Radioactive Start-up of the German VEK Vitrification Plant - 10089

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ABSTRACT

The German VEK vitrification plant has recently started radioactive operation. Its purpose is to immobilize 60 m^3 of highly radioactive waste solution once generated by the former WAK pilot reprocessing plant. Vitrification of this waste solution which contains high concentrations of noble metals is performed by a specially designed melting system developed by Forschungszentrum Karlsruhe (FZK). From processing of the waste solution about 125 glass canisters of the European standard type are expected. The canisters will be loaded into five CASTOR casks (capacity 28 canister), which will be transported to an interim storage facility. Since start-up about 25 % of the total volume has been processed. During this first phase of operation no severe problems were encountered. The performance of the melting system with respect to noble metals discharge proved to be efficient. The loading of the first CASTOR cask has already been completed.

INTRODUCTION

The German VEK vitrification plant erected from 1999 to 2004 and located at the site of Forschungszentrum Karlsruhe (FZK), has been constructed to immobilize approximatley 60 m^3 of a highly radioactive waste solution (HLLW) with a total activity of $7.7 \cdot 10^{17}$ Bq into borosilicate glass. This waste solution, stored in two tanks, originates from reprocessing operation of the former WAK pilot reprocessing plant which is now in the decommissioning and dismantling stage. The technology used by VEK is based on a liquid-fed ceramic-lined melter system that has been designed to process the highly noble metals-containing HLLW solution. Vitrification of HLLW with high concentration of noble metals poses a challenge to Joule-heated melting systems. A detailed description of the VEK process technology and the noble metals problem was published elsewhere [1,2].

Almost two years of extensive functional testing were completed in 2007 by a first extensive integral nonradioactive test of the VEK plant [3]. It was conducted under the rules of the first of two operational licenses. This first license is restricted to nonradioactive status. Results of this long-term vitrification test led to some modifications of the operation manuals. The second operational license is attributed to the management of radioactive materials inside the plant. It covers the connection of the plant to the HLLW storage tanks, the radioactive test to check the radiometric control equipment and the radioactive status of the plant after the test, and finally includes the radioactive routine vitrification operation. The second operation license was granted in February 2009 and subsequently executed. The paper describes the steps of execution until start-up of radioactive vitrification operation and presents the actual operational status of VEK.

PREPARATION OF VEK FOR RADIOACTIVE OPERATION

As a major step after release of the radioactive operational license, a second nonradioactive vitrification test carried out from April to May 2009 was performed. It was required as final training of the operators prior to processing of radioactive material in the plant. Goal of this second nonradioactive test operation using HLLW simulate has been the performance of the integral plant operation within the scope of the radioactive operational license, i. e. under the conditions and in compliance with the rules of the regulatory body by application of the operational manuals established for radioactive operation. That also included that eventually necessary maintenance steps had to be carried out by consequently using the available remote handling installations of the radioactive process cells. During the test operation of about 4 weeks 5 m^3 of HLLW simulate were converted to almost 4 metric tons of waste glass poured into 10 canisters of the European standard type (capacity 400 kg). Parallel to the performance of the second nonradioactive test, all steps were taken to prepare the plant for start-up of radioactive vitrification. This included the piping connection of the exhaust line to the central stack as well as of the piping to the storage tanks and subsequent transfer checks in both directions.

RADIOACTIVE TEST OPERATION

Preceding the start-up of the routine vitrification operation a one week test operation with a reduced level of radioactivity was conducted in September 2009. For this test a mix of HLLW simulate and a few percent of genuine HLLW was prepared. The activity of this diluted waste solution was in the range of $1.5 \cdot 10^{11}$ Bq/l. During this operation period three glass canisters were produced. The production data are given in Table I along with data from the two nonradioactive test operations. Main purpose of the radioactive test was to check the radiometric measurement equipment, to obtain information about the radioactive status of the plant during and after the test and to perform steps of a dose rate measurement program. The positive resuls from this test enabled entering HLLW vitrification operations without further adjustments.

Table I. Main Data of Two Nonradioactive Tests and the First Radioactive Test.

	Nonradioactive test I	Nonradioactive test II	Radioactive test
Time	April – July 2007	April / May 2009	Sep. 2009
Simulate/HAWC	16,9 m^3	5 m^3	1,7 m^3
Glass product	12,7 tons	3,8 tons	1,2 tons
Glass pourings	127	38	12
Number of canisters	32	10	3
Operation time (net)	78 days	23 days	8 days

STATUS OF RADIOACTIVE OPERATION

Start-up of processing of the stored HLLW immediately followed the radioactive test by mid of September. From one of the two storage tanks the HLLW has been transferred to VEK in batches of about 1.5 m^3, which corresponds to a weekly production. The sequence of batches is illustrated in Fig. 1 as a cumulative curve. It indicates that up to beginning of December 2009, 13 batches were transferred. The figure also contains the cumulative mass of waste oxides fed to the melter and the cumulative quantity of

Table II. Actual Production Data Compared with Total Production Data.

Parameter	Actual production data*	Total production data
Production time	Sep. 15-Dec. 9, 2009	18 (10**) months
HLLW volume	18.9 m^3	60 m^3
Glass production	14 264 kg	50 000 kg
Number of canisters (400 kg)	35	125
Number of pourings	140	500
Average waste glass loading	15.97 wt.%	16 wt.% (target)

* Reference date December 9, 2009
** net processing time based on design throughput and continuous operation

glass poured into the canisters. The actual production status of VEK is compiled in Table II and compared with the expected total production data. During an overall operation, time of maximum 18 months (net operation time 10 months) about 125 canisters with a capacity of 400 kg of waste glass each shall be produced. As of December 9, 2009, 18.9 m^3 of HLLW were processed. The processed waste solution was immobilized in 14.25 metric tons of glass. The glass was poured into 38 canisters.

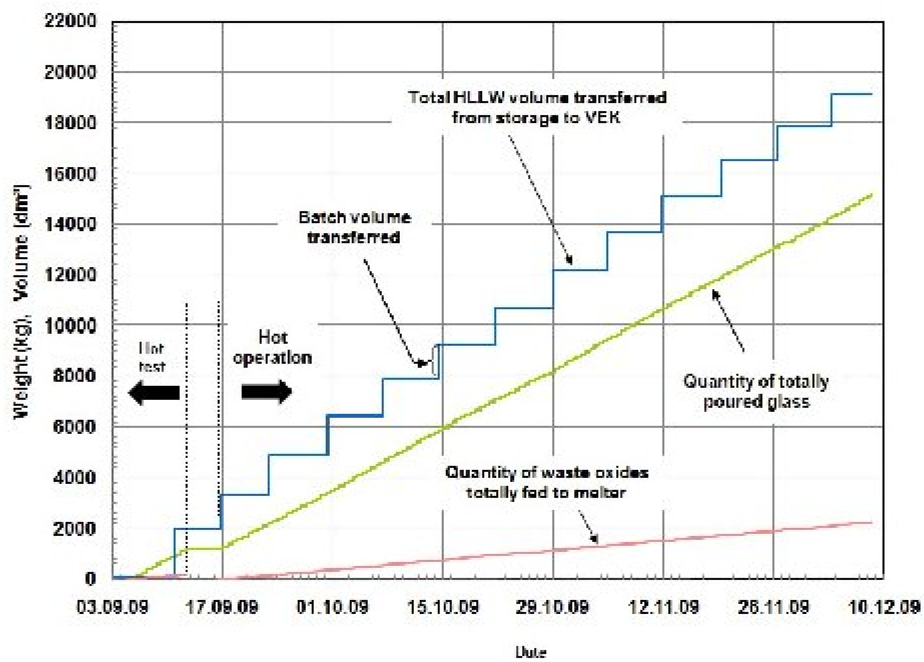

Figure 1. Cumulative data of HLLW batches transferred to VEK as well as of quantities of vitrified waste oxides and glass poured into canisters.

Melter performance

The small-scale ceramic-lined Joule-heated melter proved to work very reliable and steady. The processing of the HLLW showed similar behavior as the simulate. In both cases the design liquid throughput of 10 l/h could be met. This can be seen from the upper diagram of fig. 2 which shows an actual one week excerpt of the operational diagram. The middle diagram contains information about waste loading with oxides calculated on the basis of the melter feed streams over a balance period of approximately 25 hours. The range of tolerable waste oxide loading of the glass is 13-19 wt.% with a target loading of 16 wt.%. The data shown here are representative for the actual production time. The average loading of all produced canisters is very close to the target, see table II. The lower diagram of fig. 2 shows the pouring batches into the canisters. Each canister requires filling by 4 batches due to the relatively small inventory of the VEK melter. Production of one canister lasts about 57 hours. All pouring operations could be well controlled with respect to pouring rate as well as to the quantity of glass poured.

A main focus of the vitrification operation concerns the behavior of the noble metals in the melting process, as the HLLW is characterized by high concentration of these elements. In total approximately 460 kg of noble metals (in term of oxides) are contained in the HLLW solution. Noble metals cannot be incorporated in the borosilicate glass structure and form separate phases which tend to accumulate on the melter floor. Their presence can have a strong impact on the melter operation. The melter type applied by VEK has been equipped with a noble-metals design, which should avoid noble metals problems. Up to the actual status described here no indication of accumulation of noble metals in the melter could be observed. The data did not show any significant change in the electrical resistance of the glass pool which would appear in case of severe accumulation in the lower part of the melter. Also the performance of the pouring operation which is sensitive to the presence of the viscous noble metals sediments did not show any irregularities.

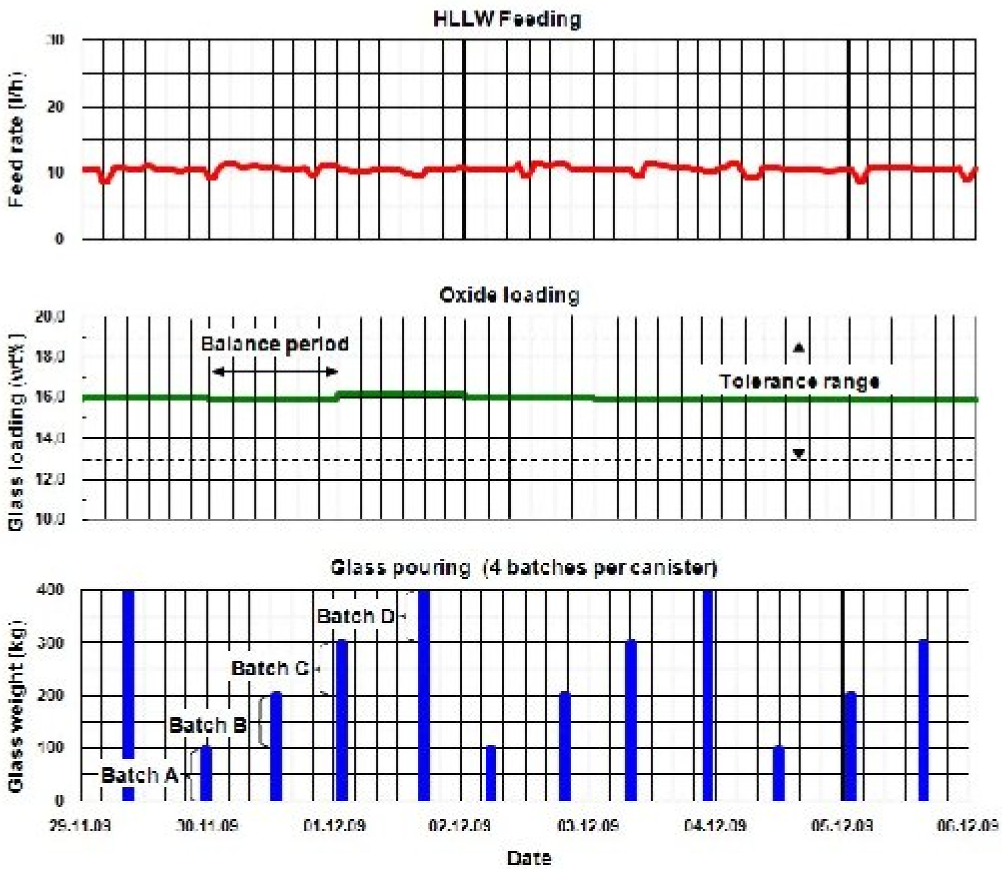

Figure 2. Weekly operational diagram. Upper diagram: melter feed rate. Middle diagram: calculated waste oxide loading of the glass. Lower diagram: Quantity of glass contained in canister.

Canister specification

From the 38 canisters already produced, each of them met well the required specification defined by a set of quality parameters established as acceptance criteria of the waste container for final disposal. The guaranteed values of these parameters are compiled in Table III and compared to those of a typical canister produced by VEK. The first 28 canisters were already loaded into a CASTOR transport cask and shipped out of the plant, awaiting their transportation to the Interim Storage North (ZLN) near Greifswald in the northern part of Germany.

OUTLOOK

Based on the current results the mission of VEK can be expected to be finished according to the time schedule in mid of 2010. After processing of the HLLW solution and subsequent flushing of the components and piping network, the produced canisters will be subject to transportation to ZLN by train by five CASTOR casks for interim storage. There they will be waiting for release of a German final disposal site. Subsequently steps will be taken to deregulate the VEK plant and to start the decommissioning and dismantling procedure of the cells and the technical equipment. Therewith another important milestone towards conversion of the WAK site to green field will be reached [4].

Table III. Typical Canister Data Compared with Guaranteed Values.

PARAMETER	GUARANTEED VALUE	CANISTER No.27
Waste oxide loading	≤ 19 wt.%	15.9 wt.%
Canister weight	< 550 kg	497 kg
Activity Sr-90/Y-90	< 4.5 E15 Bq	3.52 E15 Bq
Activity Cs-137/Ba-137	< 5.1 E15 Bq	4.33 E15 Bq
α activity	< 8.6 E13 Bq	6.07 E13 Bq
β/γ activity	< 9.6 E15 Bq	8.46 E13 Bq
Mass of U	< 7200 g	4424 g
Mass of Pu	< 210 g	135.9 g
Dose rate:		
β/γ (on surface)	< 440 Gy/h	198 Gy/h
β/γ (1m distance)	< 35 Gy/h	15.4 Gy/h
Decay heat	< 734 W	669 W

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