CANISTER QUALIFICATION FOR PROCESS AND STORAGE OF VITRIFIED HLW

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ABSTRACT

The Nuclear and Alternative Energy Agency (ENEA) is carrying out aprogram of work with the objective of developing a plant for the conditioning of radioactive liquid wastes arising at its reprocessing plants.

In the early 1980's a pilot unit, called IVET, was built at Trisaia Centre, southern Italy, and a vitrification process has been developed, based on the pot vitrification concept. This plant was designed to process and storage HLW using the same container as process and storage tank. Studies, taking into account general worries of the environmentalists and licensing authorities, were carried out on the canister design and its remote handling.

INTRODUCTION

According to ENEA program concerning HLW vitrification, an inactive pilot plant called IVET, based on the pot vitrification concept, was built at Trisaia Centre, southern Italy.

Ivet plant was built to carry out experimental activity concerning the vitrification process in order to support the design of the active station to be coupled with EUREX reprocessing plant (located at Saluggia Centre, northern Italy).

At the end of 1988, some 40 runs have been performed; they have been described elsewhere (1,2).

Afterwards, a second facility called PROTEO was built to complete the IVET plant; PROTEO is a mockup where remote handling operations concerned with the IVET plant are studied. One of the most important studies carried out at IVET-PROTEO system is the canister qualification.

The canister qualification program has been taken in great importance because of the canister employ as vitrification vessel and final storage container.

This paper describes the selection criteria of the material to be employed and the destructive and non tests carried out on the canister constructed with the chosen material and employed in complete thermal cycles in IVET and PROTEO plants.

CANISTER QUALIFICATION

The canister qualification consists of materials selection fabrication and pertinent checkings lid welding and inspection final tests Materials selection Canister materials are selected on the basis of their properties and economics. The selection is limited to austenitic stainless steels. Three stainless steel classes were investigated:

- low Ni-Cr steel (Terninoss AISI 347)
- high Ni-Cr steel (Ilssa Viola AISI 310S, Uddeholm L25)
- high Ni-Cr-Mo steel (Terninoss 310 LMR)

Low Ni-Cr-Mo steel (AISI 316) was not considered because the low percentage of molybdenum is not influential.

Also a nickel based super alloy (Wiggin INCONEL 601) was tested. Stainless steel compositions are reported in Table I. The material tests were chosen according to IVET process; in IVET plant the glass is molten directly in the storage canister (in can melting process). Four tests were performed (Fig. 1)

- corrosion resistance in HLW acid solution
- oxidation resistance in hot environment
- corrosion resistance in molten glass
- stress corrosion resistance.

All tests were carried out on welded samples; the welding of INCONEL 601 samples turned out to be very difficult; after welding the microstructure of the pieces was examinated. INCONEL 601 showed a precipitation of chromium carbides; the microstructure of the other materials was very homogeneous.

The samples were later subjected to Huey test (according to ASTM A262-6 code) to assess the corrosion resistance in HLW acid solution.

The corrosion rate was high only for INCONEL 601; that material is very resistant to oxidation at high temperature, but not to boiling nitric solution.The corrosion rate of the other materials was lower than reference value (0.05 mm/month, the threshold for "urea grade" steels): the best one is the UDDEHOLM L25; it is followed by the 310 LMR inspite of high molybdenum percentage that should make the performances worse. All specimens were subjected to a standard cycle in IVET furnace in order to assess the oxidation resistance at high temperature. After heating, the samples were pickled and weighed; the weight loss is index of corrosion. The behaviour of the materials was very good with the exception of AISI 347 (the other materials are produced purposely to be used in hot environment).

The metal pieces were settled inside a canister and subjected to a vitrification run to assess the corrosion by molten glass.After vitrification the canister was drained and the samples were analysed.

The pieces were pickled and blasted to remove the glass; weight loss is index of corrosion.

The resistance increases with nickel percentage; the best metals are in order INCONEL 601, 310 LMR and UDDEHOLM L25. The materials were later subjected to a last test to assess the resistance to corrosion during the storage after vitrification process. Metal samples were held in a boiling 5M NaCl solution for 700 hours after being subjected to the reference thermal cycle and U- bent; afterwards they were analysed by liquid penetrants to point out crack presence. Cracks are present in AISI 347 and UDDEHOLM L25; INCONEL 601 shows some pitting phenomena. Results are summarized in Fig. 2. Terninoss 310 LMR is the selected material; INCONEL 601 is rejected because of its high price and welding difficulty. The used material is SANDVIK 2RK65 that is the most commercial high Ni-Cr-Mo steel (its composition is equal to 310 LMR).

TABLE I

Composition of the Materials Investigated

Material	INCONEL 601	310 LMR	UDDEHOLM
C max %	0.100	0.025	0.020
Cr %	21.025.0	19.520.2	24.500
Ni %	54.058.5	24.825.5	20.500
Mo %	-	4.34.6	-
Mn max %	1.000	1.11.5	1.800
Si max %	0.500	0.250.50	0.300
S max %	0.015	0.010	0.015
P max %	0.015	0.030	0.200
Cu %	-	1.251.75	-
N max %	-	0.040	-
Al %	1.01.7	-	-
Fe %	17.500	-	-
Nb+Ta %	-	-	-
Material %	AISI 310S	AISI 347	
C max %	0.080	0.080	
Cr %	24.026.0	17.019.0	
Ni %	19.022.0	9.012.0	
Mo %	-	-	
Mn max %	2.000	2.000	
Si max %	1.500	1.000	
S max %	0.030	0.300	
P max %	0.045	0.045	
Cu %	-	-	
N max %	-	-	
Al %	-	-	
Fe %	-	-	
Nb+Ta %	-	10x %C min	

MATERIAL	HUEY TEST VC mm/Month	OXIDATION RESISTANCE WEIGHT LOSS mg/sqcm
AISI 304 B.M.	23.0E-3	-
INCONEL 601 B.M.	> 1.00	8.30
INCONEL 601 W.Z.	> 1.00	9.60
UDDEHOLM L25 B.M.	7.5E-3	7.10
UDDEHOLM L25 W.Z.	8.5E-3	7.20
AISI 310S B.M.	9.0E-3	7.40
AISI 310S W.Z.	35.0E-3	5.60
TSS 310 LMR B.M.	23.0E-3	6.80
TSS 310 LMR W.Z.	23.0E-3	6.90
AISI 347 W.Z.	38.0E-3	26.00
AISI 347 B.M.	42.0E-3	59.00

B.M. = Base Metal W.Z. = Welded Zone

MATERIAL	STRESS CORROSION TEST EVENTUAL CRACKS	MOLTEN GLASS RESISTANCE WEIGHT LOSS mg/sqcm
INCONEL 601	NO (Pitting)	20.00
UDDEHOLM L25	YES	205.00
AISI 310S	NO	386.00
TSS 310 LMR	NO	145.00
AISI 347	YES	470.00
AISI 304	YES	-

Fig. 2. Test Results.

FABRICATION AND PERTINENT CHECKINGS

Canisters must provide a suitable level of containment of the radioactive glass; therefore fabrication and quality assurance requirements for nuclear components, appliy to canisters. The rules of the ASME Boiler and Pressure Vessel Code, Section III, Division 1 are considered suitable to canisters fabrication. Quality assurance program concerns the following areas:

- material specifications
- welding procedures and personnel qualification
- fabrication.

The material (SANDVIK 2RK 65), previously certified in ironworks, is subjected to the acceptance test; the inspection is carried out on lots of 750 Kilograms at the most.

A sample every lot is subjected to chemical analysis and mechanical tests (according to ASTM code).

Afterwards every single piece (bar, plate) is subjected to mondestructive testings (according to ASME code).

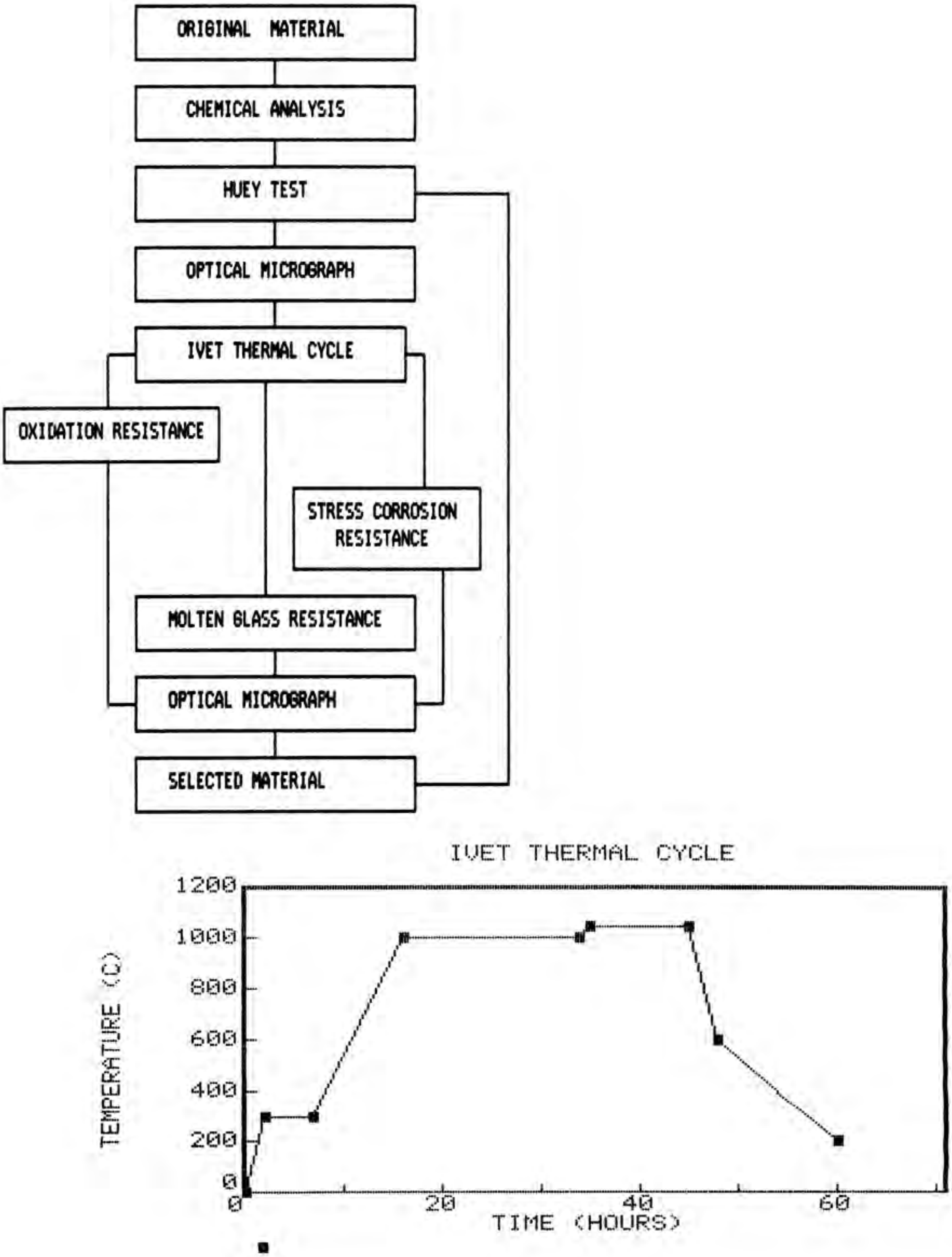


Fig. 1. Material Selection Program.

Tests and acceptance conditions are summarized on Table II. The qualification of welding procedures and personnel training is very important.

TABLE II

Acceptnce Conditions

Mechanical properties:	
Breaking load	490 MPa min
Yield point	220 MPa min
Rockwell hardness	7090 HRB
Plate thickness toler.	-0.25/ + 0.5 mm

Qualification tests are carried out before the canister production (according to ASME Section IX code). Weld beads are examined by means of radiographics and liquid penetrants; also macro and micrographs are carried out. Welding procedures are accepted if approved by a suitable Control Institution. Personnel must be in possession of welding qualification issued by an Institution: otherwise qualification tests similar to those previously described are carried out before beginning the production. Canister fabrication begins with the plate bending; this operation is executed at high temperature; afterwards every piece is subjected to visual control, in case of need liquid penetrant test is also carried out; bottoms are always tested by means of liquid penetrants. Weldings are excuted according to procedures previously qualified; weld joints must comply with ASME III - Div. 1 - Art. 42414243. All weldings are tested by liquid penetrants and checked by means of radiographic analyses.

Three final tests are carried out on the produced canisters:

- Pressure test: the canister is closed by a temporary lid; dry air is pumped at 50000 Pa; there must not be perceptible pressure drop during 15 minutes.
- Helium leak test: the max leak rate accepted is 10^{-6} atm ml/sec.

Dimensional control: all the dimensions must comply with tolerance limits.

LID WELDING AND INSPECTION

The canister is closed by a lid after it has been filled with waste glass. A twist-lock provides the mechanical connection and a welding provides the seal. Lid welding must be carried out remotely. A remote welding station was built at PROTEO plant; it consists of:

- a gas tungsten arc welder
- a helium leak detector
- an ultrasonic scanner.

The welding station is also equipped with an additional bell jar provided with an adapt tool to remove the eventual defective weld. Machine tools features have been described previously (3).

FINAL TESTS

The first six canisters, built according to the present quality assurance program, were subjected to the vitrification process in IVET plant; afterwards they were sealed by means of remote welding machine. The canisters were also subjected to dropping tests, according to IAEA regulation. The following analyses were carried out after the vitrification process and the dropping tests:

- visual control
- dimensional control
- liquid penetrant and ultrasonic test of the weld beads; these analyses were carried out also near the glass level and drop point.

Lastly the canisters were sectioned along various cutting planes and metallograph examinations were carried out. The results of the examinations carried out after vitrification were:

- there is a slight increase of diameter where the glass is present because of the different thermal coefficient between glass and steel; the creep is negligible (the lenght is practically equal);
- two canisters show a valuable corrosion phenomenon, the former on the outside surface, the latter on the inside surface, near the bottom welding; the corrosion of the other canisters is practically negligible;
- liquid penetrant test shows a good quality of weld beads both before and after vitrification process.

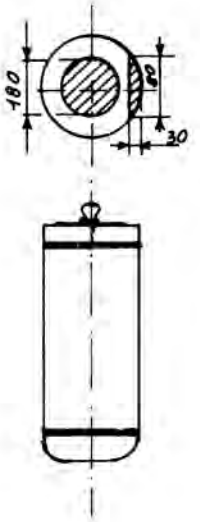
Corrosion presence is caused probably by mistakes during fabrication (plate bending and bottom welding respectively). Canisters produced afterwards have not shown any valuable corrosion phenomenon. Dropping tests are summarized in Table III. Deformations were serious only during tests 3 and 5 because the impact took place in correspondence of an empty zone. Liquid penetrant and ultrasonic tests carried out after the dropping tests showed that wall, lid and weld beads had remained sound. Several micrographs were carried out after the twist-lock closures were sectioned; all they showed an adequate welding penetration with sufficient fusion of both lid and canister with the exception of a zone without fusion due to an excessive overlap between the lid and the canister. Afterwards the lid was modified to avoid this slight fault.

REFERENCES

1. A. CANONICO et al. "Two years experience with vitrification inactive pilot plant in Italy" International Conference on Radioactive Waste Management, Seattle (1983)
2. P. MATALONI et al. "Laboratory and pilot plant studies for the solidification of aluminum rich HLW produced by EUREX plant" -RECOD 87 - Paris (1987)
3. A. CANONICO et al. "Remote handling features of the PROTEO mock-up facilities for vitrified HLW canisters" SPECTRUM 86 - Niagara Falls (1986).

TABLE III

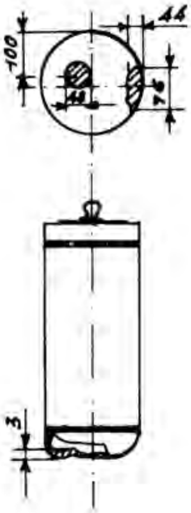
Dropping Test Deformations



Conditions: Vertical position from 9 m. onto a steel plate.

Damage: Central bottom.

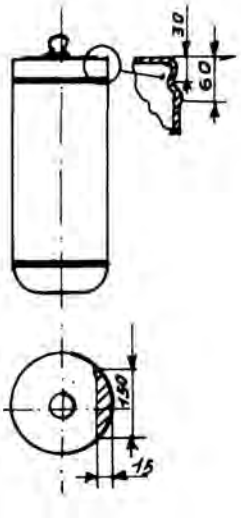
Note: This test was performed on the canisters n. 1 and n. 3.



Conditions: Vertical position from 6 m. onto a steel punch.

Damage: Central bottom.

Note: This test was performed on the canisters n. 2 and n. 4. It simulated an accidental dropping during a canister storage.



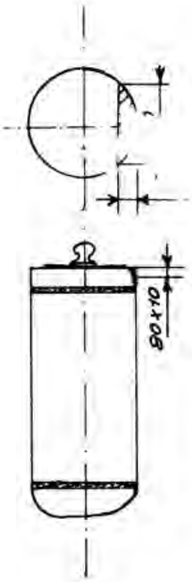
Conditions: Vertical (upside-down) with an angle of 27° from 9 m. onto a steel plate.

Damage: Between the twist lock closure and the upside of the canister wall.

Note: This test was performed on the canisters n. 2. and n. 6.

TABLE III (CON'T.)

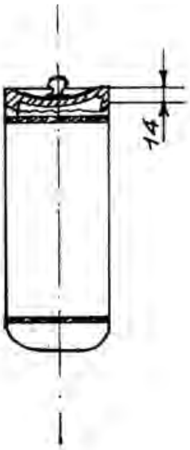
Dropping Test Deformations



Conditions: Vertical with an angle of 27° from 9 m. onto a steel plate.

Damage: Lateral bottom.

Note: This test was performed on the canister n. 5.



Conditions: Vertical (upside-down) from 9 m. onto a steel plate.

Damage: Top canister closure (lid and central lifting stud).

Note: This test was performed on the canister n. 5.