

Cold Test Operation of the German VEK Vitrification Plant - 8326

J. Fleisch, W. Gruenewald*, G. Roth*, E. Schwaab, W. Tobie*, M. Weishaupt
WAK GmbH, P.O.Box 1263, 76344 Eggenstein-Leopoldshafen, Germany

*Forschungszentrum Karlsruhe, Institut für Nukleare Entsorgung, Hermann-von-Helmholtz Platz 1
76344 Eggenstein-Leopoldshafen, Germany

ABSTRACT

In 2007 the German High-Level Liquid Waste (HLLW) Vitrification plant VEK (Verglasungseinrichtung Karlsruhe) has passed a three months integral cold test operation as final step before entering the hot phase. The overall performance of the vitrification process equipment with a liquid-fed ceramic glass melter as main component proved to be completely in line with the requirements of the regulatory body. The retention efficiency of main radioactive-bearing elements across melter and wet off-gas treatment system exceeded the design values distinctly. The strategy to produce a specified waste glass could be successfully demonstrated. The results of the cold test operation allow entering the next step of hot commissioning, i.e. processing of approximately 2 m³ of diluted HLLW.

INTRODUCTION

The German VEK vitrification plant located at the site of Forschungszentrum Karlsruhe (FZK), has been constructed to immobilize about 60 m³ of highly active and high noble metals-containing HLLW with a total activity of $7.7 \cdot 10^{17}$ Bq. Installation of process and plant equipment was completed in 2004 after a five years construction phase. After almost two years of extensive functional testing of single components and process units the plant commissioning was accomplished by the final integral cold test operation of the VEK plant. This test had been carried out from April to July 2007 using representatively simulated HLLW. It had to be performed within the scope of the first of two operational licenses and is required prior to application of radioactive material in the plant. The second operational license covers the connection of the plant to the HLLW storage tanks, the hot test to check the radiometric control equipment and the radioactive status of the plant after the test, and finally includes the hot routine vitrification operation. Whereas planning and construction of the VEK plant has been carried out by FZK, operation will be performed by WAK (Wiederaufarbeitungsanlage Karlsruhe, former reprocessing facility) company, which is also the owner of the plant since 2006.

VITRIFICATION TECHNOLOGY OF VEK

The core technology applied by VEK has been delivered by Institut fuer Nukleare Entsorgung (INE) of FZK. It is based on a liquid-fed ceramic melter especially designed to process highly noble metals-bearing HLLW [1,2]. Fig.1 shows a scheme of the VEK melter. The melter is continuously fed with HLLW from a small feeding vessel, which in turn is supplied in batches of HLLW from one of two receipt tanks (see Fig. 2). The glass forming material in form of glass frit beads (\varnothing 1-3mm) is added separately by a glass frit feeding system. Control of the glass composition is achieved by adjusting the glass frit portion to the batch volume of HLLW periodically delivered to the feeding vessel and subsequently fed to the melter and by balancing the total HLLW oxide reduce of the overtaken batch and glass bead mass streams. Melting process and pouring operation are controlled by monitoring temperature, glass level and controlling glass flow rate. Filled canisters are cooled for 3-5 days, afterwards lid-welded and decontaminated in an ultrasonic acidic pool. Off-gas treatment comprises four wet cleaning steps by a dust scrubber, a condenser, a jet scrubber and

a NO_x absorption column. Subsequent dry cleaning uses a High Efficiency Mist Eliminator (HEME), two HEPA filters and an Iodine filter. Two recycling routes - returning scrub solution from the dust scrubber to the feeding vessel directly and returning scrub solution from the other three wet cleaning components after evaporator concentration to one of the receipt tanks - maximizes the portion of immobilized radioactivity.

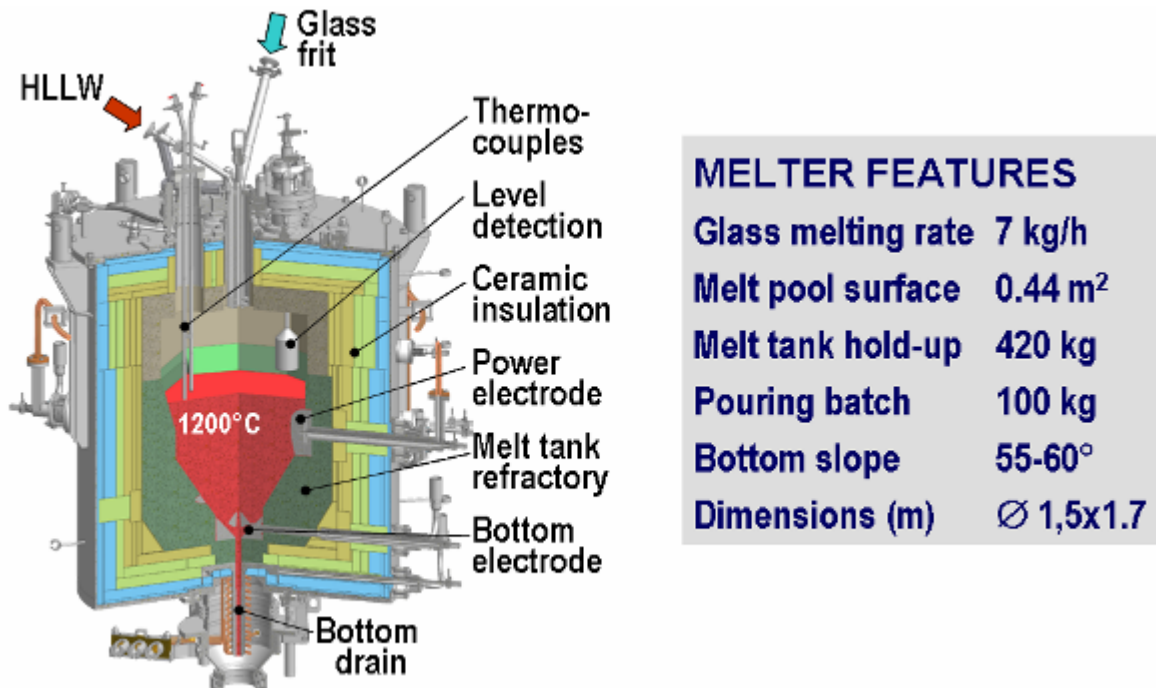


Fig. 1: Liquid-fed ceramic glass melter applied by VEK

OBJECTIVE OF THE COLD TEST OPERATION

Main goals of the cold test were:

- Long-term demonstration of the vitrification operation in accordance with the established regulations
- Verification of the operational manuals
- Proving of the procedure of sampling and chemical analysis
- Confirmation of the established retention efficiency of melter and off-gas components
- Demonstration of canister transfer, treatment and handling procedure to meet product requirements
- Education and training of operational staff

REQUIREMENTS AND BOUNDARY CONDITIONS

A main precondition of the start of the cold test operation was the completion of all function tests for single components (e.g. valves) as well as for systems (e.g. glass melter) and process units (e.g. wet off-gas cleaning). This requirement did not only comprehend process-related installations but also all other areas like ventilation system, process control system or remote handling equipment. During cold test all operations and maintenance steps requiring manual intervention had to be performed by exclusively using the available remote handling equipment as foreseen for the hot application. Manual operations are routinely necessary to carry out all steps of glass canister

handling and treatment. Control of the whole plant operation had to be carried out by means of the central process control system, consisting of a conventional and a safety system.

Execution and control of the cold test operation had to be performed in accordance with the operational manuals established for hot operation and preliminary approved by the regulatory body. Also all control steps to ensure the production of waste glass in compliance with specified parameters had to be applied.

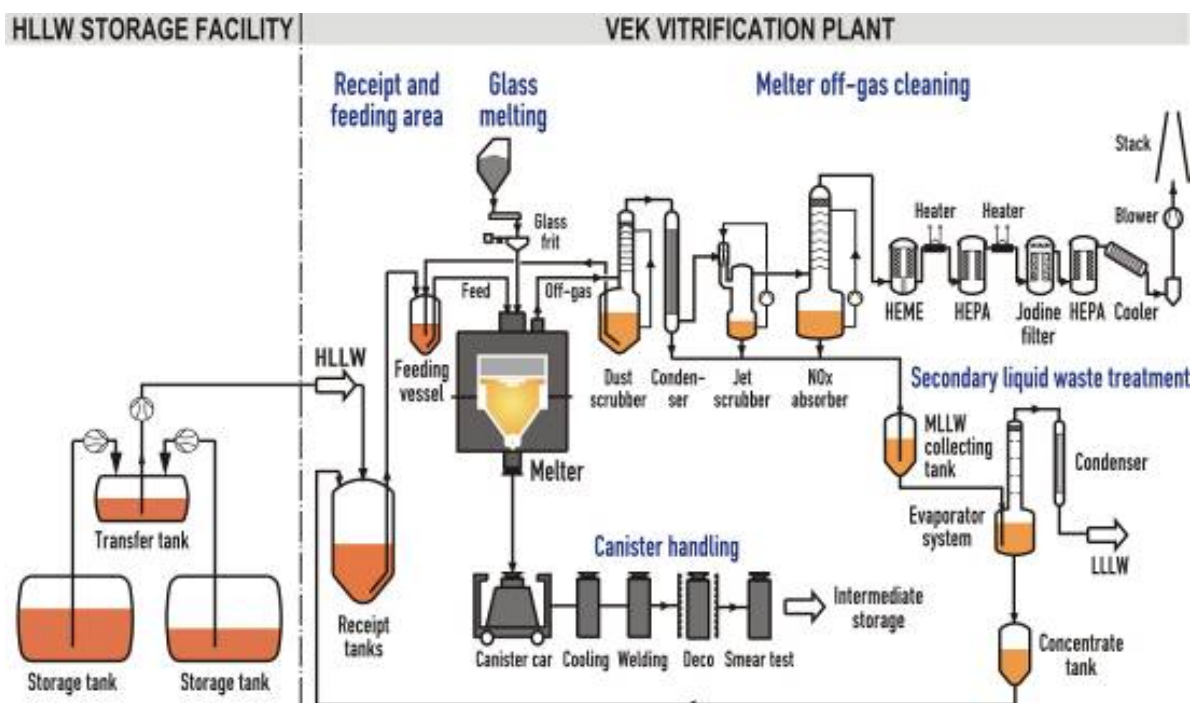


Fig. 2: Simplified process diagram of VEK's vitrification process

PERFORMANCE AND RESULTS

The Cold Test Operation of VEK took place from April to July 2007. In a continuous production operation of 77 days, interrupted by two short intended periods, 17 m³ of HLLW simulate (corresponding to approximately 25 % of the volume of the stored HLLW) had been converted into about 13 tons of glass product. The glass was poured by 127 batches of 100 kg each into 32 canisters having a capacity of 400 kg (European standard type). Control measures to achieve a specified glass were applied according to the strategy of hot operation.

Simulation of the HLLW was close to the composition of the genuine waste solution. The portion of actinides and of technetium which do not have stable isotopes was replaced by elements with similar glass-relevant properties (lanthanide and manganese) as published before [3]. Noble metals were not used in the simulate to protect the melting system during the long idling phase between end of cold test operation and later hot application and because the behaviour of noble metals has been extensively tested by the prototype melter installed in the cold test facility of INE. Longer idling phases cause settling of the noble metals and potentially leading to highly viscous layers on the melter bottom. The reliability of the melter design had been demonstrated before in extensive long-term testing in a 1:1 scale prototype facility [3].

The vitrification operation proved to be reliable and steady. Main data are compiled in Table I. During the production phase no unexpected or forced interruption due to any failure or malfunction occurred resulting in a time availability of 100 % for each of the three operation phases. The design glass melting rate of 7 kg/h could be confirmed. The control of the material streams of HLLW oxides and glass beads fed to the melter proved to be highly reliable. As for the glass quality, the average value of the waste glass loading with oxides was found to meet the target value of 16 wt.% exactly (maximum deviation <0.1 wt.%). The tolerable range of the loading is 16 ± 3 wt.%.

Table I. Overview of production data obtained from cold test operation

	Operation Part 1	Idling Phase 1	Operation Part 2	Idling Phase 2	Operation Part 3	Total Operation
Operation period	4.3.-5.13.07	13.-5.29.	5.29.-6.28.	28.-6.30.	6.30.-7.12.	4.3.-7.12.07
Feeding time	39,0 d	-	28,3 d	-	9,8 d	77 d
Simulate volume	8665 dm ³	-	6152 dm ³	-	2113 dm ³	ca.17 m ³
Glass product amount	6406 kg	-	4699 kg	-	1603 kg	12,7 t
Number of pourings	64	-	47	-	16	127
Number of canisters	16	-	11,75	-	4	31,75
Average feed rate	10,1 dm ³ /h	-	9,9 dm ³ /h	-	9,8 dm ³ /h	10,0 dm ³ /h
Average waste glass loading	16,0 wt.-%	-	16,0 wt.-%	-	16,1 wt.-%	16,0 wt.-%

Melter operation

Operation of the waste glass melter as the central component is decisive for the performance of the vitrification process. Main functions refer to the melting of a proper glass, the retention of noxious materials and to the safe and reliable glass pouring. Using a melter with a bottom drain for glass pouring requires a reliable method of glass level detection to ensure that the work level range is maintained also after long operation periods. In case of control by material balancing or other indirect methods the risk of a gradual long-term lowering or increasing of the glass level by accumulated measurement inaccuracies deviation may lead to non-tolerable operational conditions. The method of direct level control applied in the VEK melter proved to work very reliable. It is based on a special dip-tube measurement, delivering a pressure signal which indicates when a glass pouring has to be initiated. The system is described in detail elsewhere [4]. Fig. 3 shows - along with a function scheme of the measurement system - a sequence of several pressure signals obtained during cold test. Glass pouring is usually initiated at a signal level of 5 mbars. The signal disappears as soon as the measurement device emerges from the glass pool.

The sophisticated glass pouring system is an essential part of the noble metals-compatible design of the melter. Main requirements for the bottom drain are: safe and reliable function, efficient controllability, noble metals removal, melter emptying. During 127 glass discharges the control of the bottom drain system turned out to be very reliable and the characteristics of the pourings were reproducible. Fig. 4 shows a typical example of a pouring diagram containing the induction power for heating of the metallic glass outlet channel, the cumulative mass of glass in the canister and the glass flow rate deduced from the mass curve by differentiation. The diagram shows that the target glass flow rate of 120 kg/h can be maintained accurately.

In order to minimize the melter emissions to the off-gas line the melt pool coverage (cold cap) was controlled by temperature measurement. The results obtained during the cold test operation were

highly satisfying. Values of decontamination factors for Cesium and Strontium exceeded design values by far. In case of the melter decontamination factors (DF) for Cesium and Strontium were found to be above 100. As design values for Cesium a value of 30 had been established, for Strontium a design value of 60 had been specified. Due to the high retention efficiency of the melter, various elements could not be measured in the scrub solution down-stream of the jet scrubber by wet-chemical methods as the values were below the detection limit.

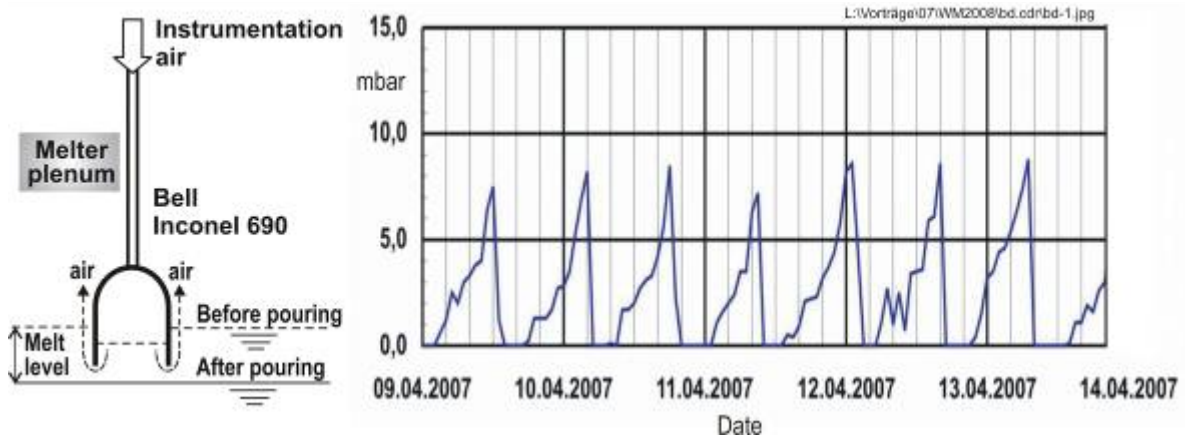


Fig. 3: Typical signal obtained from the melt level detection system applied by VEK melter. The principle is shown on the left side of the diagram

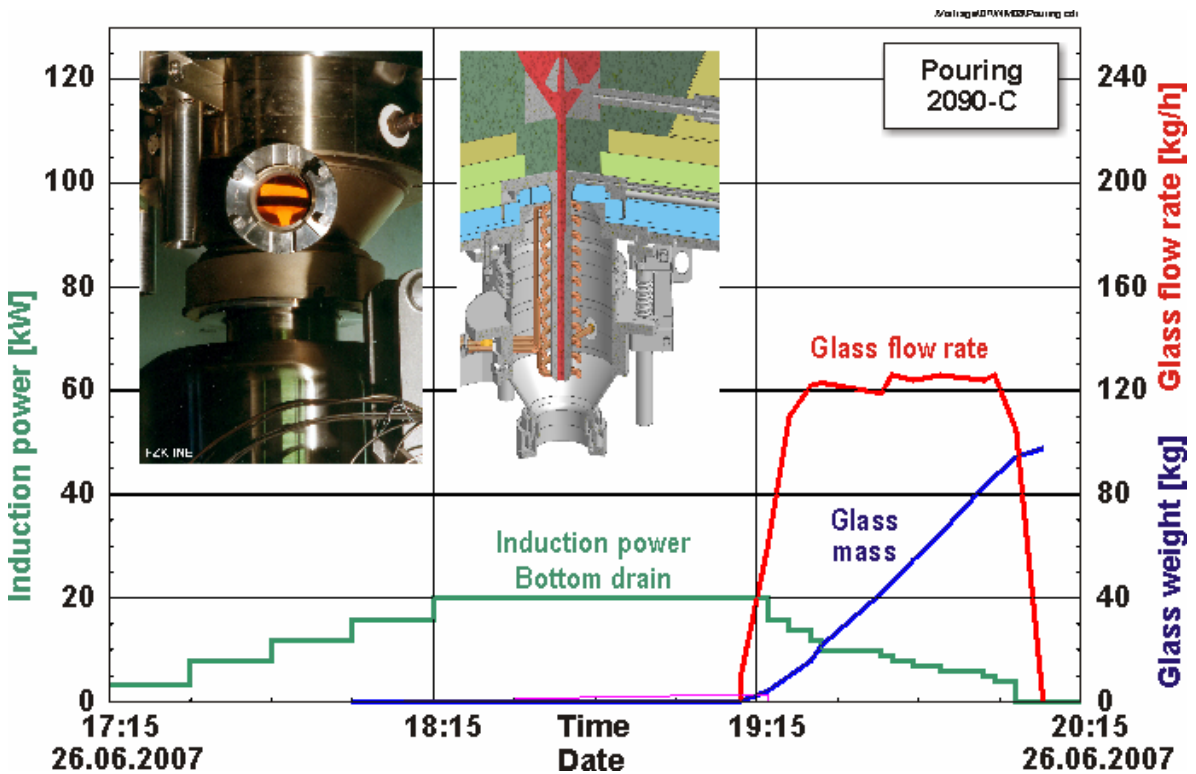


Fig. 4: Typical glass pouring diagram, containing the induction power of the bottom drain pipe, the cumulative mass of glass in the canister and the glass flow rate
Canister treatment

During the cold test operation 32 canisters were produced and had to be transferred into the canister handling cell where they had to undergo the steps of cooling (3-5 days) inside an insulated cooling station, subsequent lid-welding, decontamination by an ultrasonic acidic pool and final rinsing. Fig. 5 shows the welding of a canister. During this qualified procedure the welding parameters (e.g. electrical current) are recorded and compared to the reference data. An additional visual check completes the examination of the welding. Due to the production of simulated glass, dose rate measurements could not be carried out. After the treatment steps the canisters were stored inside the internal buffer store (capacity 36 canisters). The loading of the canisters from the buffer store into the transport cask had already been demonstrated in a separate program. According to the requirements for acceptance of the glass canisters in the intermediate and final storage facilities all the treatment steps were documented in the canister life sheet which serves for identification and characterization of the canister. This sheet also contains information about chemical composition, radioactivity inventory and production features.

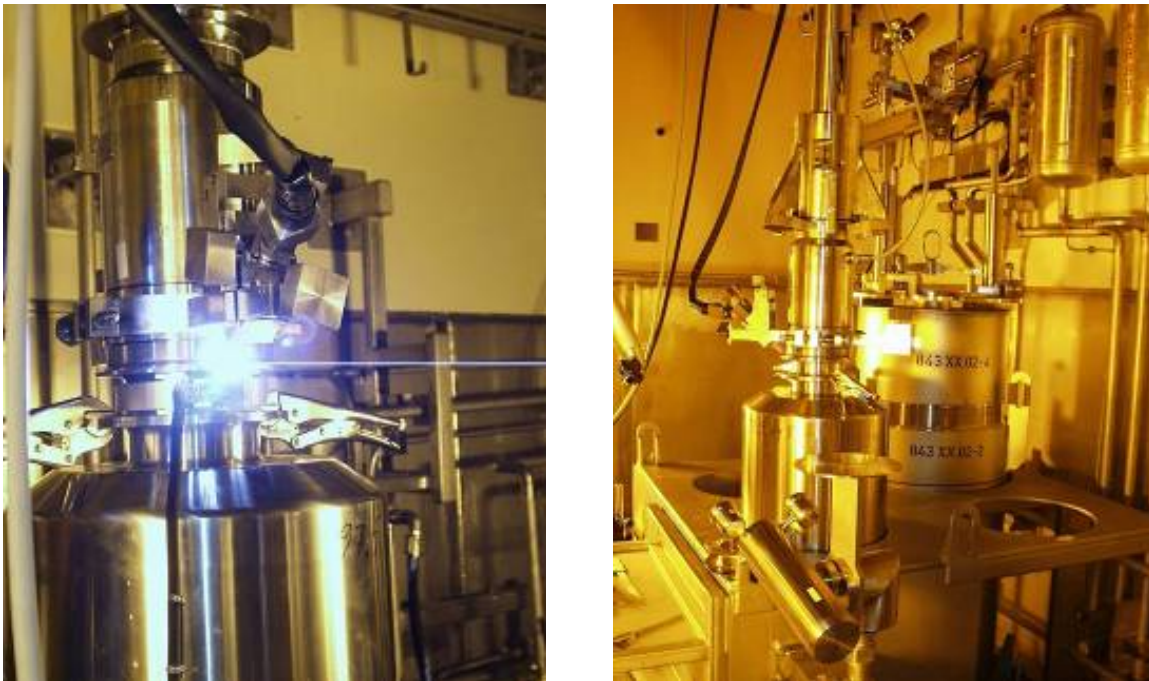


Fig. 5: Lid-welding of a glass canister (left) inside the canister treatment cell (right)

OUTLOOK

The next step of the VEK program will be the performance of a hot test of about one week in which a limited diluted radioactive waste solution (specific activity 4 Ci/l) will be processed. It serves for check of the function of the radiation measurement installations and for check of the radiological status of the plant after the test. Precondition for the execution of this test is the granting of the license for hot operation. After its availability the hot pipe connections to the HLLW storage area will be established. The hot test is scheduled for mid of 2008. The following start-up of the full vitrification operation is intended for autumn of the same year.

SUMMARY AND CONCLUSIONS

An important step of the VEK vitrification plant towards hot operation has been the performance of the cold test operation from April to July 2007. This first integral operation was carried out under boundary conditions and rules established for radioactive operation. Operation and process control were carried out following the procedure as documented in the licensed operational manuals. The function of the process technology and the safe operation could be demonstrated. No severe problems were encountered. Based on the positive results of the cold test, application of the license for hot operation has been initiated and is expected in the near future.

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