A High Capacity Storage Cask

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INTRODUCTION

Nuclear Assurance Corporation has designed a high capacity storage cask, which was built by Hitachi Zosen of Japan and delivered to Virginia Power Company. The NAC S/T cask can store 28 canisters of consolidated fuel or 28 intact assemblies with burnup credit. The basic design was approved for storage of 26 intact assemblies by the U.S. NRC on March 29, 1988, and approval for storage of 28 consolidated fuel canisters is imminent. A Topical Report submittal for storage of 28 intact assemblies is scheduled for November, 1988. The cask design permits considerable flexibility in that the same cask body can be used to store 26, 28 or 31 assemblies, or 28 canisters by changing the removable fuel basket. A drawing of the cask is shown in Figure 1.

CASK DESIGN FEATURES

The NAC-S/T cask is a lead/steel multiwall design based on previous transport casks. The multiwall design offers good resistance against missile impacts and puncture accidents, and results in a strong containment wall. The multiwall design also offers efficient shielding and reduced weight compared to single wall designs. The cask has a solid neutron shield to remove any need to monitor the shielding during a planned 20-year storage lifetime. The neutron shielding is a thermal insulator so 24 steel/copper fins penetrate the shielding to provide thermal conduction. Metallic seals are used for the cask cavity closure lid and valve port cover lids to ensure seal integrity over long periods.

MANUFACTURING CONSIDERATIONS

The production of the cask presented several significant problems, which Hitachi Zosen overcame, especially in the manufacture of the close tolerance fuel basket and in the pouring of the lead gamma shield and the Bisco NS4FR solid neutron shield.

FUEL BASKET CONSTRUCTION

One of the unusual features of the NAC S/T cask is the removable fuel basket, which is designed to contain 26 to 31 fuel assemblies or 28 consolidated fuel canisters, within the limited cask cavity of 64.49 inches in diameter. Four methods were considered for the construction of the fuel basket:

i) Plates are assembled to form a lattice as a load bearing structure and neutron absorbing materials are fitted at appropriate locations for criticality safety.

ii) Square tubes, each of which will contain a single fuel assembly or single consolidated fuel canister, are assembled as a load bearing structure and neutron absorbing materials are fitted as appropriate to the outside of the tubes.

iii) Square tubes, which are both structural members and neutron absorbers, are assembled into a load bearing structure. (This option is used in the NAC-31 S/T version.)

iv) A casting is made to form the basket structure, with integral neutron absorber in the casting or additional neutron absorber plates attached to the casting.

For the first unit of the NAC S/T cask containing 28 consolidated fuel canisters or 28 intact assemblies, method (ii) was developed as described below. First, manufacturing technology for a close tolerance aluminum square tube was developed in cooperation with an aluminum supplier and a square tube fabricator: round tubes were manufactured to a very close tolerance in diameter and thickness and then extruded to the dimensional requirements of the square tube. Next, the tubes were fitted with borated aluminum sheets with a 4.4 weight percent enriched B-10 content for criticality safety. The neutron poison sheets were developed by Eagle-Picher Industries to a 0.102±0.005-inch thickness and neutron scanned at the University of Virginia to verify the B-10 poison content. The tubes were assembled one by one to the design while restricting deformation of the assembly by means of special jigs. After the tubes were assembled, each tube was dimensionally checked with a through-gauge. The indented corners of the tube assembly were filled with aluminum castings for better heat transfer between the fuel basket tubes and the inner cask shell. Finally, both ends of the basket assembly were fitted with aluminum grid plates and the exterior surface of the resulting cylinder was machined to a total diametral tolerance of 0.030 inch. The manufacturing methods described above were verified by a mockup test: a full length, 90° quarter section was manufactured to the design, and the tolerances determined.

CASK BODY AND LEAD POUR

The NAC S/T cask has a multiwall design with relatively close tolerances, and the pouring of the lead gamma shield was complicated by the need to allow differential thermal expansion of the cask inner and outer structural steel shells. This was accomplished by welding the shells to the upper end forging and pouring the lead from the cask bottom. The technology for pouring the lead was developed by the manufacture of the HZ-75T Spent Fuel Shipping Cask, which is very similar to the NAC-S/T cask in construction. The shells were spaced at the open bottom end by formers, which were removed after the lead pour so that the bottom could be welded on. The steel shells were preheated to 600°F before the lead pour to minimize thermal stress and prevent the formation of voids in the lead. The lead was cooled progressively after the pour with a water spray to ensure uniform lead solidification. After the lead pour, a full surface gamma scan was performed using a Co-60 source and NaI scintillation counter to ensure that the minimum lead thickness was present with no voids. The integrity of the steel shells and lead shield were further verified by a thermal test, seal leak tests, and handling tests.

SOLID NEUTRON SHIELD

A solid neutron shield of borated Bisco NS4FR high hydrogen fire retardant neutron shield material was cast, also from the bottom end of the cask. The NS4FR material is a poor thermal conductor, so fins of copper/steel sandwich are welded to the outer steel shell and enclosed in an exterior 0.25-inch stainless steel skin. The fins were fabricated by Hitachi Zosen by explosion bonding sheets of 0.25-inch copper to sheets of 0.25-inch stainless steel. The copper acts as a thermal shunt across the fin and must extend essentially from the outer stainless shell to the exterior stainless skin of the neutron shield to be effective. The stainless portion of the fin allows simple welding of the fin to the outer stainless structural shell and the exterior skin. The explosion bonding of the copper and steel guarantees that the bonding is permanent and avoids concerns that the fin efficiency might degrade over the 20-year cask design life. The fins are angled at 60° to the shell surface to minimize neutron streaming. The Bisco NS4FR was stirred to ensure mixing of the materials, and vacuum defoamed to prevent voids during the pouring process. A mockup of the neutron shield including the copper/steel fins was used to verify the shield pour procedures prior to casting the large volume of material needed for the cask. Samples of the NS4FR were taken during the neutron shield pouring to ensure the minimum density and associated hydrogen content, and even distribution of the 0.6 percent B_4C. A thermal test of the cask body was performed to ensure that the copper/steel fins were installed and functioning properly.

CONCLUSION

The design of the NAC S/T cask offers versatility with a removable fuel basket, which can accept intact fuel assemblies or consolidated fuel canisters. The lead/steel multiwall design provides a strong containment system with efficient shielding yielding high capacity. The fabrication of the NAC S/T cask required development of new technologies to employ the new enriched B-10 criticality poison sheets and the explosion bonded fins in the neutron shield, but nevertheless the cask was completed in one year and one month from the receipt of the cask order by Hitachi Zosen. The close manufacturing tolerances and exacting lead pour requirements have advanced the state-of-the-art for large multiwall steel casks.

REFERENCES

1. Project No. M-40: Safety Analysis Report (Revision 2A) for the NAC Storage/Transport Cask for use at an Independent Spent Fuel Storage Installation.

2. N. Niomura et al, Fabrication Experience of HZ-75T Spent Fuel Shipping Cask, 6th International Symposium on Packaging and Transportation of Radioactive Materials, 1980, pages 842-848.

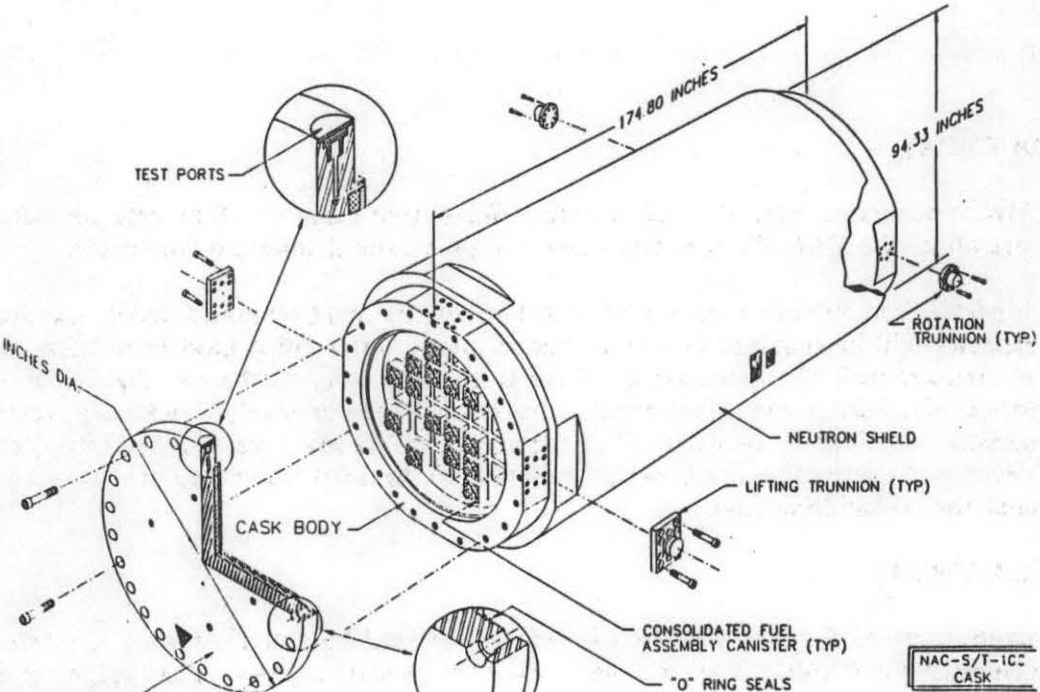

Figure 1 NAC S/T Cask