum cannot be accommodated in the present R7T7 glass formulation (MoO3 solubility is limited to about 4 wt % in oxides) with standard vitrification technologies (due to unacceptable corrosive power at high temperature), the basic data associated to the UMo project were the following :

- Development of a specific new glass formulation with a maximal MoO_3 waste loading (higher than 10 wt %) in order to minimize the UMo vitrification campaign duration (a 5 year-period corresponding to the production of less than 800 glass canisters) and to reduce the final waste storage volume,
- Implementation of a CCIM in one of the three R7 vitrification line with conservation of the 2 step-vitrification process design, and glass throughput (by substitute the 25 kg/h present melter),
- Use of the glass canister design used in R7/T7 to optimise the waste standardization management from the vitrification line to the interim storage.

A specific high temperature glass-ceramic formulation (a calcium and zirconium-enriched alumino-boro-silicate matrix) able to incorporate a nominal value of 12 % of MoO3 and elaborated at 1250°C has been developed by the CEA and has been qualified through lab and pilot testing.

Table IV : UMo glass-ceramic composition

wt %	SiO_2	B_2O_3	Al_2O_3	Na_2O	P_2O_5	MoO_3	ZnO	ZrO_2	CaO
UMo	36,0	13,0	6,2	8,8	3,7	12	5,6	7,1	5,7

The process and the associated technologies have been qualified in parallel on a full-scale pilot prototype to ensure maximum representativeness of the test conditions and to allow accurate determination of directly applicable process control parameters. The CCIM developed in this purpose, is a compact one-piece unit of 950 kg, with 650 mm in diameter, and is equipped with cooled retractable stirring device.

Engineering studies (basic and details design, nuclearization, safety assessment) have been performed in parallel in order to replace remotely a hot induction melter by a CCIM in one of the R7 vitrification cell and to operate it.

The UMo project is now engaged in a phase of exchange with safety authorities, in order to get the approval on the glass specification.

GUIDELINES FOR THE ON GOING DEVELOPMENT PROGRAMS IN SUPPORT OF VITRIFICATION OPERATIONS IN FRANCE

Vitrification in France has reached an unparalleled degree of industrial maturity. Its success is all the more remarkable in that vitrification is a complex process carried out under severe operating conditions (high temperatures, highly irradiating media, teleoperation, etc.). These results have been made possible by several key factors:

- Constant support of the development and engineering programs to propose and implement the most satisfactory solutions to meet industrial requirements and constraints.
- Leveraging of industrial operating experience.

The development work undertaken by the CEA and COGEMA in the area of technology, glass formulation and the vitrification process addresses the continual concerns for cost-effective operation of the industrial facilities and for optimizing the ratio between the glass volume produced, the characteristics of the feed solutions, the final quality of the glass block (after production, during interim storage, and following ultimate geological disposal), and the technical and economic aspects of production.

The technology and the glass formulation are inseparably related. The current and future French development programs thus cover three major areas:

1. **Support for existing glass production operations** for the purpose of optimizing the existing technologies and processes.
   The proposed modifications (generally simple adjustments) contribute to improving the production rates and the availability of process facilities while maintaining the quality of the glass produced; they also respond to requests by operators concerning not only process control aids but also operational support documentation.
   Typical examples include the work done to double the calciner feed rate, or to blend plant decontamination rinsing effluents with fission product solutions for vitrification in the AVM. In the second example, a vitrification strategy was proposed and defined in interaction with upstream decontamination operations (choice reagents, order of operations, etc.). The vitrification facility is thus no longer considered simply as and end-of-line facility.

2. **Anticipating medium-term needs** by adapting the existing facilities to changes in the vitrification feed solutions. These changes mainly concern :
   - the characteristics of the reprocessed fuel (higher burnup and therefore greater quantities of fission products, metal particles and actinides to be solidified),
   - the flow sheet implemented in radioactive liquid effluent management plants as environmental concerns increasingly lead to recycling the activity back to the vitrification line: this option thus raises not only the issue of compatibility with the vitrification process steps (calcining,

vitrification) but also of the consequences on the final glass composition, with the possibility of interacting with upstream operations.

These actions concern not only the technology, but also the glass formulation and the vitrification process:

- The equipment modifications are more substantial (new calciner, new off-gas treatment, new vitrification unit)
- The formulation changes involve extending the existing range or proposing new composition ranges, based on the following guidelines [3]:
  - technological options (hot crucible, cold crucible, maximum melting temperature…),
  - optimization of glass waste loading, thermal conditions, and/or specific features of the feed solutions,
  - application of the concept of a source term equivalent (conditioned activity/released activity).

3. **Preparation of the next generation of vitrification** based on:
   - the design options that have ensured the success of the existing vitrification process (small, compact and modular technology with induction-heated melting pots),
   - the lessons of experience acquired not only in France but also internationally with the operation of industrial vitrification facilities: in this area, the evolution from a 2-step process to a single step (direct feed onto the molten glass) is one of the major options exemplified by the startup in 2001 of a semi-industrial prototype facility implementing a large CCIM [5],
   - the development of new conditioning matrices beyond the current containment glass references: glass-ceramics as well as ceramics dedicated to specific confinement of selected radioelements are now being investigated.

   The overall management of a vitrification facility from the design stage to the secondary solid and liquid waste production are taken into account and optimized.

CONCLUSION

2004 marks in France 26 years of industrial operation of HA vitrification facilities, demonstrating the success of the French vitrification program.

From Piver to T7, feedback from hot operations and the long-term R&D programs conducted jointly with the CEA have helped to continuously improve the vitrification process in all of its aspects (glass formulation, process, associated technologies, operations and maintenance).

AVM, the first HLW industrial vitrification facilities in operation in the world is now playing an important role by vitrifying decontamination effluent coming from the rinsing and decommissioning of the UP1 reprocessing plant.

The R7 and T7 vitrification facilities, in-line with COGEMA’s two major commercial La Hague reprocessing plants, have had outstanding records of operation.

The next major milestone in the evolution of the vitrification process will be the deployment of the Cold Crucible Induction Melter technology in the R7 facility to vitrify highly concentrated and corrosive fission products.

To support the French Vitrification needs, the concerted actions of the vitrification development programs undertaken by COGEMA and the CEA thus not only confirm the role of vitrification as an industrial reality but also prepare for a major future role for the conditioning and durable disposal of radioactive waste.

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FOOTNOTES

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[i] Industrial Operator

[ii] The French Atomic Energy Commission : COGEMA's R&D and R&T provider

[iii] COGEMA's Engineering