MANUFACTURING OF A NEW TRANSPORT CASK FOR MOX AND UOX

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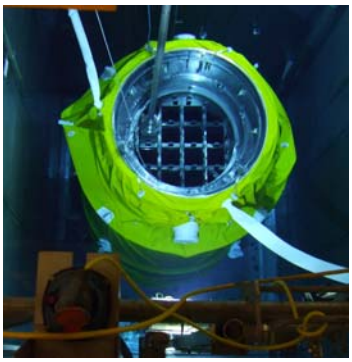
ABSTRACT

TN International has design a new cask TN®112 for transport used MOX or U02 assemblies for PWR power plants. The capacity of this unique cask is 12 fuels. A mix of the two types of fuels in any proportion can be loaded. Its heat load can reach 50 KW with a total maximum weight of only 114 t. A B(U) type approval according to AIEA 2005 has been granted. It is intended for the transport between 900 MW reactor plants and La Hague AREVA NC reprocessing plant. The first cask is already in operation and the second unit of the fleet is in construction. The high level of performance has been achieved thanks to very specific materials such as: high strength forged austenitic stainless steel, reinforced gamma shielding materials, TN Vyal B™ resin for neutron shielding, soft aluminium for shock absorption and aluminium metal matrix materials as neutron absorber. The most significant step of the manufacturing are addressed in this paper such as preparing the technical specification, procurement of the main materials, destructive and non destructive testing, special process qualification, welding and assembly, final tests, quality surveillance.

INTRODUCTION

In order to optimize the logistics related to transport of used MOX and U02 fuel between the French 900 MW reactor and AREVA La Hague reprocessing plant a new cask call TN®112 was designed and manufactured by AREVA TN International (see figure 1).

Maximal thermal power:
50 kW (4,16 kW /assembly)
MOX enrichment : 9.3 %
Maximal average burn-up :
50 000 MWd/tU
Figure 1 TN®112 in operation



The manufacturing of the first cask started in 2005. 3 years was necessary to complete this phase of the project which was performed in parallel to the licensing. A B(U) type certificate according to AIEA 2005 has been granted in France (F/396/B(U)F-96 (Aa)). Manufacturing was divided in the following sub-phases: preparation of the technical specifications, procurement of the mains materials, destructive and non destructive tests, special process qualifications, welding operations, assembly and final tests.

PREPARATION OF TECHNICAL SPECIFICATION

The manufacturing manager in charge of the technical specifications is using three main inputs coming from the Safety Analysis Report. The first one is the concept drawing, the second one is the cask description with the material characteristics and the third one is the part list with the level of control associated to each part. Four levels of control are used. Highest level of control is 1 and the lowest is 4. In order to insure the conformity to the license, the specifications are checked by the design Manager. He makes sure that all the requirements from the Safety Analysis Report are integrated in the specifications.

The number of specifications and the scope of each of them are directly link to the procurement strategy. In order to clearly define the supply to be performed by the vendor, it is necessary to prepare manufacturing drawings associated to each specification. The ones dealing with forgings are the first to be prepared. It is necessary to have one per steel or aluminium grade.

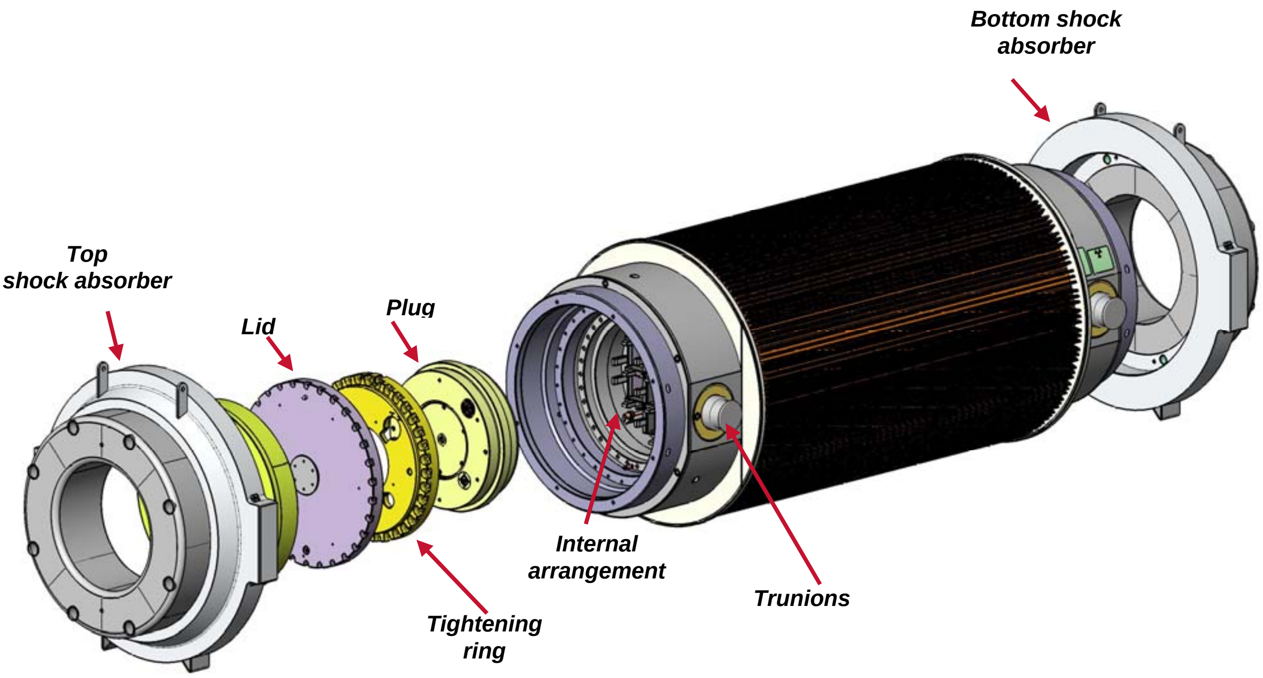


Figure 2. Main components of TN®112

PROCUREMENT OF THE MAIN MATERIALS

The main constrains on the base metal for the primary and secondary containment are linked to the risk of brittle fracture and the representativity of the drop test mock-up. A stainless steel austenitic grade was selected in order to guarantee no risk of brittle fracture at -40°C. The advantage of this solution is to avoid very long and complex demonstration associated with the brittle fracture analysis of ferritic carbon steel materials. For those materials, toughness at -40°C in dynamic conditions is a key issue as well as the plastic deformation in the 9 m drop conditions.

For the stainless steel forging material the greatest challenge is the selection of a grade of steel. The tensile properties at maximum working temperature of 200°C shall be better than the properties of the mock-up during the drop weight test at room temperature. To solve this tricky equation, it was necessary to perform a mock-up with restricted mechanical properties and a cask with very good mechanical properties. The specification for the mock-up forging was a quite unique requirement for the forge masters since they are normally trying to out perform the mechanical properties specified in the standard for a given grade. For the full size cask forging, in order to guarantee adequate mechanical properties, a high strength austenitic steel grade is used (see figure 4 mechanical properties)

Due to the maximum weight constrain, a high density gamma shielding material was developed (patent application N° WO 2008/125409). It is fitted between the primary and secondary containment in order to guarantee adequate shielding. The new material is made of lead matrix reinforced with perforated high strength steel. The reinforcement is used to avoid plastic deformation at the maximum service temperature 200°C. It is placed in the axial direction to prevent lead stellment in the 9 m axial drop conditions. The risk that the lead might fill the radial gap necessary for thermal expansion and generates a lost of radial shielding is prevented with this material.

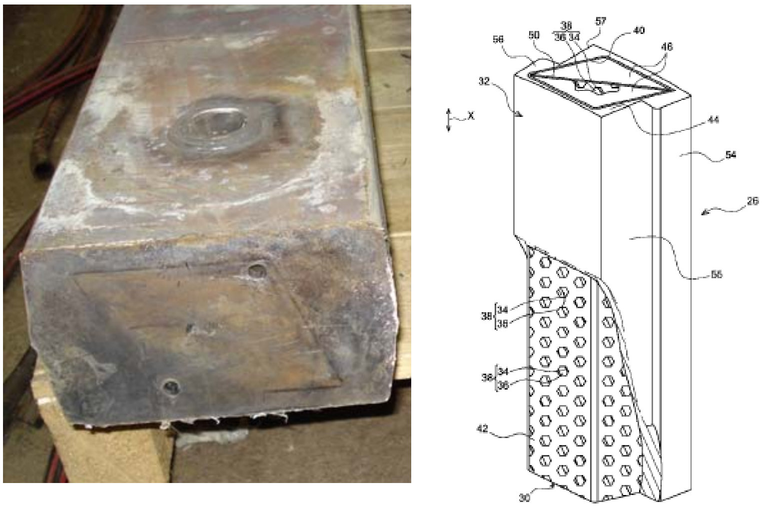


Figure 3. Reinforced Lead for gamma shielding

SPECIAL PROCESS QUALIFICATION

The TN Vyal B^{TM} resin with optimized shielding properties and enhanced thermal properties was selected (patent application N° WO 03/050822). The hydrogen content is **5,1 10^{22} at/cm3** and boron content is **8,7 10^{22} at/cm3.** The maximum service temperature of this resin is higher than the resin TN12 and resin F. The chemical stability has been improved thanks to the used of a new resin for the matrix. The fire resistance properties are excellent. It is classified M1 (self extinguishing) according to NF P 92-501 and F0 (toxicity of the smoke gases) according to NF F 16-101.

Table 1. Characteristics of neutron shielding materials

TN Neutron shielding materials	TN12	F	TN Vyal B^{TM}
H 10^{22} at/cm3	4,3	5	5,1
B 10^{22} at/cm3	9	9	8,7
Density	1,45	1,8	1,8

The TN Vyal B^{TM} resin is designed to be poured in situ. Mineral fillers (alumina hydrate and zinc borate) are mixed with the organic thermoset resin (Vinylester resin and styrene) in a tank. Degassing of the mixing is performed prior to pouring. Cross linking reaction is obtained by the addition of the catalyst (organic peroxide). Thanks to pneumatic pumps the resin is poured in the resin compartment of the cask. Since the chemical reaction is exothermic, the resin hardened and then shrinks during the cooling phase back to room temperature. The shrinkage provided gaps for the thermal expansion at the maximum operating temperature.

The pouring process was qualified on a mock-up representative of 3 compartments of the cask body. The dimensions of the compartment including the length were fully representative. After pouring the mock-up the shrinkage gaps were measured. Then the mock-up was sawed in order to performed visual examination of sections and to check the homogeneity of the density along the length.

The resin pouring in the compartment is performed by qualified operators. Qualification process is performed by a technical centre according to well defined procedures.

For welding the different forging components of the primary and secondary containment in high strength austenitic grade a specific welding procedure has been developed according to ASME IX. The base metal of the qualification welding coupon was forged using material of one of the heat used to forged components of the first cask.

DESTRUCTIVES TEST

On the primary and secondary containment high strength austenitic forging, integral mechanical destructive test samples on each forging are required. Tensile test at room temperature according to the grade of steel standard and additional hot tensile test are specified. At the same location impact test specimen 10×10 are also taken for test at -40°C. The tests were performed according to ASTM A370. The hot tensile test results at 200°C are presented in figure 4.

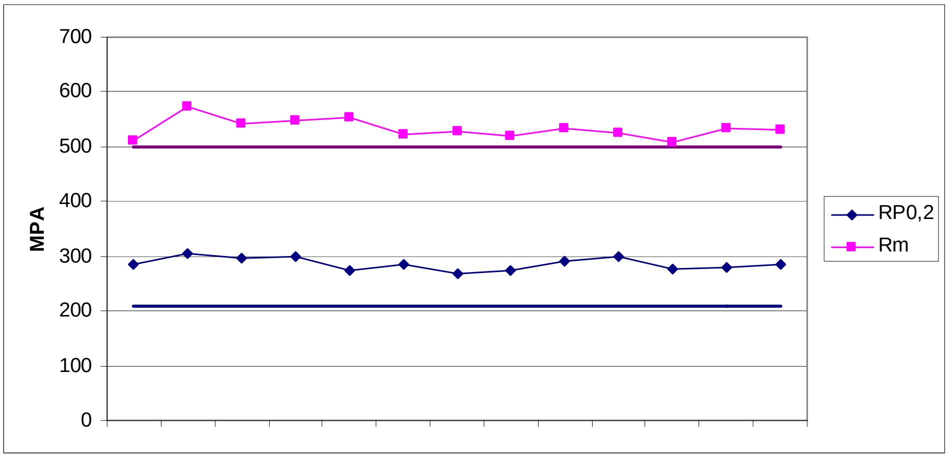


Figure 4. High strength austenitic forging tensile test results at 200°C

For aluminium forging used as shock absorbing material, integral tensile test samples are also used. Unique restricted tensile test properties were achieved by the forge master. Specific properties for $R_{p0,2}$, Rm and A% were selected to reduce the acceleration range cause by the dispersion of the tensile properties. Maximum and minimum values for those characteristics are defined in the safety analysis report.

The neutron absorbing material for the internal arrangement is **Alcan's Al-B_4C** Metal Matrix Composite (MMC). Fine boron carbide (B4C) are incorporated in aluminium alloy metal matrix. B4C is incorporated in liquid aluminium. The fraction of boron carbide powder is adjusted to achieve a minimum ^{10}B density equal or above **46.17 mg^{10}B/cm^3**. Then casting of the primary metal into logs is performed. Each log is then cut into billets which are extruded in profiles to the required thickness.

Figure 5 . Internal arrangement

Areal density Distribution of ^{10}B/ cm^2 in the profiles is checked by transmittance measurements. For each extruded length a neutron inspection coupon is prepared. The Sample showing the worst area density from neutron transmittance is tested with thermal ion mass spectrometer in order to determine the minimum actual ^{10}B content in the profiles used for the internal arrangement.

Since the design takes credit of the neutron absorber material as a structural component, the high mechanical performances are check with an extended testing program. Samples are taken from each extruded length for tensile testing.

NON DESTRUCTIVES TEST

On the primary and secondary containment forgings, trunnions, bolts volumetric tests by ultrasonic examinations and surface crack examinations by penetrant tests or magnetic test are performed. For all this examination surveillance is performed by TN Inspectors in order to ensure a very high level of quality. Quality level 3 according to EN 10288-4 is required for UT examinations of high strength austenitic forging. The DGS method is used.

For the primary and secondary containment welds the ultrasonic testing is done with acceptance level 2 of EN 1714. For the penetrant tests for those welds conformance to EN1289 level I is required.

The factory helium tests are realized by helium mass spectrometer in accordance with EN 13185. Containment welds and gaskets are helium tested and also resin casing.

FINAL TESTS

When all the individual cask components are finished, several weeks of factory tests are necessary. First of all dimensional test are finalized and the “As built” drawings are prepared with a special attention to the safety relevant dimensions. The final test phase includes: trunnion load test, hydro test, draining test, operational test with orifices connecting tools and skirt, interface tests (assembly and disassemblies of the removal components : plugs, lid, tightening rings, orifices plates, bolts, shock absorbers), leak tightness test, thermal test.

QUALITY SURVEILLANCE

For TN®112 the standard TN International quality surveillance system is used. The monitoring of the quality of the manufacturers starts with the review of the manufacturing documents issued by the suppliers. The manufacturers submits its purchasing specification, its quality plans (list of manufacturing and control operations), its welding procedures with the supporting qualification records, its coating procedures, its control procedures (nondestructive test (PT, UT, HT, VT,…) dimensional test, load test…) for approval. The list of the subcontractors from the supplier is also checked and approved by the Manufacturing Manager.

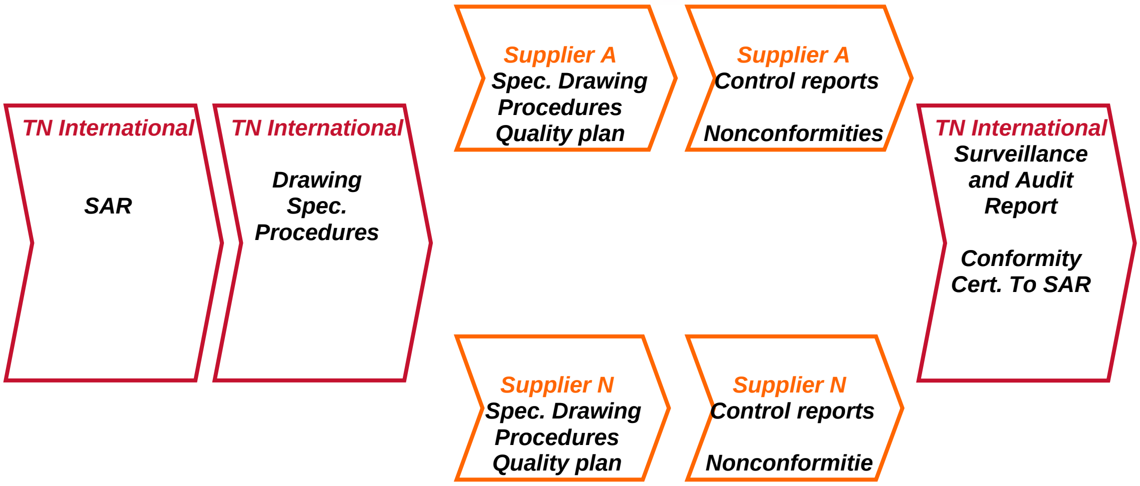


Figure 5 . Quality documentation flow chart

When the documentation is approved the supplier is able to start the work. The supplier quality departments are performing the control operations indicated in the quality plans. They shall be independent from the manufacturing. The inspector is in charge of the surveillance of the operations for which TN International requests hold points or witness points in the quality plans. The control is performed by the manufacturer as far as possible before the visit of the TN International inspector. On the day of the inspection the inspector requests spot checking. Of course this option is not possible for some tests like destructive test, load test, helium test, interface test, etc.

During the manufacturing TN International is auditing the supplier or even its subcontractors if they are supplying a component with control level of class 1 or 2.

In case of a nonconformity corresponding to contractual requirements, the supplier is submitting a non conformity sheet to TN International for assessment.

At completion of the manufacturing after all final tests, the inspector is checking the correctness and completeness of the manufacturing data records (quality plans, material certificates, control records, special process records (welding, Heat treatment, coating, etc.) non-conformity status).

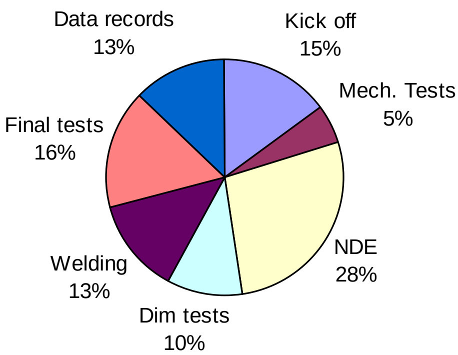


Figure 6 – Distribution of the surveillance

More than 140 days of on site inspection in the suppliers shop insure a high level of quality.

CONCLUSIONS

TN®112 is a unique cask with a capacity of 12 MOX or U02 assemblies for PWR power plant for which a B(U) type approval has been granted according to AIEA 95. New technologies were necessary to achieve this high level of performance. New materials have been developed specifically such as high strength forged austenitic stainless steel, reinforced gamma shielding materials, soft aluminium for shock absorption. It benefits from advanced solutions from TN International such as TN Vyal B™ resin for neutron shielding and aluminium metal matrix materials as neutron absorber for internal arrangement. The high level of quality is based on the ISO 9001 certification of the main suppliers, their quality control independent from the production, the quality audit and the surveillance by TN International of the manufacturing and control operations.

REFERENCES

ASME IX – qualification standard for welding and brazing procedures, welders, brazers and welding and brazing operators.

ASTM A 370 – Test Methods and definitions for mechanical testing of steel products

EN 10228-4 – Non destructive testing of steel forgings – Part 4 Ultrasonic testing of austenitic and austenitic-ferritic stainless steel forgings.

EN 1714 – Non destructive examination of weld - Ultrasonic examination of welds

EN 1289 - Non destructive examination of weld – Penetrant testing of welds - Acceptance level

EN 13185 - Non destructive testing – Leak testing – Tracer gas method.