IAEA-SM-286/156

QUALITY ASSURANCE ASPECTS OF THE FABRICATION OF THE AGN 1 CASK AND ITS TRANSPORT WITH SPENT FUEL

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Abstract

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The AGN 1 is the first cask for LWR spent fuel entirely designed and fabricated in Italy. The cask, made with a thick steel forging, has a maximum capacity of 7 elements; two ellipsoidal shock absorbers are connected to the ends of the body. The fuel elements are spaced and supported by a stainless steel basket provided with boron poisoned steel channels for criticality control. A finned water jacket is placed around the cylindrical surface to provide neutron shielding. Some of these aspects may be considered a completely new concept and design. The basic design of the cask was developed by AGIP and extended, through the detailed mechanical and thermal design to the stage of fabrication documents by the Nuovo Pignone Company, which is also the manufacturer. The most significant activities performed by Nuovo Pignone, with particular reference to quality assurance, are outlined in the paper. Since 1984, the AGN 1 has been in continuous use for the removal of spent fuel from the Trino Vercellese and Garigliano power plants to the storage pool at Avogadro. The transport campaign from Garigliano to Avogadro is performed by Borghi Nucleare, which was requested also to be responsible for the supply under proper quality assurance of all related services and engineering support. The AGN 1 non-stop transport from Garigliano to Avogadro, in fact, owing to the long distance to be covered, is one of the most demanding in Europe. In the paper, some of the most significant transport quality assurance aspects are summarized.

1. QUALITY ASSURANCE PROGRAMME FOR CASK FABRICATION

The design and fabrication of the AGN 1 transport cask obviously had to be subject to the quality assurance (QA) requirements set down in the IAEA Regulations and those indicated in the "Guida tecnica n° 8" issued by the Italian Nuclear Authority CNEN (now ENEA) and mandatory for all nuclear activities. In addition, the cask also had to comply with the regulations of the Italian Authority for Pressure Vessels ANCC (now ISPESL).

In this connection, the preliminary activities of the manufacturer Nuovo Pignone were devoted to establishing a job quality assurance programme in order to define tasks and responsibilities for the various quality related activities and to establish the number and type of technical documents to be produced to fulfil all governing requirements.

It was decided to extend the full QA requirements not only to the container itself but also to all its accessories, allowing a reduced quality level only for very few secondary components. This approach was possible since Nuovo Pignone could rely on an already active quality organization, but it raised a number of specific problems, mainly in the selection of new subsuppliers and the close supervision of these, and the need for radically new fabrication methods.

AGIP, and also the final user of the cask (ENEL, the Italian National Agency for Energy), together with the Competent Authorities were involved even at these early stages in the auditing of the Nuovo Pignone QA programme and facilities.

2. ENGINEERING

The basic design of the AGN 1 cask was carried out by AGIP. The detailed design was then done by Nuovo Pignone, still in close co-operation with AGIP. In particular, Nuovo Pignone developed the mechanical design of the containing system in accordance with ASME Code Section III and also with the ANCC Regulations.

At this stage, the involvement of the Quality Assurance Department of the Nuovo Pignone Massa plant, where the fabrication took place, greatly increased. Certain design arrangements or limitations, imposed by manufacturing techniques or by non-destructive test requirements, became evident during the preliminary joint review of workshop drawings, in particular those for the special jacket.

Naturally, all purchasing, fabrication and test activities needed to be covered by relevant documents, so that over 150 workshop drawings, 35 material purchasing specifications, 40 inspection/tests and fabrication procedures, 50 welding procedure specifications and 25 fabrication/inspection plants have been produced and reviewed by the QA Department.

Particularly in this early stage, interface activities with the QA Departments of AGIP and ENEL and with the appointed services of ENEA and ISPESL, in order to obtain their approval for the detailed project, were very important.

3. PURCHASING ACTIVITIES

The evaluation of the subsuppliers, within the Nuovo Pignone organization, is the responsibility of the QA Department alone.

For AGN 1 it was necessary to select new supply sources, as a result of the particular kind of materials to be purchased.

For the cask body, selection and audit were made of a steel manufacturer capable of producing a high integrity hollow forging, having a wall thickness of about 350 mm and a total length of over 4.5 m, inclusive of the extra length at both ends for destructive tests and additional sections to be utilized as a weld procedure qualification test sample at the Nuovo Pignone plant. This European manufacturer also had to be approved by ISPESL. The supplier's QA Programme was then positively reviewed and the supply was performed under the close control of Nuovo Pignone and with the participation of AGIP and the other involved parties at the established hold points.

Again, for the stainless steel plates (105 mm thick) for the jacket, ISPESL had to approve the supplier, and all activities were performed under the co-ordination of the Nuovo Pignone QA Department.

The choice of the supplier for the boron poisoned stainless steel plates for the basket channel fabrication was practically imposed, being restricted to only one company at the time, but anyway a stringent QA Programme was required and implemented.

The minor forgings and the bolting and carbon steel plates were purchased, still under the QA system, from habitual suppliers already approved by Nuovo Pignone.

The involvement of the Nuovo Pignone QA Department was very considerable in these purchasing activities, not only during the preliminary audits but also in the review and approval of the technical documents submitted by the suppliers, their approval by AGIP, ISPESL, ENEL and ENEA and, finally, the participation, direct and co-ordinated with all other parties in the most significant fabrication, inspection and tests stages at the supplier's facilities.

During these activities, about one hundred further technical documents (procedures, specifications, quality control plans, etc.) were reviewed.

4. SPECIAL PROCESS QUALIFICATION

Before the start of fabrication, qualification tests of special processes, specifically of the weld procedures, were carried out.

The most important weld in the project is the circumferential joint between the cylindrical body and the head. Nuovo Pignone already had experience with heavy wall butt welds but this was, and remains, the maximum thickness ever welded. For the qualification of this procedure it was decided to use a full scale test sample from the actual material, obtained from the same body forging. The bevel preparation adopted for the joint, that is a narrow gap with nearly parallel edges, was aimed at reducing the amount of filler metal and making it possible to weld almost completely from the outside in order to minimize difficulties resulting from reduced internal accessibility and increased by the preheating conditions. The weld was carried out by the multipass submerged arc procedure using a special weld machine head specifically developed in order to assure the correct positioning of the wire inside the groove.

The test sample was then subjected to the same non-destructive examination (NDE), stress relieving heat treatment, and final NDE as provided for the production weld joint. All destructive tests in accordance with ANCC Regulations and AGIP additional requirements, for a total of 120 specimens, were carried out with widely satisfactory results.

The other type of welds, even if Nuovo Pignone already had experience of them, were requalified for the job.

5. MAIN FABRICATION STAGES AND RELATED PROBLEMS

The maximum care and surveyance were exercised during the welding of the main joint in the body. This required over 115 hours of uninterrupted work in the presence of representatives of all participating parties in continuous shifts. A good weld result was essential, especially to avoid repairs that would be very critical.

The machining to obtain the finning of the jacket from the barrels fabricated by rolled plates was done in the Nuovo Pignone Florence plant which is equipped with very accurate machine tools (being a well known manufacturer of turbines, compressors and pumps).

The machining of the basket baffles was also performed there.

In order to solve certain problems related to the tight tolerances imposed by the project it was necessary to plan an adequate sequence of positioning of the pieces on the machines and to provide special fixtures in order to control the deformations during the machining itself – not only those due to the natural elasticity of stainless steel but also those due to the amount of removed material.

As an example, for obtaining the holes for fuel channels and for the tie-rods in the basket baffles, it was necessary to remove about 80% of the material. In this case, the need to respect the necessary out-of-plane tolerance by adopting adequate sequence made it necessary in view of the shape of the pieces and the surface finishing conditions to utilize different kinds of machine with different positionings.

Specific problems occurred in the production of the seven basket channels fabricated with stainless steel boron poisoned plates 6 mm thick. The three central channels were made of four plate strips welded together at the corners to form a

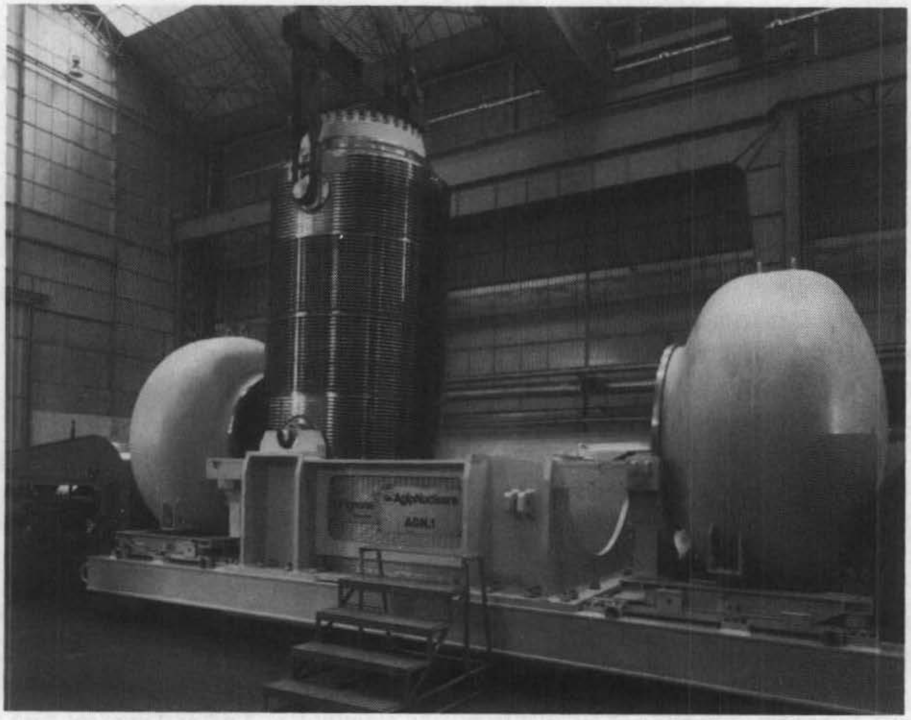

FIG. 1. Handling test at the Nuovo Pignone workshop.

square hollow parallelepiped. The remaining peripheral channels were made by a strip bent to form two sides, and welded to another two flat strips to form a pseudo-square section parallelepiped.

The special design of the basket, which was made by mechanical assembly of all the components without any welded joints in order to allow easy eventual replacement, required the channels to comply with very tight geometrical and dimensional tolerances. The distortion during both bending and welding had therefore to be limited as much as possible.

The first problem was solved by utilizing oleodynamic equipment especially designed to balance the bending effect during forming. The second problem was solved by using pulsed-arc TIG (tungsten inert gas) welding with filler metal and by providing inside the channel a special cooling fixture for quick heat removal.

A simulated test of inserting the fuel elements into each channel was performed using a mock-up reproducing the size and weight of one element connected with a dynamometer with a digital indicator.

The assembling of the finned jacket, made up of four barrels, closed by two forged rings at each end and supported by intermediate stiffening rings, required a particular sequence to reduce the deformations for weld shrinkage.

All the main weld joints in the jacket are butt welds and were fully radiographed.

Both cask cavity and neutron shield have passed the hydrostatic tests required by ANCC regulations. The tightness of all gaskets was checked by a helium leak test with a mass spectrometer in the plant.

In order to measure the maximum steady state temperature reached during transport by the accessible outer surface and to verify that it does not exceed the value imposed by the IAEA, a thermal test was conducted on the cask.

The dimensioning of the fins had already been verified by the Nuovo Pignone Research Department by tests on a full scale mock-up, and the same Department also carried out a thermal test on the completed cask. The thermal test was performed by heating up the cask with two electric resistances having a total thermal power of about 22 kW inserted into the cavity. The cavity and the jacket chamber were partially filled with water and the power was progressively increased up to the maximum value. The total time of the test was over three weeks, during which continuous readings of temperature, as measured by several thermocouples, were made.

At the end of fabrication, all the functional and handling tests were carried out. These, included positioning of the cask on its transport saddle, clamping and moving out of shock absorbers, rotation and lifting of cask (see Fig. 1).

In early 1984 the cask was consigned to the customer and the user, together with the relevant records of all quality related activities, as a natural consequence of the QA programme implementation.

6. GARIGLIANO TRANSPORT CAMPAIGN

The AGN 1 is now employed in an intensive way for the transport of Garigliano irradiated fuel elements (see Fig. 2). The programme for decommissioning of the plant foresees that all the irradiated fuel elements (more than 320) must be transferred from Garigliano, 200 km south of Rome, to the storage plant at Avogadro in the north of Italy. The ENEL entrusted Borghi Nucleare SpA, a qualified Italian firm operating in the field of radioactive material transport for more than 20 years, with the task, including the supply of all the related services and engineering supports in accordance with the QA requirements. The transport campaign perhaps is one of the most arduous ever undertaken in Europe owing to the number of transports to be carried out without stops, the distance to be covered (more than 900 km each time) in all weather conditions and the rhythm of the campaign. The ENEL requested that QA procedures and methods be used for the following reasons:

(1) The IAEA Regulations for the transport of radioactive material are orientated towards the idea of managing this activity, as well as all nuclear ones, by applying QA;

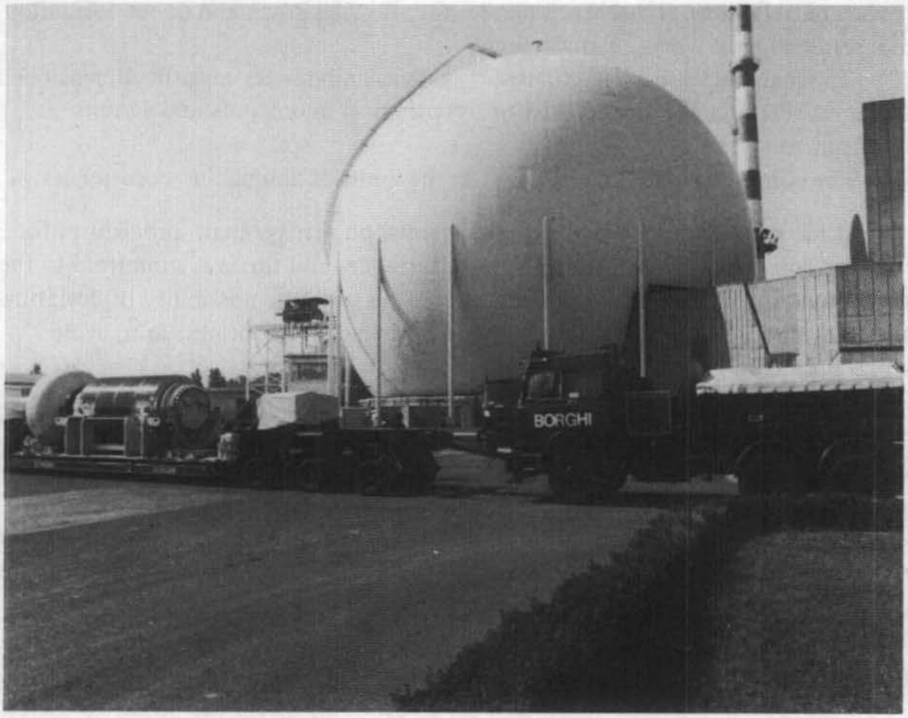

FIG. 2. Borghi convoy at Garigliano power plant.

(2) It is necessary to carry out a considerable number of transports without stops and to guarantee always that the high safety standards requested be met.

The Borghi's convoys for the transport of the loaded cask include: a special bogie hauled by a Fiat IVECO truck, an identical Fiat IVECO truck as escort, a workshop vehicle and a laboratory vehicle. The laboratory has a full set of tools and instruments for monitoring and measurements, and radioprotection and health physics interventions in emergency cases.

Borghi began to introduce QA in its own activities in 1976 and therefore had a QA programme in operation before the Garigliano campaign. However, the campaign required the implementation of special QA activities in some particular areas, namely: staff training, management procedures, the supply of vehicles and safety and intervention devices in the event of an emergency, and the controlled management of vehicles, devices and all pertinent spare parts. The transport engineering was based on three criteria:

(1) The loaded AGN 1 cask must be transported from Garigliano to Avogadro without stops, including those which could be due to anomalous occurrences

(mechanical failures, accidents along the way, slowing down and queue formation as a result of road works, bad weather);

(2) The main and subsidiary transport systems and devices must be dimensioned to be reliable and able to be used in hypothetical anomalous and serious occurrences.

(3) The convoy must be independent in the event of anomalous occurrences.

It has been necessary to draw up a manual on management procedures for intervention in the event of anomalous occurrences and this was submitted to the competent authorities. The document also deals with the possibility of deviating the transport along pre-arranged alternative intersecting routings, so to avoid stops and slowing down due to any reason.

The itineraries were chosen with due consideration given to the loads caused by the transport vehicle (about 140 t) on the structures along the way and the desirability of avoiding inhabited areas and roads carrying heavy traffic. The vehicles were manufactured especially for the Garigliano campaign with appropriate QA applied. In particular, the transport bogie is the first example in Italy of a vehicle mode with qualified welding procedures, qualified welders and also with materials certified after qualification of the manufacturer by Borghi.

All the structural welds have been tested by magnetic examinations and special impact tests have been requested on the materials.

Finally, the use of the vehicles, the equipment, the spare parts and the radioprotection apparatus is in compliance with duly drawn up procedures.

Proper forms and checklists filled in by qualified staff at the beginning of and during each transport, allow the resolution of any non-conformity which may occur.

7. CONCLUSIONS

It is difficult to deny that some time delay in the design, fabrication and testing of a spent fuel transport cask such as the AGN 1 is unavoidable if QA procedures are followed at each phase. There is also no doubt that some increase in costs occurs. In addition, more people and more organizations are involved in reviewing, checking and testing everything, and putting them together at the proper time and place is often a hard job for the QA service and the manufacturer. Delivery time and costs seem to suffer too from the application of QA requirements.

Another consequence of strict QA procedures is an increase in the amount of paper!

On the other side, one could ask what actions required by QA criteria could be omitted in such a safety-related job. The answer to that question is probably that the design, fabrication and transport work would certainly require the application of QA, even if we called it by another name.