QUALITY ASSURANCE MEASURES FOR THE FABRICATION OF THE 30 ISOTOPIC HEAT AND RADIATION SOURCES FOR THE HAW-PROJECT

R. Stippler
GSF Institut fur Tieflagerung
Theodor-Heuss-Str. 4
D-3300 Braunschweig
Federal Republic of Germany

R. P. Allen, L. K. Holton, R. F. Klein
Battelle Pacific Northwest Laboratories
Richland, Washington 99352, U.S.A.

ABSTRACT

As part of the bilateral agreement between the German Federal Ministry for Research and Technology (BMFT) and the U.S. Department of Energy (DOE), 30 canisters with highly radioactive borosilicate glass containing predetermined amounts of Cs-137 and Sr-90 have been prepared. They are designed to provide the gamma dose rate and decay heat during a five-year emplacement experiment at the Asse Salt Mine in the Federal Republic of Germany (FRG), where they serve as simulants for high-level radioactive waste.

In order to comply with the licensing requirements in the FRG for handling the radiation sources in the mine, a detailed Working and Test Sequence Plan for the fabrication of the radiation sources has been prepared. Most emphasis is concentrated on the required leak tightness of the canisters which is guaranteed by a qualified welding process and a specially designed helium leak test. This paper describes the canister processing activities and the quality assurance measures related to the tight welding and the leak checking of the canisters. The results show that the measured net leak rates of all 30 canisters are well below the maximum permissible limit of 10^{-8} atm . cc/sec.

INTRODUCTION

The High-Level Radioactive Waste (HAW) Test Disposal Project, which is performed at the Asse Salt Mine (1), has been designed to simulate the conditions of a national high-level radioactive waste repository in the Federal Republic of Germany as far as possible on a 1:1 scale. The planning values for the repository are 200° C as the maximum salt temperature and 2.5 10^5 R/h as the expected dose rate at the waste canister surface.

Because of specific licensing requirements for the Asse Salt Mine the heat and radiation sources for the test disposal have to be retrieved at the end of the project. Therefore, the emplacement boreholes are lined with high-strength steel tubes. In order to compensate the absorption of the steel liner the radioactivity of the test sources is to be increased as compared to genuine high-level radioactive waste. Furthermore, the layout of the experiment foresees a certain variation of dose rate and heat load in the boreholes by using canisters with different contents of the radionuclides ^{137}Cs and ^{90}Sr.

The 30 heat and radiation sources have been fabricated at the Battelle Pacific Northwest Laboratories (PNL) as part of the bilateral agreement between the Germany Federal Ministry for Research and Technology and the U. S. Department of Energy. They have been produced in three separate processing campaigns using a radioactive liquid-fed ceramic melter to produce borosilicate glass (2).

Due to the processing conditions the designed specifications for the sources could not be reached completely. However, taking into account the actual values it will be possible to reach salt temperatures in the range of 220° C in two of the emplacement boreholes. This is well above the repository planning value. The average radiochemical characteristics of each set of ten heat and radiation sources are summarized in Table I.

TABLE I

Average Radiochemical Characteristics of the Heat and Radiation Sources for the HAW Test Disposal at the Asse Salt Mine

Number of Canisters	^{137}Cs-Content kCi	^{90}Sr-Content kCi	Decay Heat W	Surface Dose R/hr
10	192	85	1490	272,000
10	78	143	1330	112,000
10	207	130	1860	310,000

REQUIREMENTS FOR LICENSING PROCEDURE

The experiment in the Asse Salt Mine is carried out under special boundary conditions which are not typical for a repository. This applies particularly to the heat and radiation sources being placed in pressure resistant borehole liners which are rinsed with argon. Therefore, there are no particular demands on the corrosion resistance properties of the canister material against salt or salt solutions.

On the other hand, specific requirements on the stability and leak tightness of the canisters are a consequence of the requirement for safe retrievability. It must be guaranteed over the five year test period that noradioactivity will escape from the sources leading to contamination of the liners or imposing a hazard for the mine personnel.

A further requirement on the source tightness arises rom the licensing procedure for the Single Transport Cask

Asse TB 1, which will be used to transport the source into the mine. This containers is to receive a type B(U) certificate in accordance with the international transport regulations. Since this cask may not be regarded as tight because of its bottom slider, the sealing of the radioactive material must be assured by the tightness of the canister.

The leak tightness of commonly available radiation sources is normally provided by double casing and efficient welding. The leak tightness of small capsules can then be easily tested with a helium leak check. However, hardly any radiation sources of this type and order of magnitude have been produced so far. Consequently, special requirements were imposed to guarantee the leak tightness of the heat and radiation sources by using a qualified welding process and a specially designed helium leak check system.

QUALIFICATION PROCEDURE FOR THE REMOTE WELDING

The glass-filled canisters are cylindrical with an outer diameter of 300 mm, a height of 1,200 mm and a wall thickness of 8 mm. They are made of stainless steel material no. 1.4571 (X 10 Cr Ni Mo Ti 18 10), according to DIN 17440, which has a chemical composition similar to 316 L. The canisters contain an average of 60 liters of highly radioactive borosilicate glass and are closed by a lid made of the same stainless steel.

Because of the high radiation content of the filled canisters, remote welding in a hot cell was required. A fully automatic Gas Tungsten Arc (GTA) welding process without additional filler material between the lid and the flange was selected for the tight sealing of the canisters. To guarantee a minimum penetration depth of 3 mm the lid and flange were prepared with two notches in the weld area (Fig. 1). This canister weld layout was requested by the Bundesanstalt fur Materialforschung und -prufung (BAM), Berlin, to assure a tight weld. A similar weld design has also been used on other canisters for radioactive material (3).

The welding equipment consists of two parts. The welding head (Fig. 2) with a motor-driven rotating torch was designed to be operated under hot cell conditions. Some parts, like electrode holder or motor, can easily be replaced with the aid of manipulators. The welding power supply and automatic control system is installed outside the hot cell. It serves as a source for the welding current, the high-frequency ignition of the weld electrode and controls the gas flow and the electrode rotation.

Prior to welding of the radioactive glass-filled canisters, the welding process was qualified as part of the traffic regulatory licensing procedure for the transport cask of type Asse TB1. Process testing was carried out under conditions comparable to welding of the actual canisters but without the influence of gamma radiation. The expected temperature history of the weld area during glass pouring was calculated and the flanges used for the process testing were heat-treated in a similar manner. After weld procedure development, three lids and flanges were welded as test specimen in the presence of an expert from BAM. During

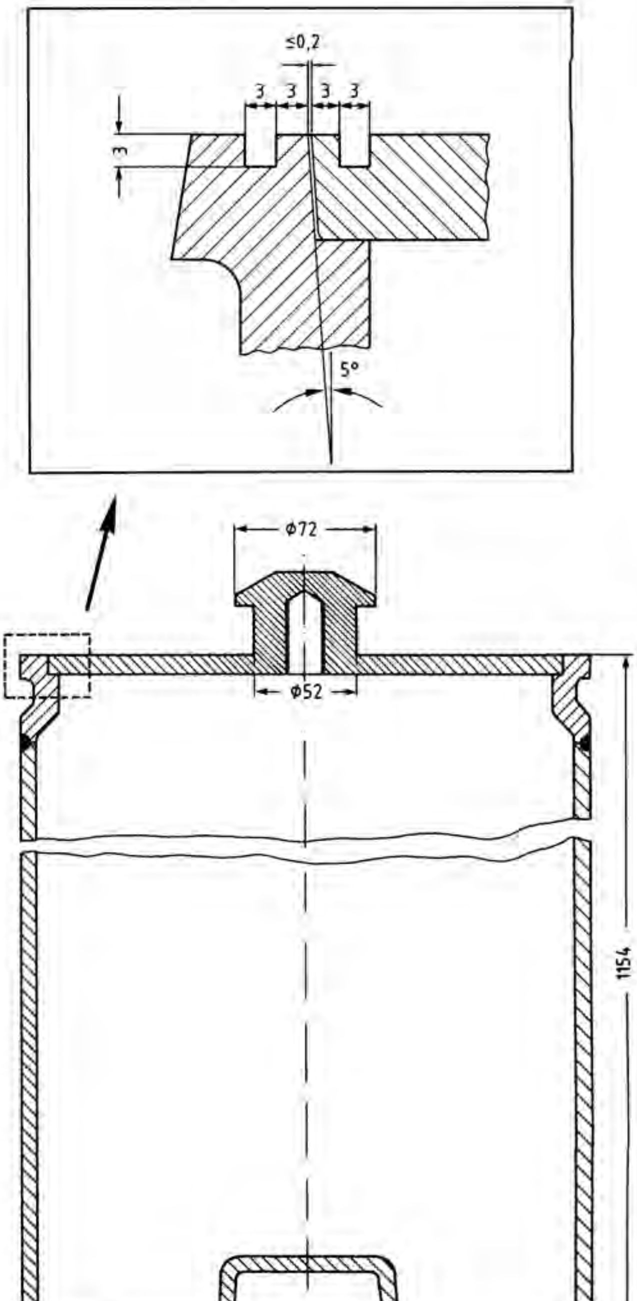

Fig. 1. Canister for the Heat and Radiation Sources and Enlarged Weld Area Between Lid and Flange.

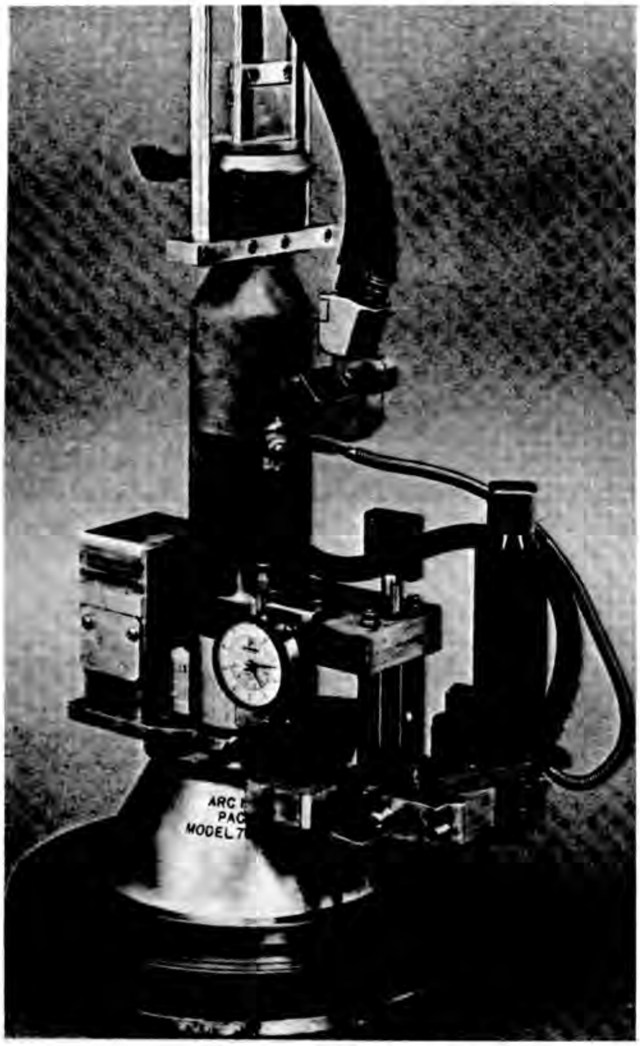

Fig. 2. Welding Head.

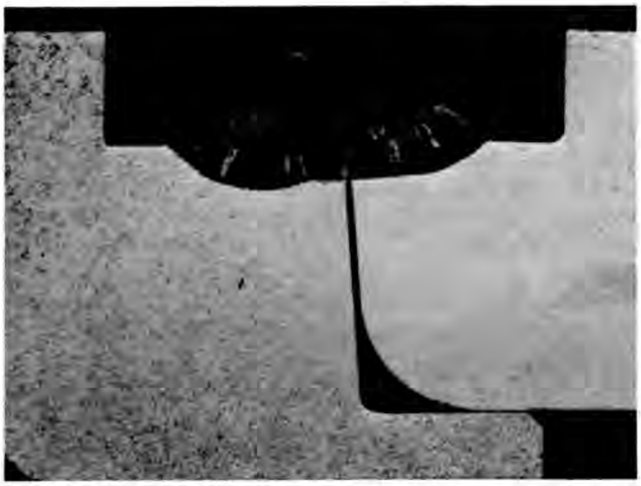

Fig. 3. Section Transverse to the Weld Seam.

process testing, two temperatures (100° C and 50° C) were selected and other welding parameters were also varied.

The test specimen were carefully examined by visual inspection, by preparation of sections transverse to the seam, and by mechanical and leak testing. The surface of the welding seam was regular and of a finely rippled quality. All sections showed a seam thickness of more than 3 mm (Fig. 3). The mechanical strength tests proved that there is no welding seam failure under a centric stress of 380 kN. The tightness of the welding was tested and showed standard He-leak rates less than 5 10^{-9} atm cc/sec.

Based on the results of this welding processing testing, the conditions and welding parameters for the actual welding of the canisters in the hot cell were specified. As part of the Working and Test Sequence Plan, a detailed welding procedure and welding plan were prepared by PNL and approved by BAM. Some of the welding parameters are listed in Table II.

Table II

EXTRACT FROM THE WELDING PLAN

Welding process	GTA welding without additional material
Weld type	Standard Lip Joint
Welding temperature	100 to 250° C
Welding position	horizontal
Electrode gap	1.65 0.05 mm
Shieldgas	75% He + 25 % Ar
Gas flow rate	31 1/min
Welding current	pulsating direct current (80 ... 200 A)
Welding speed	pulsating (0.3 ... 0 RPM)
Pulse time	0.5 / 0.7 sec
Seam overlapping	50 mm (total)
Downslope	30 mm (15 sec.)

HELIUM LEAK CHECK SYSTEM

To check the leak tightness of the canisters by a helium leak test, several techniques were discussed of bringing a known amount of helium into the canister under hot cell conditions. The selected method used a special gas cylinder which was pressurized by helium and which leaked at a predetermined rate. This source capsule was placed in the void space of the filled canister prior to welding. The capsule was allowed to build up pressure in the welded canister void space of the filled canister prior to welding. The capsule was allowed to build up pressure in the welded canister void space. The leak tightness of the canister was then measured by checking the outside of the weld for escaping helium.

The helium source capsule consisted of a 300-cc gas cylinder with a tapered glass capillary sealed in one end. The cylinder was filled with helium to a predetermined pressure, based upon the calibrated leak rate of the capsule and the canister void volume. The helium then slowly leaked out through the glass capillary at a slow leak rate ensuring that the capsule was still leaking well after the canister lid was welded. The helium leak capsule was filled to a pressure such that, if all the helium in the capsule leaked into the canister void volume, the total pressure in the void would be less than 5.6 atm, the maximum permissible pressure inside the canisters.

A computer program was written to calculate the canister void pressure versus time when given the canister void volume, helium capsule characteristics, capsule filling time, capsule emplacement time, and welding time. This program was used to determine the time required before the helium capsule had built up enough pressure in the canister void to allow leak testing.

In general, at least 24 hours were required between weld closure and helium leak testing of the weld to ensure that sufficient helium was present in the void volume to measure the helium leak rate.

The leak rate of the helium source capsule was measured at ambient temperatures before the capsule was placed into the hot canister. Therefore, a series of thermal tests on the capsule leak rate at selected temperatures from ambient to 400° C were performed. The results showed that the leak rate constant was not highly temperature sensitive. They confirmed the validity of the equations and computer programs used, where the temperature dependency of the helium viscosity was incorporated.

Functioning of the complete helium leak check system was demonstrated to BAM during training for the remote handling of the welding equipment.

CANISTER CLOSURE AND WELD VERIFICATION

The canisters were filled with glass at PNL in B cell of 324 Building and placed in specially designed canister storage racks. Canister closure operations started mid-February and were completed by the end of March 1988. Up to two canisters were processed per day. Sequentially, each canister was moved from its storage position to the weld station in front of a hot cell window. The protective lid and the weld protector ring previously placed on the canister were removed. Next, the void height between the top of the glass surface and the top of the canister was measured to calculate the void volume. This was used in determining the fill pressure for the helium capsule.

The inside surface of the canister flange near the weld joint and the top of the flange on both sides of the groove were thoroughly cleaned by using a stainless steel wire brushing wheel on a pneumatic grinder. The groove itself was cleaned using a manipulator-held stainless steel brush. After brushing, the flange area was blown with breathing air to remove loose particles and was visually inspected with a television camera.

The flange lid was thoroughly cleaned outside the cell using acetone and then alcohol. The cleaned lid and the precalibrated and filled helium capsule were then transferred into the cell. The helium capsule was placed into the canister and the lid was set on the flange. A gross helium cell background measurement was taken, and then a helium measurement was taken over the canister to assure that the capsule was releasing helium.

Then the welding head was placed on the lid centered by the pintle. The alignment of the electrode tip with the weld joint was checked in two locations 180° apart. This checking and any subsequent adjustment to the welding head were made by remote viewing through a television camera. Along with the electrode alignment check, the arc gap was adjusted.

Prior to lid-weld closure, the lid was first tack-welded to the flange in three locations spaced 120° from each other. The final closure weld was then initiated midway between the first and last tack weld so that good visual observations could be made of the weld and the weld overlap. The setting of the welding parameters were carefully supervised by an approved welding engineer. During tack welding and final closure, one person was stationed at the welding power supply to monitor the head operation.

During each weld, a continuous chart recording of the arc voltage, arc current, and rotational speed of the welding head was made. At the completion of each weld, a visual inspection of the weld using the television camera was performed. Immediately after visual inspection, the lid weld was tested for gross helium leaks using a gas sniffer probe which can detect the presence of helium from leaks as small as 10^{-5} atm cc/sec.c

After the canisters were welded and rinsed in B-Cell, they were transferred to the air lock where they remained for ~ 24 hours to allow sufficient helium to leak from the capsule and thereby to increase the helium pressure to sufficient levels in the canister void space. The canisters were then subjected to a more sensitive leak test in which they were sealed inside a 160 l cylindrical vacuum vessel. The vacuum vessel was then evacuated and the effluent tested for presence of helium using a mass spectrometer leak detector with a sensitivity in the range of 5 10^{-10} atm cc/sec.

RESULTS

Welding progressed well up to the sixth canister, when the quality of the welding arc suddenly deteriorated. This happened after the weld had gone about halfway around the weld joint. The weld was completed but showed a non-uniform appearance. Obviously, the inert gas cover of the welding arc was inadequate, and after changing the inert gas supply tube, inert gas cylinder, inert gas flowmeter and welding electrode, three tests welds were made and all were acceptable. The welding continued without major problems.

The experimentally determined vacuum vessel background and gross leak rates for the 30 canisters are shown in Fig. 4. The canister sequence number was assigned to each canister in terms of when it was processed. It should be noted that the net leak rate (gross minus background) is negative for 6 of the 30 canisters. This occurred because the

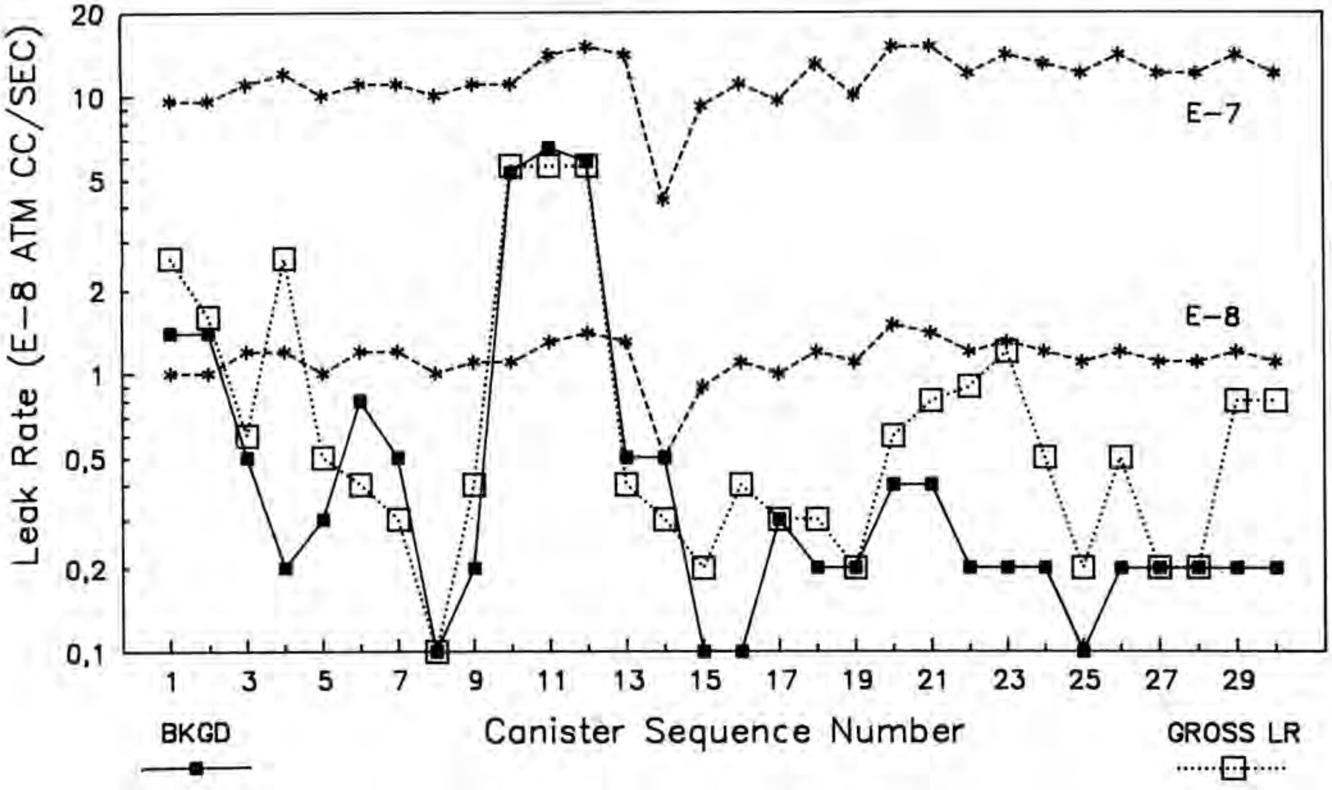

Fig. 4. Leak Detection Computation Results.

vacuum vessel had to be vented between the background and gross leak rate readings so that the canister could be removed from it. For these six canisters, it apparently caused a change in the vessel background reading but the differences were very small. The unusually high gross leak rates and background leak rates for canisters 10 through 12 are due to some contamination in the vacuum vessel which caused a high background reading. It did not pose a problem because the net leak rate was still near zero.

The experimental values at the actual conditions of the individual canisters (temperature, void pressure, viscosity, etc.) at the time of leak detection have to be compared to the specified criterion of 10^{-7} atm cc/sec maximum leak rate that is defined at ambient conditions (25°C and 1 atm differential pressure). Assuming a 10^{-7} resp. 10^{-8} atm cc/sec leak at ambient conditions, the equivalent measurable leak rate at the actual conditions of the canisters were calculated. The results are indicated as E-7 resp. E-8 and are shown in Fig. 4 also.

The low equivalent measurable leak rate calculated for the 10^{-7} atm cc/sec leak rate of canister 14 is due to the low calculated void pressure in the canister at the time of leak detection. This low equivalent measurable leak rate was far above the leak detector's limits and would have been easily detected.

Fig. 4 confirms that all canister leak rates were well below the requirement of 10^{-7} atm cc/sec and in most cases, one to two orders of magnitude lower. The graph also shows that the leak detection system was so sensitive that any actual leak rate above 10^{-8} atm cc/sec at ambient conditions would clearly have been seen for the given conditions of each canister when tested.

REFERENCES

1. ROTHFUCHS, T. and R. STIPPLER, "High-Level Radioactive Waste Test Disposal Project in the Asse Salt Mine Fed. Rep. of Germany," Waste Management '87, Tucson, Arizona, March 1-5, vol. 1, p. 89 (1987).
2. MC ELROY, J. L. et al., "Fabrication of Vitrified Isotopic Heat and Radiation Sources for the Asse Salt Mine Testing," Waste Management '89, Tucson, Arizona, Feb. 26, March 2, (1989).
3. BERTRAM, W. et al., "VerschweiBen von Transport und Lagerbehaltern fur abgebrannte HTR-Brennelemente," Kerntechnik 53, No. 2, 165 (1988).