Trunnions for Spent Fuel Element Shipping Casks

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INTRODUCTION

Trunnions are used on spent fuel element shipping casks for one or more of a combination of lifting, tilting or securing to a transport vehicle (see figures 1a and 1b).

Within the nuclear transportation industry there are many different philosophies on trunnions, concerning the shape, manufacture, attachment, inspection, maintenance and repair. With the volume of international transport of spent fuel now taking place, it is recognised that problems are occurring with casks in international traffic due to the variance of the philosophies, national standards, and the lack of an international standard.

There are no national or international standards that cover all aspects of trunnions. Various countries have standards/guides which cover some aspects of trunnions with other countries applying standards for equipment-used for similar purposes.

It was agreed through the ISO that an international standard was required to harmonise.

In 1984 an ISO 'working group' was formed of European and U.S. representatives to write an international standard on trunnions. The WG was formed from representatives of cask owners, operators, designers and regulatory bodies. The remit of the working group was to evolve a standard which would cover all aspects of trunnions which the nuclear transportation industry felt was lacking.

It was not possible to evolve an international standard. It was only possible to evolve an international guide. To evolve a standard would mean superseding any existing national standards which already cover particular aspects of trunnions i.e. deceleration forces imposed on trunnions used as tie down features. Therefore the document is a guide only and allows existing national standards to take precedence where they exist.

The guide covers design, manufacture, maintenance, repair and quality assurance. The guide covers trunnions used on spent fuel casks transported by road, rail and sea. The guide details the considerations which should be taken account of by cask designers, i.e. stress intensity, design features, inspection and test methods etc. Manufacture, attachment and pre-service testing is also covered. The guide details user requirements which should also be taken account of, i.e. servicing frequency, content, maintenance and repair. The application of quality assurance is described separately although the principles are used throughout the guide.

One of the main features of the guide is the manner in which the design influences the whole life cycle of a trunnion. Guidelines at each stage of the design process lead the designer through objective decision making processes regarding all aspects of the design. Insufficient thought by the designer may cause difficulties in manufacture, attachment, inspection, testing, maintenance, servicing and repair. Throughout the guide this message is conveyed.

The WG completed its work in 1988 with the submission of an international guide 'Trunnions for Spent Fuel Element Shipping Casks' to the ISO. Publication is expected in 1989.

The paper covers the major points made in the ISO guide.

DESIGN

Trunnion systems shall be designed so that, under both normal and accident conditions, the forces in the trunnions and trunnion attachments shall not impair the ability of the package to meet the requirements of the IAEA regulations.

Trunnion attachment to a cask may be by welding, bolting or interference fit and bolting. The guide applies to these methods of trunnion attachment (see figures 2a and 2b).

DESIGN FOR TIE DOWN

The designer should consider the different modes of transport the cask is intended for. The orientation of a cask during sea transport could be at right angles to the orientation of the same cask during a rail transport. The designer should consider all possible methods of cask orientation during transport to ascertain the most exhaustive requirements.

STRESS INTENSITY ON TRUNNION SYSTEMS DURING CASK TIE DOWN

At the most severely stressed point, the following stress intensities shall not be exceeded.

The following shall be assumed to be acting:-

a) in the direction of transport: twice the total weight (transport)

b) at right angles to the direction of travel: the total weight (transport)

c) vertically upwards: the total weight (transport)

d) vertically downwards: twice the total weight (transport)

It shall be assumed that none of the above act simultaneously.

For materials exhibiting a clearly-defined yield point or characterised by a guaranteed conventional yield stress $R_e(T)$:

Note

σ = stress intensity

$R_e(T)$ = Clearly defined yield point or minimum yield strength of 0,2 per cent of residual elongation (0,2 per cent proof stress) and in the case of austenitic steels 1,0 per cent of maximum elongation (1,0 per cent proof stress).

$R_m(T)$ = Minimum tensile strength

a) where the ratio $R_e(T)R_m(T)$ is not more than 0,66:

$\sigma \quad < 0{,}5\ R_e(T)$

b) where the ratio $R_e(T)R_m(T)$ exceeds 0,66:

$\sigma \quad < 0{,}34\ R_m(T)$

For materials exhibiting no clearly-defined apparent yield stress and characterised by a guaranteed minimum tensile strength $R_m(T)$:

$\sigma \quad < 0{,}29\ R_m(T)$

Design for Lifting and Tilting

In some cases, the designer may be required to design casks to have secondary or redundant trunnion systems (see Figure 3.). The designer is advised to design the primary and secondary/redundant trunnion systems independent of each other.

Stress Intensity on Trunnion Systems during Cask Lifting

Along the lifting axis the total weight shall be assumed to be acting.

For materials exhibiting a clearly-defined yield point or characterised by a guaranteed conventional yield stress $R_e(T)$:

a) where the ratio of $R_e(T)/R_m(T)$ is not more than 0,66:

$\sigma \quad < 0{,}32\ R_e(T)$

b) where the ratio of $R_e(T)/R_m(T)$ exceeds 0,66:

$\sigma \quad < 0{,}21\ R_m(T)$

For materials exhibiting no clearly-defined apparent yield stress and characterised by a guaranteed minimum tensile $R_m(T)$:

$\sigma \quad < 0{,}18\ R_m(T)$

Fatigue Analysis of Trunnion System

Designers are advised to take into account the fact that the trunnion life may be reduced due to the effects of fatigue caused by cyclic stresses during transport, lifting or a combination of both.

Design for Manufacture, Maintenance (periodic inspection, periodic testing, component replacement and repairs)

During manufacture and upon completion of manufacture and assembly, inspection and testing shall be carried out. The ease of inspection, testing and assembly shall be influenced by the design and shall be repeatable in service by the same methods used during manufacture.

Consideration to be given during design to the methods of maintenance which may be employed during the 'in service' life of trunnion systems. Insufficient design thought with respect to these factors may cause difficulties in carrying out maintenance.

Designers are advised to take into account the fact that the design requirements be based upon the 'in service' conditions which will prevail and not base the design requirements on manufacturing tolerances which may be exceeded on the cask in service.

The designer should allow an adequate margin between manufacturing and 'in service' limits and tolerances. Where practical, the designer is advised to add a margin to account for 'in service' wear, damage and diameter reduction which can be utilised during the life of the trunnion.

The designer is made aware that casks with trunnions designed for tilting are susceptible to surface damage on the trunnions during tilting operations. The designer is advised to determine the level of surface damage that is acceptable for continued use of the cask. The acceptance criteria should be determined by carrying out a fracture mechanics analysis to determine the amount of damage which can be allowed in terms of depth from the surface and position on the trunnion.

It is recommended that trunnions should be wholly stainless steel or stainless steel covered (using a carbon or alloy steel base material). The use of stainless steel on exposed surfaces will facilitate decontamination.

MANUFACTURE

Manufacture should be carried out in all cases, to pre-determined quality plans. The quality plans should be agreed and approved by the manufacturer/designer/purchaser or independent organisations as appropriate, prior to manufacture commencing.

Testing During Manufacture and Assembly

Testing during manufacture and assembly should include but not be limited to:-

a) Chemical analysis

b) Mechanical testing of material properties

c) Non Destructive Examination

d) Overload testing

Non Destructive Examination (NDE)

NDE should be carried out during specified steps of the manufacture to verify the material condition at that step. In the case of trunnions welded to casks, the trunnion to cask weld and the heat affected zone should be UT scanned after completion of welding (see figure 4).

Some or all of the NDE should be repeated during the in service life of the cask. In this respect, it is important that adequate records of the 'in manufacture' NDE are retained.

Overload Testing

Overload testing of trunnion systems should be carried out to verify the assembled condition. Testing should be carried out on pairs of trunnions which are used together. Testing, where possible, should simulate the mode in which the trunnions normally operate. Trunnions should be overload tested by a minimum factor of 50% of the lifting or transport total mass, whichever is the greater.

MAINTENANCE

Maintenance should be carried out to meet the designer's recommendations.

Maintenance may be comprised of one or more combinations of periodic inspection, periodic testing, component replacement or repairs. The content of the maintenance should be dependant upon the frequency at which maintenance is being carried out and the feature being maintained.

Regular periodic inspection at pre-determined frequencies should be carried out, to ascertain if the 'in-service' limits have been exceeded or an unacceptable amount of wear or damage has taken place.

Specific components e.g. trunnion attachment screws, gaskets etc may be replaced at specific periodicities as a preventative maintenance measure.

Repair of trunnion systems may be considered necessary if the 'in-service' limits are found to have been exceeded by wear, corrosion or damage.

Periodic Inspection

The features to be periodically inspected and the type of periodic inspection will depend on the type of trunnion system and the periodicity at which it is being carried out.

Attachment Threads in Cask Body

The attachment threads in the cask body, used in conjunction with retaining screws or bolts, should be checked to ensure they are capable of carrying out their designed function of retaining the trunnion in its position on the cask body under all envisaged design stresses (shear, tensile and bending as appropriate).

Trunnion Surfaces

The surfaces of the trunnions should be checked to ensure they are in a condition which shall not be detrimental to the designed strength i.e. by having damage or corrosion which could lead to fatigue failure of the trunnion system.

Attachment Screws or Bolts

In the case of attachment screws or bolts that are not discarded, those screws or bolts should be checked to ensure they are (in conjunction with attachment threads in the cask body) capable of carrying out their design function of retaining the trunnion in position on the cask body under all envisaged design stresses.

Weld Areas

For welded trunnions, the welds attaching the trunnion to the cask body should be checked to ensure they do not contain any flaws which may be detrimental to the designed strength e.g. propagation of an internal flaw which could lead to fatigue failure of the trunnion.

Repairs

At any time damage may occur which may result in trunnion systems being rendered unfit for further use and requiring immediate repair or repair within a specified timescale. Wear and corrosion may also take place, which may result in trunnion systems exceeding predetermined in service limits.

Maintenance Schedule

A maintenance schedule should be a summary of all the maintenance requirements, including frequencies.

The schedule should take account of cask utilisation and time to ensure the recommended maintenance frequency/periodicity is implemented so that trunnion systems are always in a fit condition.

The content of maintenance schedules should be agreed between the designer, regulatory authority, owner/operator, maintenance organisation and independent organisation as appropriate.

The following information should be contained in a maintenance schedule:-

a) Frequency of maintenance.

b) Features to be maintained and methods to be used.

Recommended Frequency/Periodicity

At each handling where the cask is handled by using its trunnions.

After each 15 transport cycles within a maximum period of 3 years whichever comes first.

After each 60 transport cycles within a maximum period of 6 years whichever comes first.

For any cask not used for more than 6 months a visual inspection shall be carried out every 6 months and before the cask re-enters service.

For casks not used for more than 3 years a visual inspection shall be carried out every 6 months. In addition, a 15 cycle type maintenance shall be carried out before the cask re-enters service.

For casks not used for more than 6 years a visual inspection shall be carried out every 6 months. In addition, a 60 cycle type maintenance shall be carried out before the cask re-enters service.

QUALITY ASSURANCE

It is recommended that the quality assurance principles to be applied are consistent with those detailed in IAEA Safety Series No. 37.

The quality assurance requirements for trunnions may form part of a more comprehensive quality assurance system for all aspects of spent fuel element shipping casks.

The manner in which quality assurance principles are implemented may vary from country to country and from organisation to organisation. In any event, the basic intent of the principles should be kept in mind at all times and the detailed implementation should be arranged accordingly.

A quality assurance programme covering all aspects of the guide should comprise of the following elements:-

Introduction
Quality Assurance Programmes
Organisation
Document Control
Design Control
Procurement Control
Material Control
Process Control
Inspection and Test Control
Controls of Use and Care of Packages
Non-Conformity Control
Corrective Actions
Records
Staff and Training
Audits

Graded Approach to Quality Assurance

The grade of a package or package component is determined by its safety significance in terms of direct or indirect influence upon shielding, criticality and containment.

The most exhaustive safety significance shall determine the grade. In the case of trunnions for spent fuel element shipping casks the most exhaustive safety significance is failure of a trunnion system during cask handling at a nuclear installation. Therefore, trunnions for spent fuel element shipping casks should be treated as grade 1 items.

Grade 1 items should be subject to exhaustive controls during design through to maintenance regarding quality assurance aspects.

References

Trunnions for Spent Fuel Element Shipping Casks ISO/TC85/SC5/WG9 6th draft (1988)

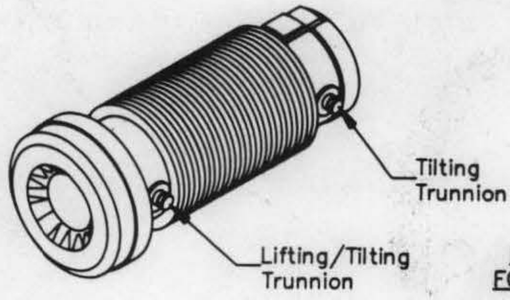

FIGURE 1(a) – CASK FOR L.W.R. SPENT FUEL

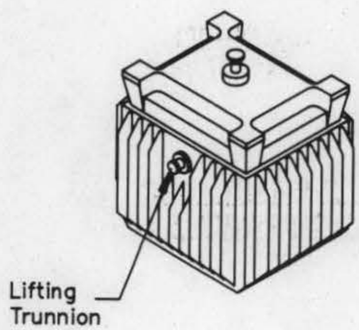

FIGURE 1(b) – CASK FOR MAGNOX SPENT FUEL

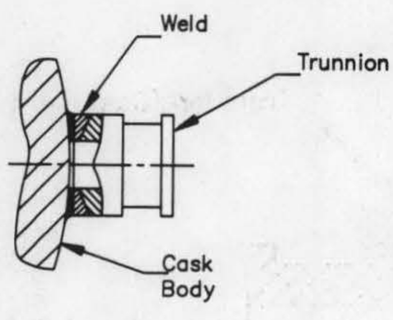

FIGURE 2(a) – EXAMPLE OF WELDED TRUNNION

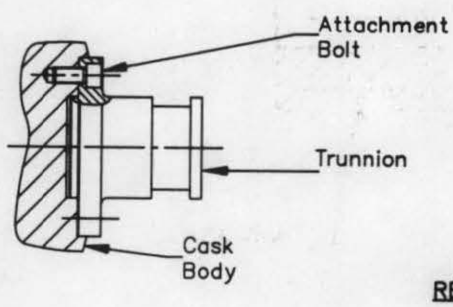

FIGURE 2(b) – EXAMPLE OF REMOVABLE TRUNNION (BOLTED)

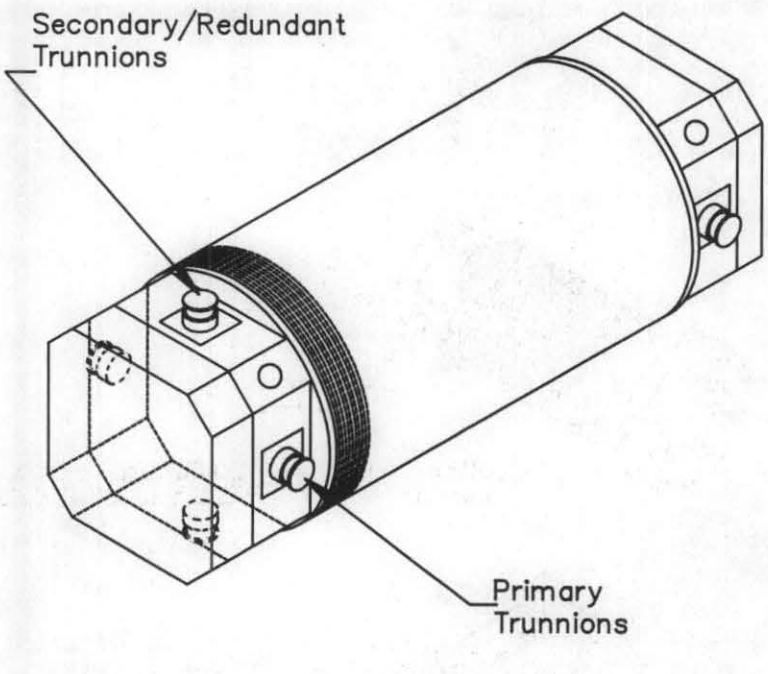

FIGURE 3 – CASK HAVING PRIMARY AND SECONDARY/ REDUNDANT TRUNNIONS

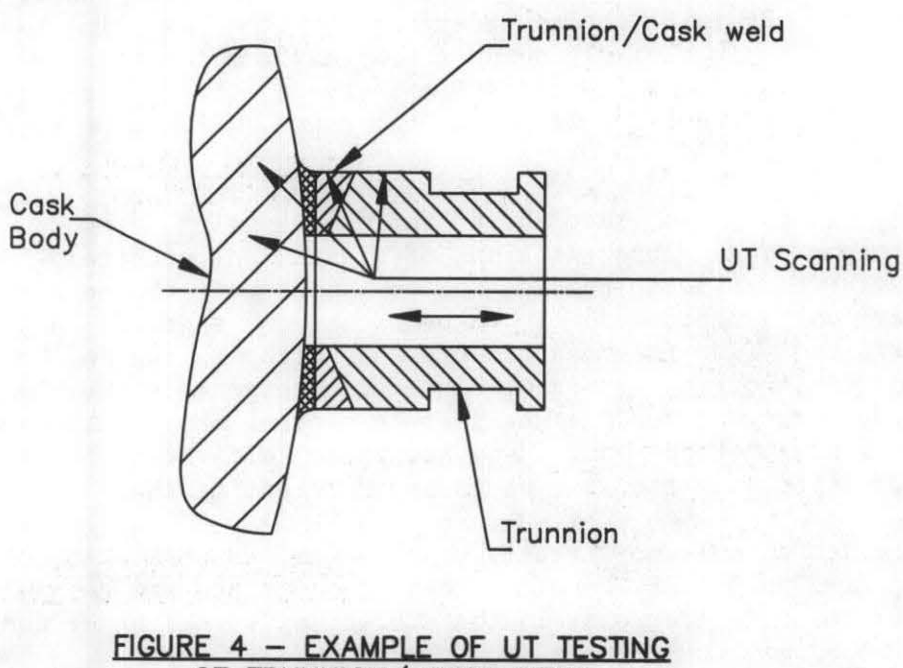

FIGURE 4 – EXAMPLE OF UT TESTING OF TRUNNION/ CASK WELD