Successful Hot Operation of the German Vitrification Plant VEK – Results and Experiences – Paper 11277

J. Fleisch, W. Grünewald, G. Roth*, F-J. Schmitz, W. Tobie*, M. Weishaupt*

WAK Rückbau- und Entsorgungs- GmbH, P.O.Box 12 63,
76339 Eggenstein-Leopoldshafen, Germany

** Karlsruher Institut für Technologie, Institut für Nukleare Entsorgung,*
Herrmann-von-Helmholtz Platz 1, 76344 Eggenstein-Leopoldshafen, Germany

ABSTRACT

The German VEK project has been established to vitrify approx. 55 m³ of high-level liquid waste (HLLW) with a total radioactive inventory of 7.7E+17 Bq in the new VEK vitrification plant erected from 1999 to 2004. Immobilization of the waste solution stored at the site of the former German WAK pilot reprocessing facility is the precursor to further decommissioning and dismantling of the WAK facilities which have been underway since the mid-nineties. Within a minimum operation period of only 9 months from September 2009 until June 2010 the highly noble metals containing HLLW was successfully processed and the storage tanks of WAK were finally emptied. Subsequent to hot vitrification of the concentrated HLLW solution an extensive cleaning of the storage tanks and VEK plant components is being performed. Rinsing liquids are being vitrified after mixing with simulated inactive HLLW solutions.

The efficiency of the melting process performance with respect to noble metals was optimized by application of air bubbling subsequent to a complete waste glass exchange after the first six months of hot operation. In total nearly 500 kg of noble metals (in terms of oxides) were processed. The overall plant availability was in the range of 97% with only short lasting HLLW feeding interruptions caused by mainly remote exchange and cleaning of the off-gas-pipe, rinsing of the wet off-gas-line, leakage of a cooling water hose, melter emptying and insertion of an air bubbling device due to a suspected emerging of noble metal sediments.

From processing of the waste solution actually 140 glass canister of the European standard type have been produced containing 400 kg waste glass with a waste oxide loading of 15 - 16wt.%. The glass canisters will be transported by CASTOR casks to the interim storage facility.

This paper gives an overview of the successful hot operation of the VEK plant. Operational data, results and lessons learned during one year of hot operation are presented in detail.

INTRODUCTION

A major prerequisite for the complete dismantling and removal of the Wiederaufarbeitungsanlage Karlsruhe (WAK, Karlsruhe Reprocessing Plant) was the vitrification of the originally about 60 m³ of high-active liquid waste concentrates (HLLW). For this purpose, the Karlsruhe Vitrification Facility (VEK) was built from 2000 to 2004. After long-term cold testing with 17 m³ inactive HLLW simulate, the vitrification facility was ready for operation in 2007. In February 2009, the Baden-Württemberg Ministry of the Environment granted the operation license and nuclear test operation and subsequent vitrification operation started.

Parallel to the VEK operation license, EWN GmbH was also granted by the Federal Office for Radiation Protection (BfS) the modification license for the storage of five casks of the type CASTOR® HAW 20/28 CG with VEK canisters at the transport cask store of Zwischenlager Nord (ZLN, interim store North). This license had been preceded by an extensive cold test program in 2008 to test canister handling and dispatch of the cask at VEK with subsequent transportation to ZLN and by tests of the handling steps at the transport cask store of ZLN.

With this, all technical and formal requirements for hot vitrification operation were fulfilled.

VITRIFICATION OPERATION

Commissioning and Canister Production

While the VEK was commissioned, cold and hot tests were carried out in various stages [1]. A crucial phase consisted of an integral cold test operation of the complete facility with inactive HLLW simulate over a duration of several months including a final check of the interaction of all systems, including instrumentation and control, and the training of the operation staff. The facility was ready for operation after the controlled and monitored areas of the VEK had been set up, the HLLW and MLLW transfer lines between the HLLW storage building and the VEK had been installed, and the VEK exhaust air line had been connected to the existing stack system.

As a longer period had passed after the cold integral test in 2007 and some technical modifications had been made, a second cold test was performed in 2009 directly before the hot test started. In this phase, another about 5 m³ of a HLLW simulate were vitrified and 3.8 Mg glass product were filled into 10 canisters (see also Table 1).

Table I. Production data of cold and hot test operation

Parameter	Test Operation		Hot test
	Phase 1	Phase II	
Period	April/July 2007	April/May 2009	Sept. 2009
Simulate/HLLW	16.9 m³	5 m³	1.7 m³
Spec. radioactivity	-	-	1.5 E11 Bq/l
Glass product	12.7 Mg	3.8 Mg	1.2 Mg
Glass pourings	127	38	12
Numb. of canisters	32	10	3
Operation time	78 d	23 d	8 d

In September 2009, trace active test operation of VEK started [2]. First, about 50 l HLLW was transferred from one of the storage tanks to one of transfer tanks of VEK containing about 1.8 m³ of simulate already. The resulting waste mixture with a specific activity of about 1.5 E11 Bq/l served as a basis for active test operation to verify radiation protection measures and test the radiation measurement instruments, which had not been possible before. Over a period of eight days, a total of 1.7 m³ diluted HAW waste solution was vitrified and three canisters of reduced activity were produced. Activity of the canister inventory increased in a stepwise manner from 2.2 E13 Bq (canister 1) to 7.1 E13 Bq (canister 3). Then, the VEK was operated further with undiluted HLLW solution. Only when the sixth canister was filled, was a value of 4.6 E15 Bq adjusted, which corresponds to about 80% of the nominal inventory of 6.2 E15 Bq. Then, routine vitrification operation started in mid-September 2009 without any further interruption.

Every week, about 1.5 m³ of HLLW was transferred routinely from one of the two HLLW storage tanks to one of the two VEK entrance tanks. The vitrification process was run continuously at a rate of 10 – 11 l/h HLLW (see Fig. 1).

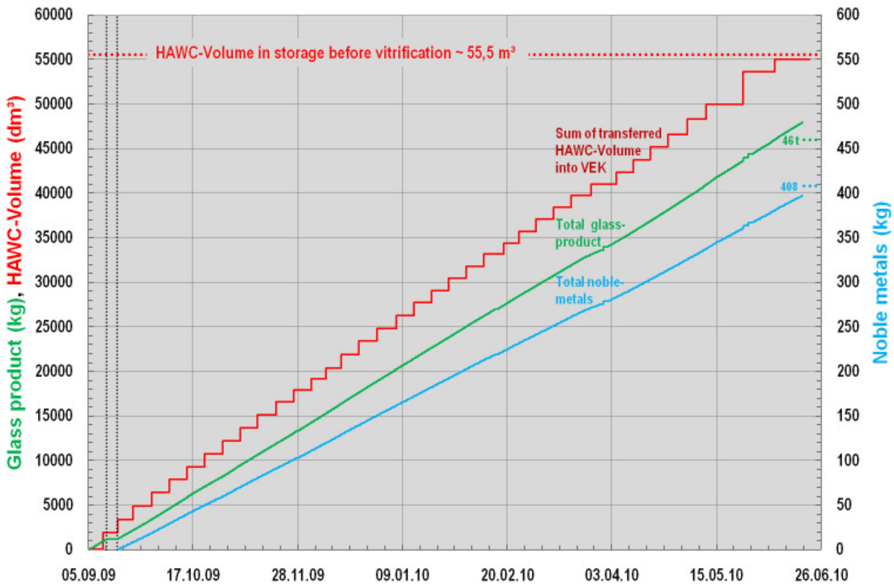

Fig. 1. Cumulated data of the HLLW volume transferred to VEK and of the HLW glass product

The total amount of 55.5 m³ HLLW was immobilized in 48.8 Mg glass product by June 2010. 123 canisters were produced in total (see Table II).

Comparison with the planned maximum operation time of 18 months (10 months net) reveals a remarkably high availability of the complete vitrification process. Operation troubles with an interruption of HLLW injection were due to the change-out of a cooling water hose (5 hours), rinsing of a nozzle in the offgas system (14 hours), change-out of the melter offgas pipe (22 hours), remobilization of noble metal deposits (total inventory about 356 kg) by the installation of an air bubbler, and glass exchange with addition of solids from the offgas pipe (81 h).

A program for rinsing and shutdown of the HLLW storage tanks and the components of the VEK, including melter, was started in July 2010. To adhere to the guaranteed canister specification, chemicals were added to the rinsing solutions prior to vitrification. In September 2010, one of the storage tanks was cleaned by more than 90%, with another 14 m³ of waste solution being processed to 10 canisters. The shutdown program was completed by November 24, 2010.

Table II. Current operation data in comparison with planned values

Parameter	Production data HLLW operation[1)]	Production data of shutdown rinsing [2)]	Planned values
Operation time	9 months	5 months	18 (10 [4)]) months
HLLW volume/ rinsing solution	55.5 m³	22 m³	60 m³
Glass product	48.8 Mg	6,8 Mg	50 Mg
Glass pourings	478	65	500
Number of canisters (400 kg)	123	17	125
Waste load	16.2 – 16.7 wt.%	about 15-16 wt.% [3)]	16 wt.%
Availability	97%	-	56% (100% [4)])

1) Reference end of HLLW operation June 21, 2010
2) Reference Nov. 24, 2010 , start of rinsing and shutdown program
3) incl. simulate
4) Net operation time at design throughput July 1, 2010

Behavior of the Melter

The directly heated ceramic melter was developed by the Institute for Nuclear Waste Disposal (INE) of Karlsruhe Institute of Technology (former Forschungszentrum Karlsruhe) in the 1990s. Within the framework of the VEK project, it had been tested at INE under inactive conditions. It proved to be a reliable component also under hot operation conditions. The design throughput of 10 l/h was adhered to with high precision. The mean waste oxide loads of the glass product are listed in Fig. 2 for balancing periods of 25 h and the complete operation time until June 2010.

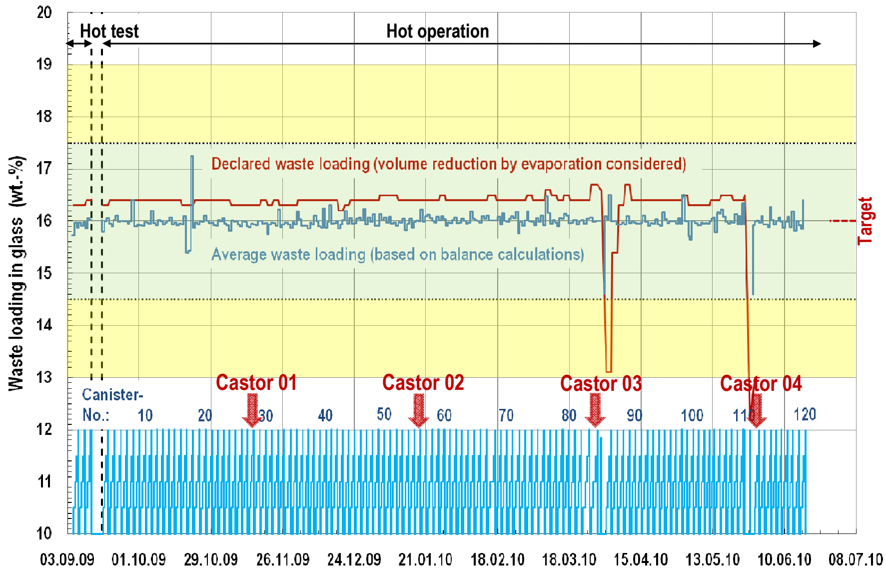

Fig. 2. **Weekly operation diagram**
Top: Mean load of the glass product
Bottom: Glass product quantity/canister and CASTOR loads

The permissible waste oxide load of 13 – 19 wt.% was adhered to with small deviations only, the operation value being 16 wt.% ± 1.5 wt.%. Fig. 2 also shows the glass pours for canisters Nos. 1 to 123. Usually, production of a canister takes about 57 h. All total canister weights were controlled reliably via the glass flow rate and weight measurement of the canister carriage (max. 400 kg).

The melting process is greatly influenced by the behavior of the noble metals Ru, Rh, and Pd that are contained in the HLLW and insoluble in the glass. In total, 408 kg noble metals (in the form of oxides) passed through the melter during vitrification operation. Noble metals cannot be bound in the borosilicate glass matrix and tend to accumulate and form electrically conductive layers at the bottom of the melter. The discharge behavior is affected adversely by the high viscosities. This influences the operation of the directly heated melter. The design of the VEK melter with funnel-shaped walls at an angle of 45° at the bottom largely prevents such sedimentations. The electric operation data of the main electrodes are plotted in Fig. 3 versus operation time (voltage, current, and power input).

After about 7 months of operation, a significant decrease in voltage and power can be noticed which, may be attributed to the onset of noble metal deposition. A complete glass exchange and use of an air bubbler to improve convection in the glass bath caused the operation parameters of the melter to return to their previous values. Other interruptions of HLLW feed and reductions of the power input are obvious from Fig. 3.

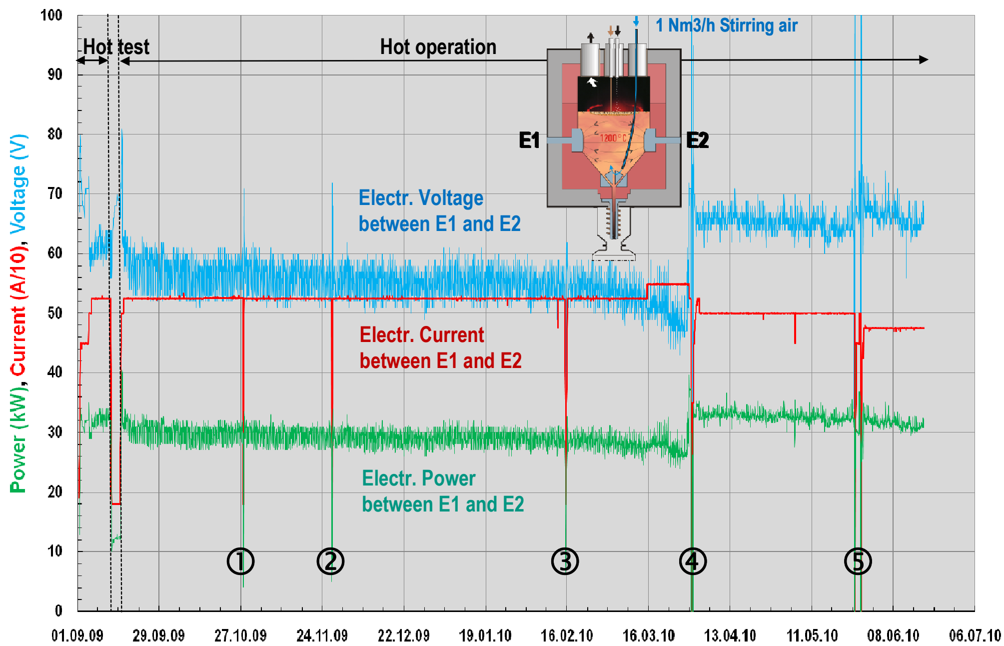

Fig. 3. Electric operation data of the melter and operation failures

These interruptions were caused by the

① Exchange of the cooling water hose of the melter – interruption of feeding for 5 hours
② Removal of deposits in an offgas nozzle by rinsing – interruption of feeding for 14 hours
③ Exchange of the melter offgas pipe – interruption of feeding for 22 hours
④ Mobilization of noble metal deposits by an air bubbler and exchange of the glass inventory – interruption of feeding for 35 hours (see above)
⑤ Glass exchange with addition of solids from the offgas pipe – interruption of feeding for 81 hours

The Cs retention factors of the melter did not confirm the known results from the operation of the PAMELA plant and of inactive operation of the prototype test facility at INE. Long-term plugging of the offgas pipe between the melter and the wet scrubber, which is the first component of the wet offgas cleaning system could not be prevented, although the offgas pipe is cleaned periodically by pressurized air blasters.

Chemical analysis of the deposition suggests volatile compounds between Cs and Tc, which are not observed for other HLLW compositions. Mechanical cleanings of the offgas pipe and complete remotely controlled exchange of the component were required for further safe vitrification operation and maintenance of the necessary negative pressure in the melter.

Canister Specification

So far, all canisters produced have met the specified composition and quality parameters. The guaranteed canister parameters are compared with the data of a typical VEK canister in Tab. III.

Table III. Comparison of typical canister data with guaranteed parameters

Parameter	Canister No. 27	Guranteed values
Waste oxide load	**15.9 wt.%**	**≤19 wt.%**
Weight	**497 kg**	**< 550 kg**
Activity Sr-90/Y-90	**3.52 E15 Bq**	**< 4.5 E15 Bq**
Activity Cs-137/Ba-137	**4.33 E15 Bq**	**< 5.1 E15 Bq**
α activity	**6.07 E13 Bq**	**< 8.6 E13 Bq**
β/γ activity	**8.46 E13 Bq**	**< 9.6 E15 Bq**
Mass U	**4424 g**	**< 7200 g**
Mass Pu	**135.9 g**	**< 210 g**
Dose rate		
β/γ (surface)	**198 Gy/h**	**< 440 Gy/h**
β/γ (1 m distance)	**15.4 Gy/h**	**< 35 Gy/h**
Thermal output	**669 W**	**< 734 W**

Experts from the Jülich product control office (PKS) have accompanied the vitrification process by regular audits, checked singular deviations, and confirmed the data.

CASK LOADING AND INTERIM STORAGE

The VEK is equipped with a passively designed canister buffer store with a capacity of 36 positions to decouple continuous vitrification from the transportation of the casks away from the site. Five CASTOR casks are available for the interim storage of the canisters. The storage license for the casks at the transport cask store of ZLN was granted by the BfS in parallel to the VEK operation license. Until transportation of the casks to ZLN, keeping the casks ready for transportation on the VEK area will be covered by the operation license (see Fig. 4). Directly after the production of a canister, contamination and dose rate measurements are performed to verify the radiological and inventory data, and the canister data are then transmitted to PKS for review. After each 28 canisters are produced, all canister data are passed on to the supervisory authority of the state of Mecklenburg-West Pomerania responsible for interim storage and its experts. This ensures timely clearance for loading. Meanwhile, 5 CASTOR casks have been loaded according to schedule (see also Fig. 2). No operation interruptions due to delayed review or cask preparation have occurred.

Fig. 4. Handling of a CASTOR cask outside of the VEK

At the VEK loading cell, the canisters are loaded remotely into the cask insert. The primary lid of the cask stored in the cell is placed remotely onto the cask after loading. Subsequent fixing of the screws has not caused any problems, manual tightness and dose rate measurements confirmed or remained far below the specified values. To minimize the dose to the operation and loading staff, a special neutron shield is applied at the head end of the cask. Further cask handling outside of the facility takes place using mobile devices. Transportation of the CASTOR casks is planned to take place in 2011.

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