**Proceedings of the 17th International Symposium on the Packaging and Transportation of Radioactive Materials
PATRAM 2013
August 18-23, 2013, San Francisco, CA, USA**

Qualification of the DAHER-NCS Fuel Rod Encapsulation Process for Transport and Storage

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ABSTRACT

During the previous PATRAM in 2010, DAHER-NCS has presented a new concept for the encapsulation of spent fuel rods. This process is required in order to allow the transport of damaged rods. For these last three years, DAHER-NCS has kept continuing the improvement and qualification of the encapsulation device.

For the qualification process a smaller test model was used. In the meantime a full size prototype of the brazing equipment was designed and manufactured. This prototype was successfully tested in dry conditions as well as submerged under water in a spent fuel pool. The quality of the drying process and the brazed plugs is reproducible in all tested conditions and comparable to the results of the brazing of the device used for the qualification process.

Furthermore a test method to check and guarantee the leak tightness of the encapsulated rods was developed and validated. The leak tightness is proven by an integral Helium leakage test.

Within the next two years the operation in three European nuclear power plants (BWR and PWR) is projected.

Currently the transport within the type B(U)F package NCS45 of brazed capsules produced by this process is licensed. So DAHER-NCS provides a solution for the removal of damaged spent fuel rods out of the pool and their transport in safe conditions. The next step will be to qualify the brazed capsules for long term intermediate storage.

INTRODUCTION

To investigate a fuel rod with a very high burn up or with damages it is necessary to transport this rod, for example to a hot cell. Because of the unknown conditions of the fuel rod, the rod has to be encapsulated in leak tight conditions for a safe transport. Currently this encapsulation process is possible in dry conditions (in a hot cell) by a welding process, but there was no solution to produce such a capsule under water.

An encapsulation concept working under water developed by DAHER-NCS was presented during PATRAM 2010 in London, (1). With this technology it is possible to encapsulate single fuel rods with an extensive quality control during the brazing process and later on the brazed capsule to ensure the safe and leak tight condition of the capsule.

This paper describes the achievements of the last three years in the development of this Underwater-Brazing-Equipment (UBE). As reported in (1) for the qualification of this procedure a 1:3 size model was successfully used. In the meantime a full scale prototype was built and tested in dry conditions as well as submerged under water in a spent fuel pool. The results of these tests and the improvements resulting in these tests are presented in this paper.

ENCAPSULATION CONCEPT

The encapsulation process is equal to that one used for the smaller model during the qualification process. In detail there are the following steps, assuming that the UBE is positioned in the spent fuel pool of a nuclear power plant:

- Insert lower plug in tube and put this tube in the UBE. This step is performed outside the pool and can easily be done by hand with a special tool developed to handle the tube. For that reason the tube has special attaching points.
- Insert fuel rod. The next step is the insertion of the fuel rod. This can be carried out with the usual equipment to handle a fuel rod which is available in every power plant.
- Insert upper plug. After that the upper plug has to be put in the UBE. Later the plug will be the attachment point for the brazed capsule, so it is constructed with an equivalent shape meaning the same tool to handle a fuel rod can be used to move the plug. After the plug is in its position, the UBE can be closed.
- Drying. The complete UBE will be dried. Because the tube is not closed now, also the inner volume in the tube (where the fuel rod is), is dried. After a successful drying test the UBE is filled with helium.
- Lift capsule: To move the plugs in their correct position the capsule is lifted by a mechanical system that can be operated by a single person standing outside the pool. The correct position is controlled by underwater cameras through windows in the UBE.
- Brazing of plugs: After that the plugs can be brazed. First the lower plug is brazed. The process is controlled in two diverse ways. On the one hand there is an optical control with underwater cameras, on the other hand important parameters of the brazing process like temperature and applied power are monitored and recorded. The upper plug is brazed in the same way afterwards.
- Helium leakage test: In the last step the capsule is put in the testing station where a helium leakage test is performed.

Now the successfully brazed capsule is ready to be transported in a the NCS 45 transport cask.

FULL SIZE PROTOTYPE

The UBE consists of two brazing stations, see Figure 1 and Figure 2. Both stations are equipped with a window for visual controls, a connection for the electric power and a pyrometer for the temperature control during brazing. The stations are connected by a tube whose length can be adjusted to the length of the fuel rod or rather to the length of the capsule. Furthermore this connection tube is used to center the tube to ensure the correct positioning in the inductors during brazing.

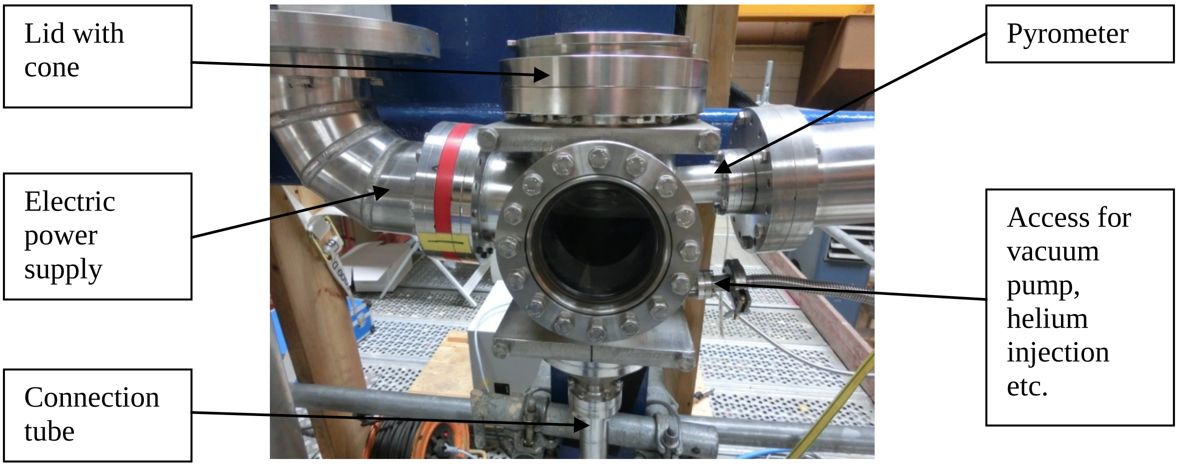

Figure 1 Upper brazing station

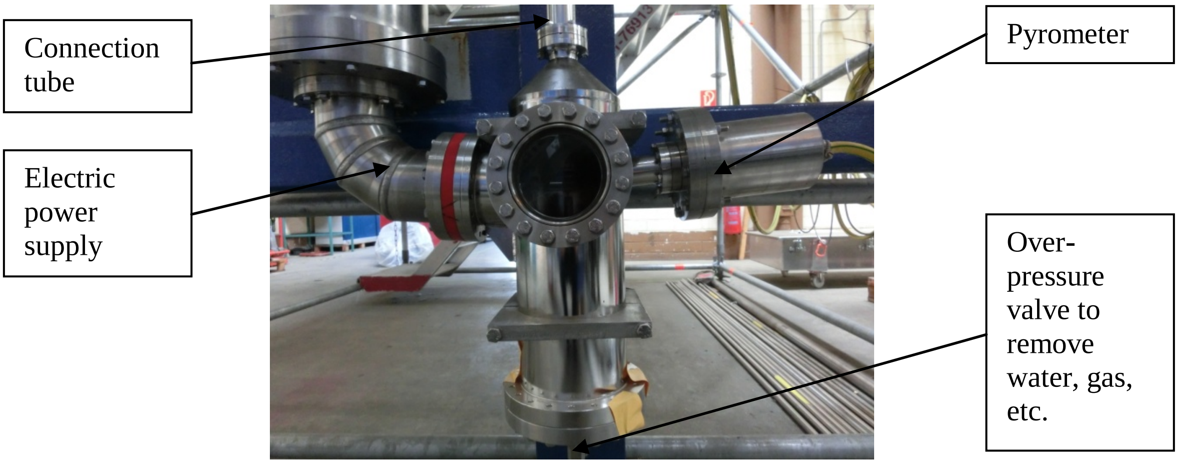

Figure 2 Lower brazing station

All parts of the UBE, especially its connections, are designed to allow an easy operation from outside the pool, even if the UBE is positioned on the floor in a depth of approximately twelve meters.

Figure 3 shows the testing station for the helium leakage test. The practical use of the UBE showed that it is an advantage to perform the helium leakage tests in a separate chamber. In this way a lot of time can be saved by avoiding time to prepare the test in the brazing chamber, e.g. by removing the helium out of this chamber after brazing. Furthermore this way allows more precise results of the helium leakage rate measurement because the tests are performed in an atmosphere which was never in contact with helium. Some tests showed that the helium rate of the underground in the brazing chamber might be to high if it is not cleaned sufficiently.

The safe condition of this additional movement of the capsule is guaranteed by the documentation of the brazing process. The mechanical connection of the plugs is ensured in this way as shown in the process qualification.

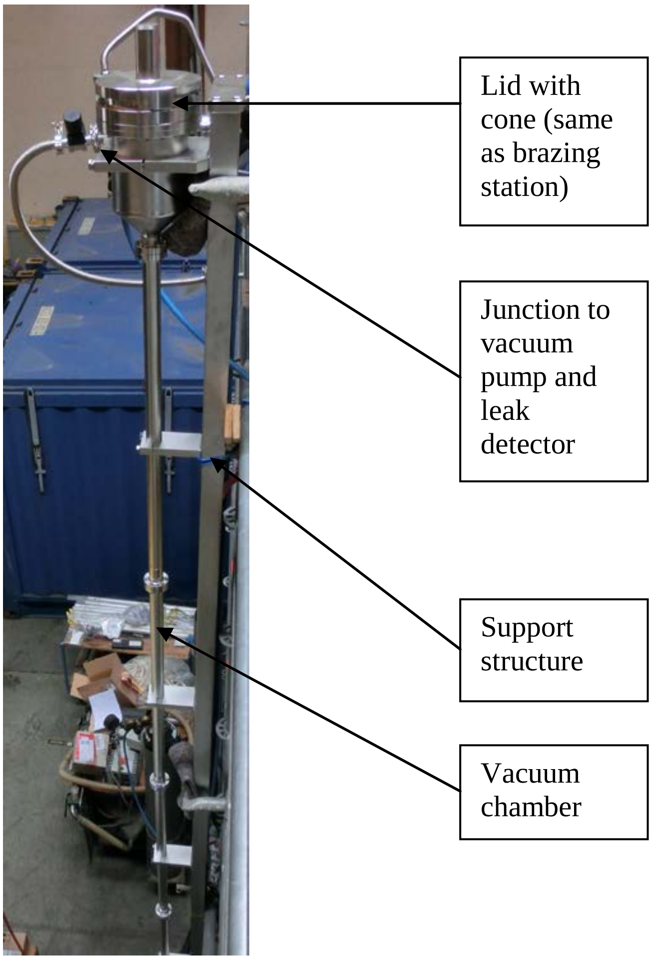

Figure 3 Testing station for the helium leakage test

BRAZING TESTS

Brazing tests were carried out in dry conditions as well as under water. The setup for the full size prototype is very similar to that one of the previous smaller model. The required power and time for heating are equal. Typical curves for the power and temperature measured at the brazing area of the tube are shown in Figure 4.

First the plug which has a depot of the brazing solder is heated up to approximately 1100°C. At a temperature of 1000°C the temperature stays constant for a short time. This indicates the melting of the solder. The further heating is required to ensure a complete melting and a good flow behavior of the liquid solder. After the brazing temperature is reached, it has to be kept for some time to guarantee the liquid flows over a sufficient area. The tests showed that the solder does not only flow down but also flows up driven by capillary forces.

All tests in dry conditions showed a high reproducibility of the quality and of the achieved leakage rates of the capsules. In all cases the helium leakage rate was well below the requirements for the transport.

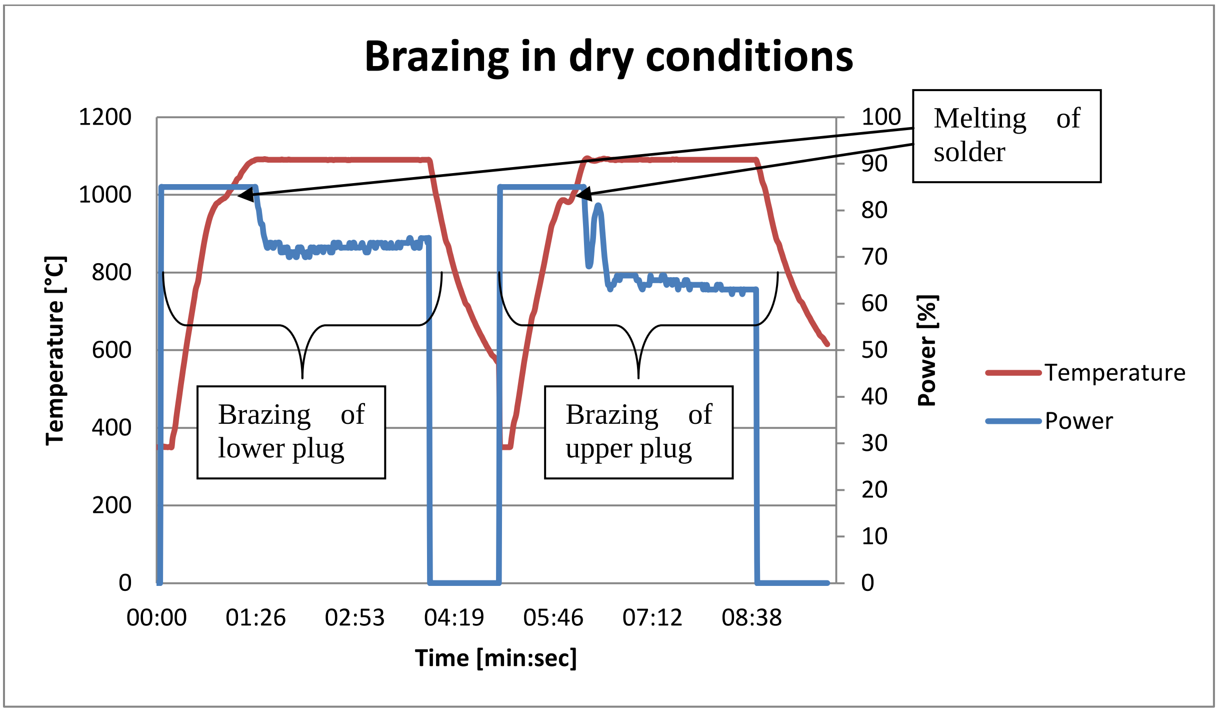

Figure 4 Documentation of brazing temperature and power, UBE in air atmosphere

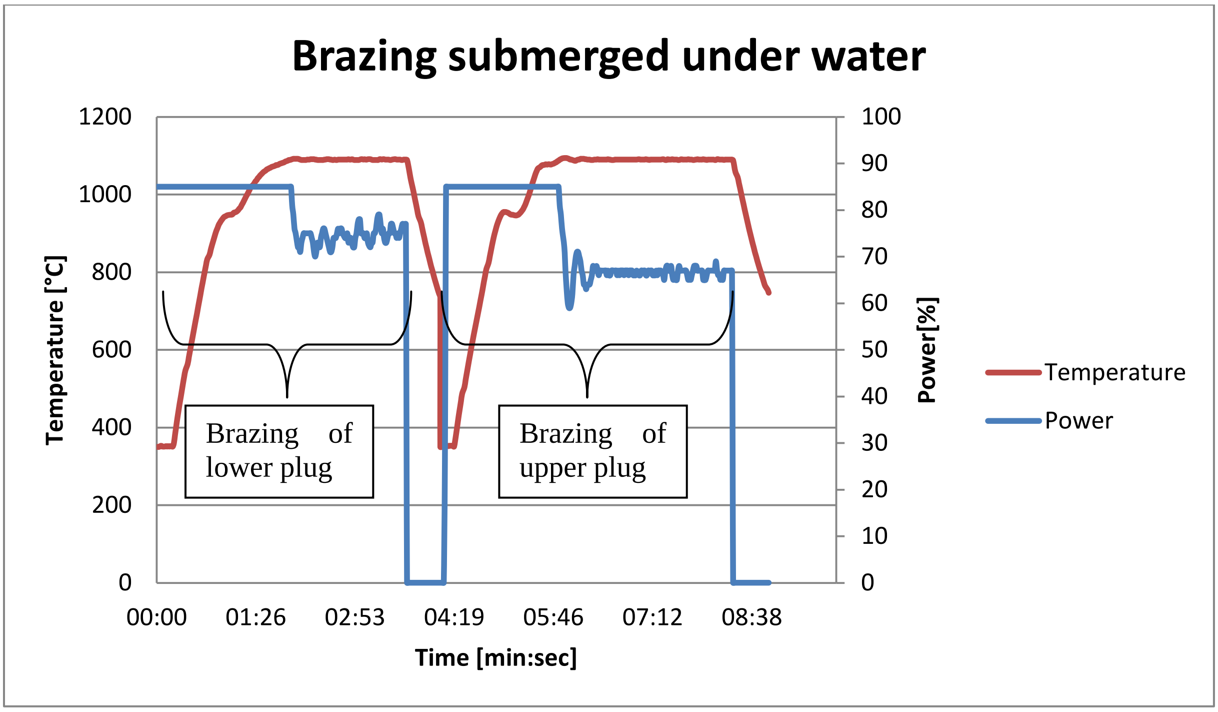

Figure 5 Documentation of brazing temperature and power, UBE submerged under water

Figure 5 shows the curves for temperature and power recorded at a brazing trial when the UBE was submerged under water. During these tests the lid of the brazing station was cover with approximately two meter water. The temperature curve is very comparable to that one in Figure 4 showing the behavior in dry conditions. This leads to the same brazing result. It was proven by the following helium leakage test. The capsules brazed under water showed no leak and have also the same leakage rate as the capsules brazed in dry conditions.

These tests showed that the behavior of the UBE is very similar under water and that the brazing under water is possible with the same quality requirements.

SCHEDULED OPERATIONS

The design of the UBE allows very flexible and different ways how to place the UBE in the pool of a nuclear facility. The following figures show different option how to put the UBE in the pool. The first solution used for the operation test in a pool was a hanging construction fixed at the balustrade of the pool. This solution allows the operation in conditions that are independent of the floor of the pool. Furthermore it has advantages concerning the tipping, buckling or earth quakes aspects. So it is possible to use a light construction in this way.

The second solution was developed for a nuclear power plant in Germany, where a cold handling trial is scheduled in autumn 2013. Here the UBE is put on the ground. Four independent feet allow the adjustment in case of unevenness of the floor. This rack has to be designed stronger (meaning it has a bigger mass) due to mechanical aspects but allows a very quick positioning of the UBE in the plant. Furthermore it has advantages regarding the flexibility of the positioning in the pool. Just an area of approximately 1.5 x 1.5 m is required, no wall of the pool, special attachment points etc. are required.

Figure 6 UBE hanging at wall of pool (before filling with water)

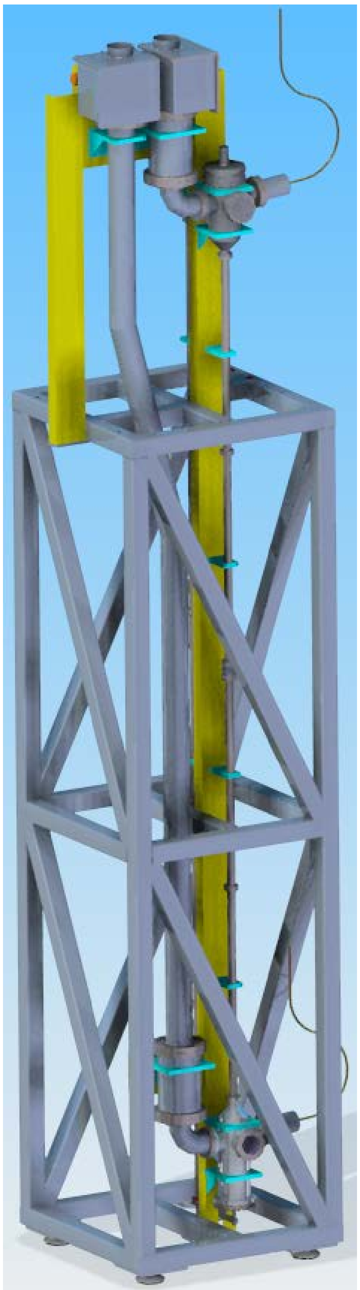

Figure 7 UBE in standing rack (will be used for cold handling trial this autumn)

SUMMARY

During the last three years the development of an Underwater Brazing Equipment was continued by DAHER-NCS. Based on the positive results of the smaller model successfully used for the qualification tests, a full size prototype was designed and manufactured. This prototype was tested in dry conditions as well as under water. The brazed capsules show reproducible results for both conditions and independent of the dimensions. The correctness of the brazing is controlled by temperature and power measurements during the brazing, conducted with visual controls with underwater cameras. After the brazing an integral helium leakage test is carried out on the capsule in a special testing chamber, which is part of the UBE. Helium leakage rates which are well below the requirements for the transport can easily be achieved.

The development of the UBE is nearly finished now. The next milestone will be the first operation in a nuclear power plant. The corresponding cold handling trial is scheduled for autumn this year, the first capsulation of fuel rods should follow during 2014 in the same power plant.

LITERATURE

1. **Stanke, Simon.** Encapsulation of Fuel Rods for Transport. *PATRAM 2010.*