DESIGNING OF SOURCE CONTAINER FOR GAMMA IRRADIATION CHAMBER UNIT

Primary shielding material of this source transport container is generally lead (Pb) which is completely encased and seal welded inside a material whose melting point is above 700 ^{o}C. Depleted Uranium (DU)/tungsten can also be used for primary shielding. In case of DU appropriate cladding should be provided over it to prevent degradation of the material due to oxidation and hydride formation. The combination of all these materials (Lead, Depleted Uranium / Tungsten) can also be used as primary shielding material for the construction of source container of GIC.

Design and fabrication guidelines with respect to certain critical components/sub-assemblies of source container of GIC are as follows:

A.1 Outer Shell Encasement Thickness

The recommended minimum outer shell encasement thickness for lead –in-steel container may be calculated by the following equation:

$$t_{os} = 1.3\ (w/s)^{0.71}$$

where:

t_{os} = Outer shell thickness of container in mm, w = Total mass of container in kg,

s = ultimate tensile strength of encasement material in MP_a,

(1MPa = 0.102 kgf/ mm^2, i.e. kilogram-force/square millimeter)

Note: (i) The above thickness is to be multiplied by a factor 1.3, when diameter of container is less than 760 mm (30 inches), and

(ii) Ultimate elongation of the encasement material should be greater than 40%.

A.2 Inner Shell Thickness (t_{is})

Thickness of the inner shell cavity of source container which houses radioactive material should be calculated and established carefully such that the inner shell cavity remains serviceable under all expected external and internal loads.

External loads are imposed due to:

(a) static head of molten lead during pouring,
(b) the shrinkage of lead upon cooling, and
(c) expansion of lead resulting from a fire, or displacement of lead as a result of impact.

Whereas the internal loads occur possibly from the thermal expansion of internal components such as source cage or basket etc.

In view of the above, the inner shell thickness of the source container should be designed as if it were an unfired pressure vessel and meets, as a minimum requirements of Division

1 of Section VIII of the ASME Boiler and Pressure Vessel Code. This Code relates size, material of construction, and internal and external pressures to thickness.

The inner shell thickness so derived from the above considerations should have a minimum thickness equal to that of outer shell thickness due to its service conditions and other fabrication criteria such as for preparation of weld joints particularly that for corner joints which have been found to be most vulnerable from development of gross crack during 'Mechanical Test' (9 meter drop test followe d by 1 meter puncture test) for Type B package.

A.3 Encasement Penetration

When lead is encased in steel, it is recommended not to carry out any tapping or drilling holes into the encasement without providing suitable size welded backing steel material, so that molten lead does not flow out from the container as a result of any fire.

A.4 Tubes through Encased Shielding

Access tubes or drain tubes which pass through any encased shielding should be seal welded to the encasement and should have a wall thickness which is at least 5% of the tube outside diameter. The orientation of access tubes or drain tubes passing through the shielding material inside the source container should not have a straight path; it should have a zigzag path, so as to restrict the leakage radiation levels on the outer surface within the permissible limits.

A.5 Dished End for Corner Welds Joints of Encasement

Most vulnerable weld joints are corner welds joining the shells to top and bottom plates of the container. During the mechanical test (9 meter drop test and 1 meter puncture tests) of Type B package, these welds are required to bend or rotate through an angle of 90^0, which may result in developing a gross crack unless the corner is adequately designed.

In view of this it is recommended to remove the weld joints from the vulnerable areas by using a dished or formed head in place of a flat plate for ends of the container. The design of other welded joint that is not a part of the container assembly, should be carried out based on sound engineering practices.

A.6 Container Closure Lid (Lead Plug) & Closure Bolts

The primary functions of a closure lid or lead plug is to provide proper access to the inner shell cavity within the container for source loading / unloading operations inside a hot cell and then firmly securing the sealed sources after source loading in such a manner that the source assembly remain confined inside the container during both normal as well as accident conditions of transportation.

Closure bolting system of lead plug which fastens the lid with the main body of the container is, therefore, recommended to be designed to withstand expected decelerating forces resulting from 9 meter drop and 1 meter puncture tests.

Bolt size of less than 12 mm diameter normally should not be selected because of the danger of overstressing the smaller sizes of bolts.

A.7 Source Cage Assembly

Source cage assembly facilitates holding of the sealed sources normally in cylindrical configuration and it is loaded remotely in the container. A properly spaced locations of sealed sources inside the source holder helps to provide a better dose uniformity inside the sample chamber of GIC.

A.8 Lifting Lugs of Outer Shell (Encasement) and Slings

Lifting lugs for the purpose of this ‘safety guidelines’ are the lifting devices that are integral part of the container and should be capable of withstanding a load arising due to snatch lifting. Therefore, these lifting lugs system along with their lifting wire rope slings are recommended to be designed to withstand a total load of at least three times the weight of the package (total weight of container and its packaging) to meet the snatch lifting requirements.

A.9 Construction of Materials of Encasement and other Related Components

The primary objectives of source container are to shield and to contain adequately a source of radioactive material while meeting all the stipulated requirements under a number of environmental conditions as specified in the safety regulations.

The properties of material of construction therefore should have adequate strength at elevated temperatures, and ductility and resistance to brittle fracture at -40 ^{O}C. In addition, factors such as ability to resist corrosion by decontamination solutions, galvanic corrosion between adjacent materials and stress corrosion should be considered.

Materials that require a minimum of 20 Joule (15 ft-lb) energy to break a ‘Charpy keyhole Specimen’ at temperature of -40 ^{O}C are considered adequate to meet the safety requirements.

Austenitic stainless steels conforming to ASTM specifications or equivalent standards should be meeting the above properties adequately and it is recommended to use ASTM A240 type stainless steel of grade 304 for outer and inner shells as well as for other structural parts of container unless the applications require the added corrosion resistance for decontamination in the heat affected weld zones that is provided by grade 304L, 321, and 347 of stainless steel.

However considering all the above requirements, it is advisable to use SS 304L grade or its equivalent for fabrication of source container.

A.10 Materials for Bolting, Pipes and Tubes

Materials for bolting, pipes and tubes should be also of austenitic stainless steel from the above considerations. However, wherever the above stringent criteria are not required in

the case of bolting materials, the low alloy steel bolting material could be used rather than stainless steel to minimise galling of threads during repeated assembly operations.

A.11 Shielding Material

If lead is used for shielding, it is normally specified as ASTM B29, pig lead, chemical grade having minimum of 99.96% purity. No Antimony (Sb) material should be added as alloying material to lead, as it lowers the melting point and has tendency to form cracks, spongy area and voids.

B) SHIELDING INTEGRITY (RADIOMETRY) TEST

Shielding integrity tests should be carried out because a void or low-density region will create a 'hot spot' or elevated radiation region on the cask surface when in use.

Before the initial use of the source container for transportation of radioactive source, the integrity of the shielding of the container/cask should be demonstrated. The container should be loaded with the type of radioactive source for which it is designed (or an equivalent source), and the entire outer surface should be surveyed for ascertaining that the leakage radiation levels are within the permissible limits as specified in section 2.3 of this 'safety guidelines'.

Gamma Scanning and Probing

This test is a quality control operation often specified to ensure that the container will comply with the prescribed radiation leakage requirements when it is loaded with the radioactive material to be transported. When the test is included in the contract, the requirements should be given as below:

The fabricator should prepare a gamma scanning procedure, which should include following information in detail:

(a) Electronic equipment used
(b) Radiation source and its activity/strength
(c) Type of radiation detector with its desired sensitivity
(d) Calibration standards for both scanning and probing
(e) Grid pattern
(f) Positioning equipment
(g) Method of reading and recording the radiation levels observed
(h) Measuring technique
(i) Acceptance criteria.

The procedure used for assessing the shielding integrity/radiometry of GIC should be acceptable to the manufacturer / their authorised representative prior to its application. The results of radiometry should be recorded. The procedure and all the results should be made a part of the fabrication record.