VEK VITRIFICATION PLANT ON THE WAY TO HOT OPERATION

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ABSTRACT

The German VEK plant is expected to be the next vitrification plant, which will be put into hot operation in the near future. The VEK vitrification project has been established to condition approximately 70 m^3 of high-level waste solution with a total radioactivity of nearly 9E17 Bq, remaining from operation of the former pilot WAK reprocessing plant, which is under decommissioning since 1991. The VEK project was started in 1996 and is scheduled to be finished in 2006.

After start-up of the construction of VEK in early 2000, civil work was finished in 2002. Currently the installation of the infrastructure and process equipment of the plant is in progress. After termination of this installation phase and the subsequent functional testing, commissioning of the plant and integral testing during a cold vitrification operation is envisaged for the second half of 2004.

Hot operation is scheduled to start in early 2005 with an expected total net operation time of about one year. The production output will be about 130 canisters each containing 400 kg of waste glass with a total activity of 6E15 Bq each. External inspectors under the responsibility of the federal government will perform control of the quality properties of the produced waste glass canisters with respect to acceptability for interim storage as well as final disposal.

The paper gives an overview about the current status of the VEK plant and the recent progress in construction. The strategy of commissioning and cold test operation as well as of hot operation are described in detail. The process control steps to ensure acceptable waste glass canisters are described.

INTRODUCTION

The VEK vitrification plant is being erected to solidify the high-level waste (HLW) solution that has been generated by reprocessing operation of the WAK plant. The VEK plant is owned by Forschungszentrum Karlsruhe (FZK), which also supplies the vitrification technology based on a liquid-fed Joule-heated ceramic melter. Following the PAMELA plant in Belgium, the VEK-Project is the second application of FZK's vitrification technology, which has been realized and is close to hot operation. Prior to it's implementation in the VEK plant the suitability and performance of the vitrification technology had been successfully demonstrated by extensive non-radioactive testing in a full-scale prototype facility [1]. Other main objectives of prototype testing were to facilitate licensing and support planning, to gain an operational database inclusive of malfunctions, and to qualify the vitrification process for production of suitable glass product.

The VEK operation is a key milestone of the total decommissioning and dismantling project of the former reprocessing plant Karlsruhe WAK, which was shut down in 1990 and where dismantling has continued with significant progress during the last decade [2]. The dismantling of the reprocessing building has been executed since 1996 and is expected to be finalized in 2006.

The further continuous decommissioning of WAK until green field includes dismantling of the HLW storage buildings. This step first requires vitrification of the stored HLW, which strongly depends on the completion of the VEK installation work and the subsequent short and undisturbed commissioning of the VEK plant. Therefore civil work and component installations as well as functional tests and commissioning activities have been executed in parallel so far. The program for plant commissioning by inactive operation including remote handling tests in the hot cell areas and for the hot start-up of the plant has been established and the necessary operational licenses have been already partly applied for. The operational license also covers dismantling of the melter and other cell equipment which has already been considered in the VEK planning. The operational license for plant commissioning will also be used for finalization of the qualification procedure for the glass product approval.

STATUS OF VEK

Licensing

Licensing of the plant, which is under control of the federal state of Baden-Württemberg, in total comprehends five partial licenses consisting of three partial construction licences and two operational licenses as shown in Table I. Actually the subjects concerned with the first two construction licenses are already executed whereas that of the third one (process equipment installation) is in an advanced state of realization. The application for the first partial operational license was made in 2003 and that for the second one is scheduled for the beginning of 2004. The first operational license includes the first start up of the ceramic waste glass melter and covers the inactive plant operation under hot conditions using simulated HLW as feeding media . The draft operating instructions for the whole plant equipment are needed for this licensing step.

The second license for operation covers the connection of the HLW transfer pipes between the storage tank building and the VEK receipt cell. At this stage of licensing the operating instructions of all systems must be available together with the final version of the operational manual, including the files to describe normal plant operation as well as measures in case of malfunction or accidents.

Licensing of the product is separate from plant construction and operational licensing and is under the responsibility of the Federal Office for Radiation Protection (BfS) with the Produktkontrollstelle Jülich (PKS) as independent experts. The basis for governmental approval is a process qualification manual, where all relevant process conditions and guaranteed product parameters along with the control measures, which are applied to ensure a proper glass, are laid down. The glass product qualification is completed in general and will be finally confirmed during the cold test phase of VEK.

Table I Licensing steps of VEK construction and operation

Licensing Step/Subject	**Status**
Partial Erection Licenses (3)	
1. Preparation of construction site External power supply station	Granted 1998, executed
2. Civil construction work Integrated mechanical equipment	Granted 1999, executed
3. Installation of process equipment	Granted 2001, under execution
Operational Licenses (2)	
1. Plant commissioning, cold test operation	Applied, Scheduled September 2004 Execution until April 2005
2. Connection of HLW transfer pipe Hot operation	Application scheduled December 2004 Execution expected May 2005

Construction

Civil work was finalized in 2002 with the installation of technical equipment on the lower levels of the building already running in parallel. Figure 1 gives an impression of the VEK site by end of 2003, with the building completed and the final installations running. The separate building for normal as well as emergency power supply has been already in operation since 2001 and covers all site requirements with respect to electricity, communication and fire indication systems.

Fig. 1 VEK construction site (December 2003). front view of process building with characteristic structure of canister storage cooling air channel

The equipment of the core process is being installed in several hot cells as indicated in Fig. 2 which shows a longitudinal cross section of the process building: the high-level liquid waste (HLLW) receipt cell containing two receipt tanks as well as the secondary liquid waste treatment, the vitrification cell with the melter, an HLW feeding vessel and the first two off-gas treatment components (dust scrubber and condenser), and the canister treatment cell . The two off-gas treatment cells (wet/dry) are located behind the rear wall of the hot cells and are not visible in Fig. 2. The wet off-gas cell contains a jet scrubber and a NOx-absorber, the dry off-gas cell contains two redundant sets of filters (glass fibre filter, 2 HEPA, Iodine filter). The components of the receiving cell are

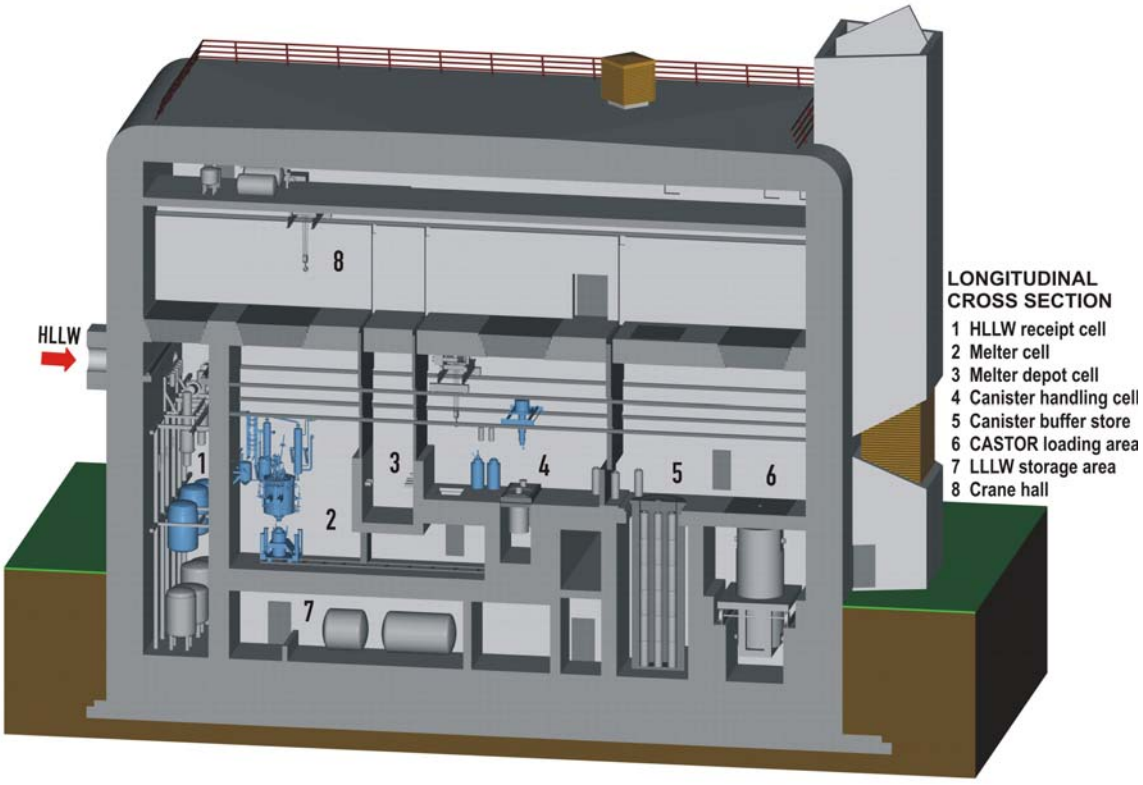

Fig. 2 Longitudinal vertical cross section through the central area of the VEK building, indicating the status of completion

already installed, the welding of the piping is in progress. The waste glass melter, designed and constructed by Institut für Nukleare Entsorgung (INE) of FZK is ready for installation in the vitrification melter cell (Fig.3). The other process components, e.g. vessels, evaporator systems, off-gas scrubbers, the glass frit feeding system and the automatic sampling devices are also prepared for installation or in a final stage of manufacturing. The mechanical equipment, e.g. hall and cell cranes, power and master slave manipulators, shielding doors and visual windows, the transport cask loading and handling station are nearly completely installed and partly in provisional operation for installation purposes. The secondary low-level liquid waste (LLLW) collecting system is ready for functional testing. The plant ventilation system with it's channels and inlet and exhaust air fans is completely installed and already provisionally in operation. The transport and storage cask (type CASTOR®) area is nearly completed.

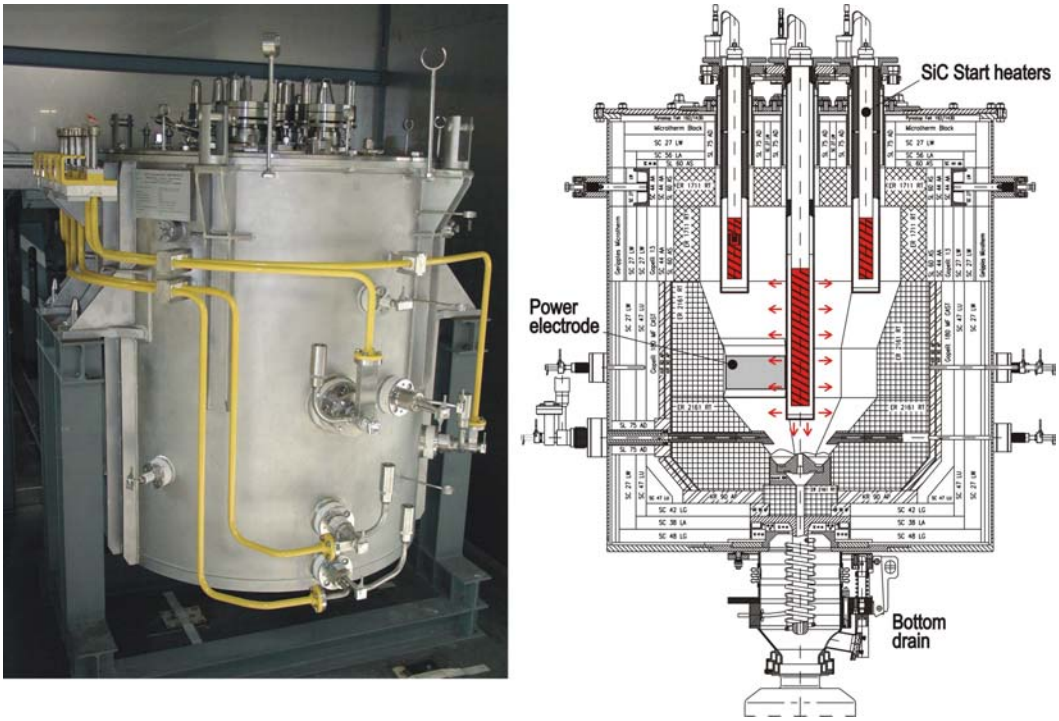

Fig. 3 Photo of the completed VEK melter (left). Melter sheme showing start-up equipment (right)

PLANT COMMISSIONING

Parallel to the ongoing remaining installation work - mainly the hot cell piping, the control system and control room panels/displays, the electrical installations and specific mechanical hot cell devices – the first functional tests of components and systems are being executed. This stepwise procedure started in 2003 with components of the ventilation and power supply systems, followed by the communication and fire protection systems. Functional tests of all the process equipment, e.g. tank calibration, characteristics of air-lifts, pumps and jets, including the process control system are scheduled for 2004 with the main objective to get the plant ready for inactive operation by the end of 2004. The testing of the melter functioning will be performed with the cold, empty melter. The electrode powering will be simulated using a special electrical arrangement. Proof of the glass pool heating as well as of the bottom drain operability takes place during the commissioning phase.

Procedure of Inactive Commissioning

Following the function tests an extensive remote handling test program will be carried out with a proof of the feasibility of all remote operations. This procedure mainly concerns the melter cell with the melter and dust scrubber as replaceable components. The check will cover the complete disconnection/reconnection of these components from/to the cell environment and also the exchangeability of melter parts (e.g feed inlet tube, off-gas pipe, thermocouples and other measurement devices) as well as the repair procedure of a failed canister car. The remote tests also include the proof of the exchangeability of filter packages and of failed pumps inside the dry off-gas cell.

After completion of the functional testing and the remote handling tests, the melter will be put into operation. As a first step it will be gradually heated up to about 1000°C by control of a tempering program using five external heating elements, see Fig. 3. These SiC heaters will be inserted into the melter cavity through openings in the melter ceiling that during operation will be used for insertion of components for melter feeding, off-gas removal and process control. Subsequently to the heating up

procedure of about three weeks, batches of glass-frit will be fed into the melter and heated up by the external heaters until the glass becomes molten. After the glass melt contacts the power electrodes, Joule heating by the power electrodes will be set into operation and the external heaters will be removed. In the following step the feed inlet tube, thermocouple measurement device, off-gas tube and glass level detection system will be installed and connected to the relevant systems. Prior to liquid-feeding of the melter a series of glass pouring operations will be performed to establish the routine procedure.

The integral inactive plant operation will then be started within three stages: (1) melter feeding with water over a couple of days, followed by feeding of water and a glass frit composed similar to the final product and finally feeding HLW simulate along with production glass frit. The first stage will mainly be used to establish the operational parameters of the off-gas line, whereas the second stage will enable the check of the process control systems of the melter (e.g. level detection system). The third stage will be the cold test operation, which will be performed under representative hot conditions. Inactive sampling from the wet off-gas line components as well as from the evaporator units will be carried out to follow-up the process and verify selected retention data gained from prototypic testing. The cold test phase is expected to last three months.

Staff Training

Approximately 50 operators including the shift leaders, which will be needed to run the active plant in 2005, were already pre-trained in the prototype non-radioactive facility over a three months period. During that test the staff was involved in a specific training program with simulated failure scenarios and upset operational conditions. These staff members will be further involved in the functional tests of components and systems, carried out under the responsibility of the different suppliers, and in the inactive commissioning phase of the VEK plant itself.

A special training of the laboratory operators is scheduled in 2004 before hot start-up, using simulated radioactive samples, testing the different analytical procedures and the time required for the characterization of the HLW batches which are transferred weekly from the storage tanks into one of the receiving tanks of the VEK. The availability of the HLW composition in time is the precondition for the continuous vitrification operation and for the avoidance of any glass products out of the specified range.

Hot Start-up

Active operation is scheduled to start in 2005 by connecting the HLW-, MLW- and vessel off-gas pipes between VEK and the adjacent storage buildings. Prior to the receipt of pure HLW some 100 litres of a diluted HLW solution will be transferred from the LAVA (HLW storage plant) plant to one of the receipt tanks of VEK. During this initial hot test operation the radiation control instruments and the radioactive emissions at the stack will be finally checked.

CONTROL AND QUALITY ASSURANCE OF THE GLASS PRODUCT

Glass product qualification

In general, two options exist to verify waste acceptance requirements:

- Process qualification with subsequent inspections or
- Random checks of the waste product to be disposed of.

In case of the VEK glass product with a high dose rate, process qualification with subsequent process inspections was chosen. An independent expert group of the German government has evaluated a set of 16 parameters to be relevant for the acceptance of HLW waste glass canisters for final diposal. This set of

parameters defines mainly the radiological, chemical (e.g composition, leach rates under disposal conditions), and physical/mechanical (e.g. dimension, weight) properties of the glass product. The complete list is given in Table II. The qualification of the VEK vitrification process will be approved by the federal office BfS with the assessment of PKS as independent experts.

Table II Parameters relevant for acceptance of glass canisters

Parameter		**Parameter**	
1	Total activity	9	Mass ratio waste oxides to glass frit
2	Activity of relevant nuclides	10	Homogeneity
3	Safety against criticality	11	Physical conditions
4	Thermal properties	12	Hydrolytic stability
5	Dose rate	13	Quality of the canister
6	Surface contamination	14	Mass of the glass canister
7	Quality of glass frit	15	Stackability and handling properties
8	HLW composition	16	Identification of the glass canister

Based on the reference composition of the waste to be vitrified and a nominal waste glass loading of 16 wt.%, a specified set of parameters has been established for the product. Major guaranteed parameters for the qualified process are compiled in Table III.

Process and Product Control

In general the glass production has to be controlled in respect of melt composition, melting temperature, glass homogeneity and glass pouring [3]. The composition of the melt is determined by the mass flow ratio of waste constituents (oxides) and glass formers of the melter fed into the melter. The mass flow rates are controlled on basis of the HLW analysis in the receipt tank, the analysis of the glass frit composition and by:

Table III Major guaranteed parameters of the glass canister

Parameter	**Guaranteed Value**
Waste oxide loading	≤ 19 wt.%
Mass of glass canister	≤ 550 kg
Activity Sr-90/Y-90	≤ 4.5 E15 Bq
Activity Cs-137/Ba-137	≤ 5.1 E15 Bq
Total α-activity	≤ 8.6 E13 Bq
Total β/γ-activity	≤ 9.6 E15 Bq
Total mass of U	≤ 7200 g
Total mass of Pu	≤ 190 g
Decay heat	≤ 734 W

measurement of the HLW and glass frit feeding rates to the melter. The melting process is controlled by the glass pool temperature, by the residence time in the melter responsible for mixing and homogenization of the glass and by the glass pouring conditions. Maintenance of the process parameters within the specified ranges leads to the production of an acceptable waste glass.

In addition to the indirect proof of the glass product specification by process control means, direct measurements of produced canisters, (weight, gamma, and neutron dose rates), will be carried out to verify production data before introducing the canisters into the VEK buffer storage. The various control steps during operation are indicated in Fig. 4.

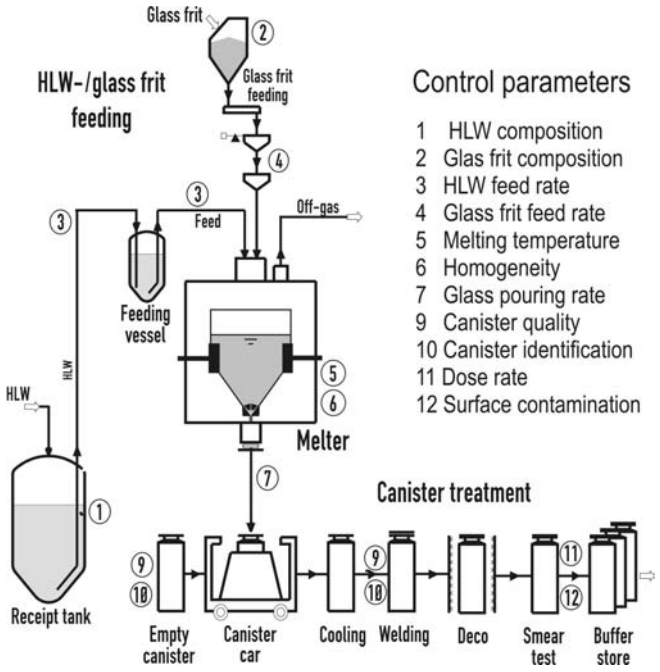

Fig. 4. Control Measures Applied for the production of Specified Glass Product

Quality Assurance Measures

The total set of quality measures are laid down in the governmental approved quality plan. For every produced canister all required data will be compiled by the responsible operator and controlled by inspectors either on documentation basis or by on-site inspections carried out to ensure that the qualified process conditions will be met.

According to the actual draft of the VEK quality plan the following QA measures will be implemented:

- Certified laboratories will analyze glass and waste composition
- Control devices, e.g. tank level indicators, weight control, gamma/neutron detectors, will be adjusted during installation and will be periodically checked during operation
- All product-relevant operational data will be registered by the control system [4]
- The manufacturing of the stainless steel canisters is based on specific quality rules

SUMMARY

The progress of the VEK construction and installation has reached a status, where functional tests are being carried out stepwise and will be completed for all systems in 2004. Extensive prototype testing forms the basis for the scheduled short commissioning period with inactive HLW simulate. The operational license and the qualification of the melting process are in an advanced state of acceptance. The system of process and product control guarantees a glass product well inside specified limits.

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