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Transport of Radioactive Material Code of Practice

Lifting Points for Radioactive Material Transport Packages

Produced by the Transport Container Standardisation Committee

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Terms of Reference for TCSC: Examine the requirements for the safe transport of radioactive material with a view to standardisation and, as appropriate, produce and maintain guidance in the form of Standards documentation.

Publisher

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FOREWORD

The provision of adequate means for lifting a radioactive materials transport package is essential for safe and efficient handling and minimises the risk of injury and damage. This code makes recommendations on the design, testing, examination and marking of lifting points for radioactive material transport packages approved in the UK.

The code defines the recommended design criteria and minimum safety factors for lifting points, which includes methods for designing specific handling features such as, lugs and trunnions.

This document is an updated version of the previous issue dated June 2003. The amendments are relatively minor, being restricted to updating of supporting references and related documents to maintain the currency of the document.

1 GENERAL

1.1 Scope

1.1.1 This code of practice gives advice on the design codes, loads, materials, identification, labeling, certification, maintenance, inspection and testing of lifting points for radioactive material transport packages.

1.1.2 The derivation of design loads (and their combinations) that should be considered is explained.

1.1.3 The code defines the recommended design criteria and minimum safety factors for lifting points in relation to the lifting gear used.

1.1.4 Recommended methods for designing lugs and trunnions are included.

1.2 Related Documents

BS 2573: Part 1: 1983	Rules for the design of cranes: specification for classification, stress calculations and design criteria for structures. **Note this Standard is classified by BSI as Current, Superseded.**
BS EN 1677-5:2001	Components for slings. Safety. Forged steel lifting hooks with latch. Grade 4.
BS 3551: 1962	Specification for alloy steel shackles.
BS 3580: 1964 (1985)	Guide to design considerations on the strength of screw threads.
BS 4278: 1984	Specification for eyebolts for lifting purposes.
BS 7608: 1993	Code of practice for fatigue design and assessment of steel structures.
BS 7910: 2005	Guide on methods for assessing the acceptability of flaws in metallic structures.
BS EN 13001-1:2004	Cranes – General Design - Part 1 : General Principles and requirements
BS EN 13001-2:2011	Crane safety – General Design – Part 2 : Load actions
BS EN 13001-1:2004	Crane safety – General Design – Part 3-1 : Limit states and proof competence of steel structure
ASME III	Boiler and Pressure Vessel Code: Rules for Construction of Nuclear Power Plant Components

ASME VIII Boiler and Pressure Vessel Code: Pressure Vessels

DIN 580 Lifting eyebolts.

Regulations for the Safe Transport of Radioactive Material, 2009 Edition, Safety Standards Series No TS-R-1, IAEA.

The Department of Transport, Radioactive Materials Transport Division "Guide to an application for Competent Authority approval of radioactive material in transport (IAEA 1996 Regulations)" Ref. DETR/RMTD/0003 January 2001.

Safe use of lifting equipment. Lifting Operations and Lifting Equipment Regulations (LOLER) 1998.

Safe use of work equipment. Provision and Use of Work Equipment Regulations (PUWER) 1998. Approved Code of Practice and guidance.

Lifting Equipment Engineers Association "Code of Practice for the Safe Use of Lifting Equipment".

IAEA Guidance in TS-G-1.1 and TECDOC-717 (Guidelines for the Safe Design of Shipping Packages against Brittle Fracture – 1993).

1.3 Definitions

Appointed Person A person appointed to control lifting operations. It is inappropriate for the crane driver to be an Appointed Person.

Competent Person A person appointed to (a) supervise and plan lifting operations, (b) carry out examination and certification of lifting equipment and accessories. (Note: it is unlikely that the same Competent Person will perform both functions, see LOLER regulations 8 and 9.

Design Load The maximum load that can be considered applicable to a particular lifting point for design purposes, i.e. that part of the package weight taken by the lifting point multiplied by the impact factor.

Lifting Equipment Any machine that is able to raise, lower or suspend a load. Machines incorporating a guided load and continuous mechanical handling devices are covered by PUWER.

Lifting Point A generic term for the permanent point(s) or attachment(s) from which a package can be safely lifted. The term includes lifting lugs, trunnions, inherent features of the packaging, eyebolts and, in certain cases, forklift pockets.

Lifting Accessory Any item used to connect a load to a lifting appliance but which is not in itself capable of providing any movement to lift or lower a load.

Load Compensating Features A term used for lifting gear that has inherent design features that ensure the attached lifting points equally share the load to be lifted.

Safe Working Load The maximum load which lifting gear and appliances may raise, lower or suspend under the service conditions which apply.

Safety Factor The ratio of the permissible stress in a lifting point (for that material and loading condition) to the stress developed when the design load is applied.

2 REGULATORY REQUIREMENTS

2.1 IAEA Regulations

The IAEA, "Regulations for the Safe Transport of Radioactive Material", TS-R-1 includes requirements for lifting points in the general requirements for all packaging and packages, i.e.:

Para [606] The package shall be so designed in relation to its mass, volume and shape that it can be easily and safely transported......

Para [607] The design shall be such that any lifting attachments on the package will not fail when used in the intended manner and that, if failure of the attachments should occur, the ability of the package to meet other requirements of these Regulations would not be impaired. The design shall take account of appropriate safety factors to cover snatch lifting.

Para [608] Attachments and any other features on the outer surface of the package which could be used to lift it shall be designed either to support its mass in accordance with the requirements of para [607] or shall be removable or otherwise rendered incapable of being used during transport.

2.2 Competent Authority Guide

The Department of Transport "Guide to Application for Competent Authority Approval of Radioactive Material in Transport" (Type B or fissile packages only) includes in Part II the following requirements.

Para [4.1.1] Identify and discuss all attachments that can be used for handling either the package or its components (IAEA 564, 606, 612, 636).

Para [4.1.2] Give details of any special lifting equipment required, together with maximum and safe working loads. State how any special lifting equipment requirements are advised to Consignors/Operators. Additional indelible markings on the package, adjacent to the handling/lifting features, may be used to ensure that design intent is observed.

Para [4.1.3] Show by analysis or test, that any lifting attachments on the package will not fail in normal use. Include a snatch factor of 100%, unless there are valid and justifiable reasons for a lower factor (IAEA 607).

Para [4.1.4] If the integrity of the handling system is to be evaluated by analysis, identify and discuss the basic loading conditions. The Applicant may present this data in a convenient tabular form. Normal asymmetries of loading must be addressed and the worst case loading used in subsequent analysis. For example, in a rigid, redundant, lift system it is unlikely that all supports will be effective through life if normal tolerances, clearances or wear are assumed. The applicant should consider such cases.

Para [4.1.5] Identify the criteria, codes or standards used to determine design limits, load combinations, allowable stresses, etc. If the applicant wishes to define allowable stresses without reference to appropriate standards or codes then the applicant must bear in mind that: (i) the package is subjected to dynamic loading, and (ii) co-existing stresses invariably *result from the loading. The applicant must ensure that allowable stress is less than yield stress or 0.2% proof stress.*

Para [4.1.6] Consider the effects of fatigue loading, at local details, on handling features over the design life of the feature. The applicant should consider that all lifting and handling operations are enhanced by the snatch factor and be analytically demonstrated to have a minimum fatigue life compatible with the design life of the handling feature. The applicant should provide references from which stress concentration factors have been derived for the local structural detail under consideration.

Para [4.1.7] The Applicant should identify, justify and discuss any analysis simplifications.

Para [4.1.8] Show how any possible feature of the package that could possibly be used for lifting has either been designed to act as a lifting point or is removed or is otherwise rendered incapable of being used as a lifting point (IAEA 608). Additional indelible markings on the package adjacent to the handling/lifting features may be used to ensure that design intent is maintained.

Para [4.1.9] Provide verifiable evidence which demonstrates that the overall conclusion of the evaluation has achieved the requirement of the criteria, code or standard. One method of presenting verification of the design intent is to tabulate the results of actual stress/allowable stress from the analysis of structural details to demonstrate that the requirements of the code or standard have been met.

2.3 LOLER and PUWER

2.3.1 The introduction of LOLER and PUWER does not impact greatly on this document since it is mainly concerned with design, testing, examination and marking of package lifting points and not lifting operations in general.

2.3.2 The key relevant requirements of LOLER are:

All Lifting Equipment shall be thoroughly examined by a Competent Person:

a) before going into service for the first time.
b) after installation and before being put into service for the first time.
c) after assembly and before being put into service at a new site or location.

All Lifting Equipment exposed to conditions causing deterioration which is liable to result in dangerous situations shall be thoroughly examined:

d) Lifting Accessories, at least once in every six months
e) Other Lifting Equipment, at least once in every 12 months OR
f) In either case, in accordance with an examination scheme.

2.3.3 The key relevant requirements of PUWER are:

a) all work equipment is constructed or adapted to suit the purpose for which it is to be used. It must only be used for the purpose for which it was designed.

b) all work equipment is properly maintained in an efficient state; in effective working order and in good repair. Planned Maintenance & Records.

c) work equipment shall be inspected (a) after installation and before going into service for the first time, (b) after assembly at a new site or location, to ensure it has been installed correctly and is safe to use.

d) where the use of work equipment involves a specific risk, every employer shall ensure that the use and repair is restricted to those who have been trained and authorised.

e) all persons who use work equipment shall have available any information and instructions as to ensure their health and safety pertaining to this work equipment.

f) all persons who use work equipment, including those who supervise or manage the use of work equipment, shall receive adequate training, including training in the methods of use of such equipment.

3 DESIGN

3.1 Designing to a Standard

3.1.1 A person working alone should not be expected to lift more than 25 kg unaided. Loads up to 50 kg (that is any package that can be lifted by two people) should be able to be handled in a controlled manner and provided with the means to do so. This weight should be seen as an upper limit since it does not allow for lifting above waist height for, say, loading onto a lorry or van. The shape of the packaging must also be taken into account. Provided it is reasonable and practicable, manual lifting points should be fitted to any packaging with a gross weight of more than 20 kg. It is recommended that, to facilitate mechanical handling, lifting points should be designed into a packaging weighing more than 50 kg, unless some inherent features of the packaging make this unnecessary. Specialised lifting equipment is available for some types of packaging, notably open-head drums.

3.1.2 Lifting points should be designed in accordance with a recognised construction code or design standard. This is inferred in TS-R-1 para 607 and recommended in the "Guide to an Application for UK Competent Authority Approval of Radioactive Material in Transport". The code or standard used may depend on whether the package is designed to be a pressure vessel. Refer to Section 3.3 for further information.

3.1.3 The recommended approach for most applications is to design lifting points to BS 2573 : Part 1 "Rules for the design of cranes". This standard is applicable to structures loaded by lifting operations and therefore can also be used to verify the suitability of a lifting point design. This design standard should also be used to verify the suitability of convenient inherent features of a transport package that could be used as lifting points.

3.1.4 Irrespective of the code of construction or standard used, designers should note that the stress assessment of the lifting point and the surrounding structure should never be considered as absolute stress levels but as being superimposed on possible existing stresses in that region. Designers should seek specialist advice in case of uncertainty.

3.1.5 Designing to appropriate codes and standards will result in lifting points that are of adequate strength for lifting. These codes do not necessarily guarantee that lifting points will withstand the knocks that transport packages inevitably suffer during handling operations. (For instance, BS 2573 : Part 1 does not impose minimum thickness requirements.) The designer should therefore not design down to a standard but rather design for suitable robustness and use the standards to demonstrate structural adequacy. Other factors that should be considered include manufacturing processes and the degree of corrosion that is likely to arise over the packaging's life.

3.2 Design requirements

3.2.1 All transport packages shall be designed with adequate provision for safe lifting. Wherever possible, designers should aim to eliminate welds from the load path, or at least to minimise weld stresses. Where practicable, the design of lifting points should provide for the use of shackles. If the lifting points are trunnions, a suitable locating or locking feature must be incorporated in the trunnion and/or lifting gear to ensure that the lifting gear is retained in the correct position during operations.

External features that can be used as lifting points, whether by deliberate design or not, must be able to support the weight of the packaging. Lifting points fitted to some sub-assembly that cannot support the entire package weight must be made safe prior to dispatch. This could be achieved by, removal, fitment of a device to prevent their use (e.g. padlock) or by concealment under a locked cover. Refer to Section 3.4.4 for further information.

3.2.2 Specifically designed lifting features shall be provided except where:

a) The provision of such features may interfere with the assembly and/or functioning of the package, in which case alternative measures for allowing safe handling must be taken.

b) Due to shape, weight, weight distribution or strength, the basic design provides adequate facilities for safe lifting.

c) Inherent features of the package can be designated and rated as lifting points.

d) Proprietary lifting points are used, e.g. eyebolts, ISO corner fittings.

3.2.3 The preferred type of lifting point to be used will depend on the particular design of transport package being considered. Some examples are listed below (not in order of preference).

a) Welded-on lifting lugs with holes suitable for shackles or hooks. Generally, shackles are preferred to hooks since they are more secure and minimise the dimensions of the lifting lugs.

b) Bolted-on lifting lugs with holes suitable for shackles or hooks.

c) Integral lugs with holes suitable for shackles or hooks.

d) Trunnions (welded or bolted).

e) Holes or features inherent in the design of the package which may be designated as lifting points.

f) Eyebolts.

It is important that the effect of the loads due to lifting are considered throughout the whole packaging structure. It is not acceptable to terminate the assessment at the weld or bolts that secure the lifting point. Also, since some packagings are lifted in more than one orientation, the full range of operating conditions must be addressed. As part of this exercise it is important to identify the weakest part of the lifting system in order to demonstrate that failure of any component will not affect the safety of the package. Where a lifting point is attached to a massive steel structure this is generally a straightforward matter. If the lifting point is attached to a member of comparable thickness it is often good practice to fit an intermediate spreader plate. See Figure 1.

3.2.4 Where a package has two or more lifting points they should be of identical design, regardless of the load distribution. Where practicable, lifting points shall be positioned so that each supports an equal proportion of the total load. The number of lifting points should be kept to a minimum consistent with package stability, material permissible stresses, the SWL of the lifting gear, and the lifting appliances likely to be available. Single lifting points are not recommended except for small packagings where space restrictions would make two lifting points impracticable. Two types of permanently attached lifting points are discussed in the Appendix: welded and bolted. Figures A1, A2 and A3 illustrate the basic geometric features.

3.2.5 When eyebolts are used as lifting points they constitute part of the design and the strength of the adjoining structure should be considered. The main type are:

a) Collar eyebolts to BS 4278, threaded ISO metric. These are normally used in pairs with a two-leg sling.

b) Link eyebolts to BS 4278, threaded ISO metric. These are used in place of collar eyebolts where loading is not confined to a single plane. They permit the rated load to be applied in any direction within an angle of 15° to the axis of the threaded shank.

c) Stainless steel eyebolts to DIN 580.

Note: Dynamo eyebolts must not be used. They are intended for vertical lifting only and excessive stress is imposed on the threads if loading is more than 5° out of vertical.

The following measures should be observed:

d) Threads should be metric coarse, 6H fit, to BS 4500.

e) The area around the tapped hole should be spot faced to ensure that the eyebolt seats square to the axis of the hole. All of the eyebolt thread must be engaged and, in the case of blind holes, the depth of the tapped hole should be at least 10% greater than the length of the eyebolt shank.

f) When eyebolts are used in pairs, the maximum load that can be lifted reduces as the angle between the slings increases. Similarly, if an eyebolt is used at 90° to its axis (trunnion loading) a reduction in the permissible load also applies. See Figure 2(a).

g) Where eyebolts are used in pairs the plane of the eye of each eyebolt should not make an angle of greater than 5° with a line between the two eyebolts. See Figure 2(b). Shims or machined washers should be used if necessary.

3.2.6 At the design stage the number of lifting points and their design load should be considered along with the requirements of the lifting gear. The number of lifting appliances, the type of lifting gear (including sling angles), the available headroom, the number of lifting points and design load for each lifting point must be considered together to optimise the design. The effectiveness of the lifting gear (with or without inherent load compensating features) will govern the design load requirements of the lifting points. Examples are:

a) A package is to be handled by one lifting appliance and a four legged sling; the package has four lifting points. This arrangement could suggest that each lifting point should be designed to have a design load of 25% of the package weight. In practice however each leg will probably not be equally loaded. It is more likely that two opposite slings will share the load and impose double the rated load on two of the lifting points. A similar situation could occur with two lifting appliances and their associated lifting gear.

b) If an H beam is used exclusively to lift a four lifting point package the inherent flexibility of the beam can be used to justify rating each lifting point to 25% of the package design load. Designers must however be aware that this approach is not considered to be good practice and will be examined carefully by the Competent Authority; the approach outlined in (a) above is likely to be approved more readily.

3.2.7 Figures 3 to 6 illustrate the design load for one, two, three and four lifting points respectively at the maximum included angles for multi sling arrangements.

3.2.8 A sketch showing the lifting arrangement and associated notes should be suitably placed on the general assembly drawing(s) and the operating and maintenance instructions. The notes should include reference to the lifting tackle and appliance(s) to be used in conjunction with the lifting points.

3.2.9 Fork lift pockets must be assessed to ensure that the surrounding structure is of adequate strength. Such pockets should enclose the forks to prevent the package toppling.

3.2.10 Where a lug is formed from a flat plate the applied load must in all cases lie in the plane of the lug unless it has been specifically designed for out of plane loading.

3.2.11 The hole in a lifting lug should be designed so that it cannot be used with a shackle with too low a safe working load. This may be achieved by:

a) positioning the hole the maximum distance from the edge consistent with the size of the correctly rated shackle.

b) fitting a boss so that only a correctly rated shackle can fit over the lug.

3.2.12 Where bolted lifting points are used, operating and maintenance procedures must ensure that the package is only ever lifted with the correct grade of fastener in place, tightened to the correct torque. If the bolts are frequently disturbed, and wear of the tapped holes is possible, then the use of studs should be considered.

3.3 Packagings as pressure vessels

3.3.1 Whilst Section 3.2 is applicable to transport packages in general, pressurised or vacuum containers conform to codes of construction such as PD 5500, ASME III and ASME VIII, and these require additional design considerations. The design of these vessels must make due allowances for stresses set up by welded or bolted-on lifting points, pads and/or jacking points. Data sheets and instructional drawings shall be made available for the pressure vessel approval authority. The welding and materials of construction of lifting points that are directly connected to a pressure/vacuum vessel shall be as specified in the relevant code or standard. Where lifting points are welded directly to pressurised parts the materials of construction shall be similar to that of the vessel.

3.4 Design Loads and Acceptable Stresses

3.4.1 The loads that can be applied to lifting points depend on the particular lifting operation and environmental conditions that the transport package is exposed to. BS 2573 : Part 1 Section 3 calls for such loads to be assessed in combination. This code of practice recommends that the following load combinations should be assessed:

a) Lifting of transport package without the effects of wind load:

The lifting point(s) shall be designed to withstand the following load combination:

$L_1 + L_3 + H_1$ where:

$L_1 =$ the dead loads due to dead weight. For a lifting point this is zero.
$L_3 =$ the live loads, that is the package gross weight, multiplied by the impact factor. (See BS 2573:Part 1 Section 3.1.4 and para 3.4.2 below).
$H_1 =$ the combined effect of the two most severe horizontal loads. (See BS 2573:Part 1 Section 3.1.5). These are likely to be zero, though the designer may wish to account for the relatively small sideways component that arises when the load is moved horizontally.

b) Lifting of transport package with in-service wind loads

The lifting point(s) shall be designed to withstand the following load combination:

$L_1 + L_3 + H_1 + V_1$ where:

$L_1 =$ as (a).
$L_3 =$ as (a).
$H_1 =$ as (a).
$V_1 =$ the load due to the service wind acting horizontally in any direction where applicable. A procedure to determine the wind load is shown in BS 2573:Part 1 Section 3.1.7. This value is likely to be insignificant. The designer may wish to verify this if the packaging has a large surface area to weight ratio.

c) Repeated lifting of transport package

The lifting point(s) shall be designed to withstand the following load combination:

$L_1 + L_4 + H_2$ where:

L_1 = as (a).
L_4 = the live loads multiplied by the impact factor and nominal load spectrum factor. (See BS 2573:Part 1 Sections 3.1.4 and 2.3, and section 3.5 below).
H_2 = H_1 but excludes horizontal skew loads due to traveling.

3.4.2 The Guide to Applications for Competent Authority Approval of Packages requires a "snatch factor" of 2 to be applied. (This corresponds to the Impact Factor of BS 2573:Part 1 Section 3.1.4). Hence the package design load will be:

$L_1 + 2.L_3 + H_1$

The design loads applicable to various arrangements of lifting point are given in Figures 3 to 6.

3.4.3 Having calculated the stress induced by the design load a comparison with an allowable stress for that loading condition must be made. This is usually done by calculating the ratio of the allowable stress to the calculated stress. It is recommended that a conservative approach be adopted to design and that the allowable stress should be taken as the material basic stress (BS 2573:Part 1 Section 5) reduced by a duty factor of 0.95 (BS 2573:Part 1 Section 4.3.1). That is, the safety factor is:

$$\frac{\text{(Material basic stress) x 0.95}}{\text{(Calculated stress due to lifting point design load)}}$$

This must be greater than 1.

3.4.4 The most common basic stresses for plate and rolled sections are given below; BS 2573:Part 1 Section 5 should be consulted for the full range of values.

Stress arising from:	**Basic stress**
Simple axial tension	Material yield stress x 0.6
Tension due to bending (plate etc)	Material yield stress x 0.65
Shear	Material yield stress x 0.37
Bearing	Material yield stress x 0.8

BS 2573 : Part 1 Section 6 covers basic stresses in welded and bolted connections. Provided that the requirements of para 6.1.2.1 are met, the basic stress in a full penetration butt weld is equal to that of the parent metal. The position with regard to fillet welds is rather more complicated and is discussed in

6.1.4. Section 6.2 covers bolted joints. All bolts on a package should be tightened by controlled means, so that the basic stresses are as follows:

Stress arising from:	Basic stress
Axial non-fluctuating load externally applied	Material yield or proof stress x 0.48
Axial fluctuating load, externally applied	Material yield or proof stress x 0.4
Shear	Material yield or proof stress x 0.375

Refer to BS 2573 : Part 1 para 6.2.1.2.3 for bolts in combined tension and shear, and para 6.2.1.2.5 for bearing.

3.4.5 In some instances a lifting feature fitted to a package sub-assembly may still be accessible when the package is lifted during operations; for example, the lid lifting pintle on a waste flask. In this case the designer must demonstrate that the sub-assembly lifting feature is capable of lifting the entire package safely. However, since use of the feature in this way would occur rarely, if ever, and then as the result of an error by the operators, the design may be assessed against the material yield stress rather than the basic stress, and with an impact factor of 1.3.

3.5 Classification for fatigue assessment

3.5.1 A group classification for the lifting point (BS 2573 : Part 1 Section 2) provides a standard approach for certain aspects of the design of the lifting point. Group classification enables a fatigue analysis (BS 2573 : Part 1 Section 8) of the design to be based on the specified life and conditions of service.

3.5.2 Group classification for the lifting point covers the range A1 to A8 (see BS 2573 : Part 1 Table 3) and is determined by considering two aspects of design as follows:

a) Class of utilisation is described in BS 2573 : Part 1 Section 2.2 and is solely dependent on the total number of lifting operations that are expected during the service life of the transport package. A range of operating cycles (BS 2573 : Part 1 Section 2.2.1) from infrequent to continuous use is shown in BS 2573 Table 1 and corresponding utilisation classes can be obtained (U1 to U9).

b) State of loading and nominal load spectrum factor are described in BS 2573 : Part 1 Section 2.3 and determined from the conditions of loading to which the lifting point will be subjected. Essentially the state of loading characterises the extent to which the lifting point carries its maximum load.

Example 1: Some lifting points may be designed as the sole lifting attachments to lift a varying number of modular sections of a transport package. A situation could exist where only one section (with lifting points attached) is frequently lifted and multi sections lifted less often. The maximum load in this case would be the total weight of all modular sections.

Example 2: The state of loading could vary when a package is handled on different sites. The design of a four legged sling arrangement on one site could be such that equal loads are applied to all four lifting points. The lifting gear used on another site could be such that load compensation is not inherent in its design resulting in two diagonally opposite lifting points sharing the load.

A nominal load spectrum factor (BS 2573:Part 1 Section 2.3 and Table 2) quantifies such lifting variations and can be determined if details of the magnitudes of the lifting point loads and the number of times each will be lifted during the proposed service life is known. The magnitudes of these factors can range from 0.5 to 1.0 depending on how light or heavy the state of loading is.

3.5.3 Permissible fatigue stresses are obtained from BS 2573:Part 1 Table 24, the stress depending on constructional detail and the stress ratio f_{min}/f_{max}. The most frequent case is that the package is a single module and is always handled in the same way, often with the same lifting gear. In this case the lifting point load will not vary during service and its state of loading is defined as "very heavy" with a corresponding nominal load spectrum factor of 1.0. The minimum load will be zero, with no stress reversal, so that f_{min}/f_{max} (BS 2573:Part 1 Table 24) will be zero. Where bending and shear stresses are present the principal stress at that point shall not exceed the appropriate permissible tensile or compressive fatigue stress (BS 2573:Part 1 Section 8.5).

3.5.4 BS 2573:Part 1 is useful for the fatigue assessment of welded-on lifting points but less useful for bolted-on lifting points. Very little information is provided to assess the suitability of bolts under cyclic loading. If, however, bolts and studs are tightened to a suitable torque that induces an axial load greater than the load arising during normal service then, when calculating fatigue life, it may be safely assumed that the cyclic component is no more than 20% of the nominal load. It must be appreciated however that bolt preload tends to reduce over a period of time and that regular tightening with a torque wrench may be necessary to maintain it at the required value, see Section 5.2.4. BS 2573:Part 1 Section 8.7.1 states that bolts subjected to stress reversal should be sized on the basis of (f_{max} + f_{min} x 0.5).

3.5.5 Fatigue analysis of steels that do not comply with BS 4360 cannot be carried out using BS 2573:Part 1. (Note: BS 4360 has been withdrawn, refer to section 1.2). BS 7608 is a comprehensive reference on fatigue design and assessment of steel structures which covers a relatively wide range of materials and can be used to assess both welded and bolted-on lifting points. However, exclusions to the standard include out-of-plane joints between hot rolled rectangular or square hollow sections and pressure vessels.

4 MATERIALS

4.1 Selection

4.1.1 If BS 2573:Part 1 is being used as the design standard, then steel shall be selected from either:

a) standard structural steels to BS 4360, or

b) other steels, provided they conform to a published specification and that they have mechanical properties comparable with steels to BS 4360 and have been subjected to equivalent tests.

4.1.2 If a fatigue analysis of the lifting point is required then at the design stage special attention should be given to the material specification, i.e. a material should be chosen that is covered by a published code or standard. The code or standard must include a procedure to check the suitability of the material under the proposed cyclic loading during the serviceable life of the transport package. It should be noted that a bolt-on lifting point can have an advantage over a welded lifting point when the acceptable number of operational cycles is less than the number predicted for the life of the package, since routine replacement can be specified in the operating or maintenance instructions.

4.2 Limitations

4.2.1 Only steels that do not exhibit brittle fracture behaviour may be used; that is the transition temperature must be below the minimum ambient temperature at which the package is to be used. Limitations may be imposed on thick sections where there is no supporting evidence of appropriate impact or other test requirements. For further information on impact test requirements see the relevant standards that have replaced BS 4360 (refer to Section 1.2) and BS 2573:Part 1 Section 4. For further information regarding the selection of steels to counter brittle fracture, see IAEA Guidance in TS-G-1.1 and TECDOC-717 (Guidelines for the Safe Design of Shipping Packages against Brittle Fracture – 1993) .

Note: BS 4360 has been withdrawn; superseded by BS 7613:1994, BS 7668:1994, BS EN 10029:1991, BS EN 10113-1:1993, BS EN 10113-2:1993, BS EN 10113-3:1993, BS EN 10155:1993, BS EN 10210-1:1994

5 TESTING AND EXAMINATION

5.1 Legislative Requirements

5.1.1 This code recommends that relevant established procedures adopted for cranes should be used for the testing and examination of lifting points. BS 7121:Part 2: 1991, Code of Practice for the Safe Use of Cranes, covers inspection, testing and examination requirements, and the following information is based on this standard and established good practice.

5.2 Test Requirements

5.2.1 A proof test by a competent person is required to demonstrate that the lifting points are stable, structurally sound, and fit for the use for which they were designed.

5.2.2 The proof test applies a load in excess of that which would normally occur and should therefore always be carried out with care, as near to the ground as possible, and at the lowest possible lift speed. The test should be performed in accordance with a written procedure.

5.2.3 The size of the proof load is normally the same as the design load, though a different value may be used if it is justified by particular circumstances. If the proof load exceeds the design load, calculations must be carried out to ensure that the stress in any part of the packaging does not exceed the material yield stress.

5.2.4 Proof testing is normally carried out only once. It must be performed again if any alteration or repair has been made which may have affected the strength of the lifting points.

Section 3.5.4 discusses retightening bolts, possibly on a routine basis. Depending on the frequency that this is carried out, a judgment must be made as to whether the bolts should be replaced, whether a thread gauge should be used on the tapped holes, and consequently whether a proof load test should be carried out. For instance, it is common practice during fuel flask maintenance to discard the trunnion attachment bolts one by one without removing the trunnion. As each bolt is removed the tapped hole is gauged and a new bolt fitted and, on completion, the trunnion is proof load tested. For many packaging designs this would be considered unnecessary and some other appropriate level of inspection and checking specified. This may be limited simply to checking bolt tightness. Alternatively, bolts and tapped holes may be visually inspected for corrosion and then tightened to a pre-determined torque. If bolts are replaced, their inherent quality assurance may then be used to justify not proof load testing.

In a few cases, the consequences of a dropped load may be judged sufficiently severe to justify carrying out a proof load test before every lift. The usual overload is 10%.

5.3 Types of Examination and Acceptance Standard

5.3.1 Pre- and in-service examination by a competent person is required to ensure that lifting points are always safe for use throughout the life of the package.

Examination of the lifting points should be included in the packaging periodic maintenance. As a minimum this should require a visual inspection and a statement as to their condition on the maintenance record, together with any remedial action required. To make routine visual inspection easier it is often useful if the more sensitive areas, say an attachment fillet weld, are protected by a clear lacquer rather than by paint.

5.3.2 Prior to any test, the competent person should ensure by thorough examination of the lifting points, that they are:

a) free from any defect that would preclude it from safely handling the test load.

b) in the correct configuration and condition as would be used in normal service.

c) used in conjunction with lifting gear that is representative of that used in normal service. For example, lifting gear sling angles or lifting gear that may or may not have inherent load compensating features.

5.3.3 After testing, a thorough visual examination should be carried out by a competent person to ensure that the lifting points and the surrounding local areas of the mating parts have withstood the test load without signs of structural damage that will affect the safety of the lifting points or mating parts. Indications of material yield or incipient failure are:

a) cracking

b) permanent deformation

c) paint flaking

5.3.4 If the designer considers it necessary, or the design code requires it, the thorough examination should be supplemented by the following:

a) Non-destructive testing. This would normally be dye-penetrant or magnetic particle inspection. Where the package contents are particularly hazardous, ultrasonic or radiographic inspection should be considered. Any defect found should be assessed in accordance with a recognised published acceptance standard, e.g. BSI publication PD 6493:1991, "Guidance on methods for assessing the acceptability of flaws in fusion welded structures", and endorsed by the competent person controlling the examination.

b) The opening up of concealed or encased parts by a skilled person to the extent required by the competent person.

6 CERTIFICATION

A certificate should be issued by the inspecting authority to prove that the lifting points have been proof load tested to the specified load and manner. This will be issued:

a) Prior to the packaging entering service for the first time.

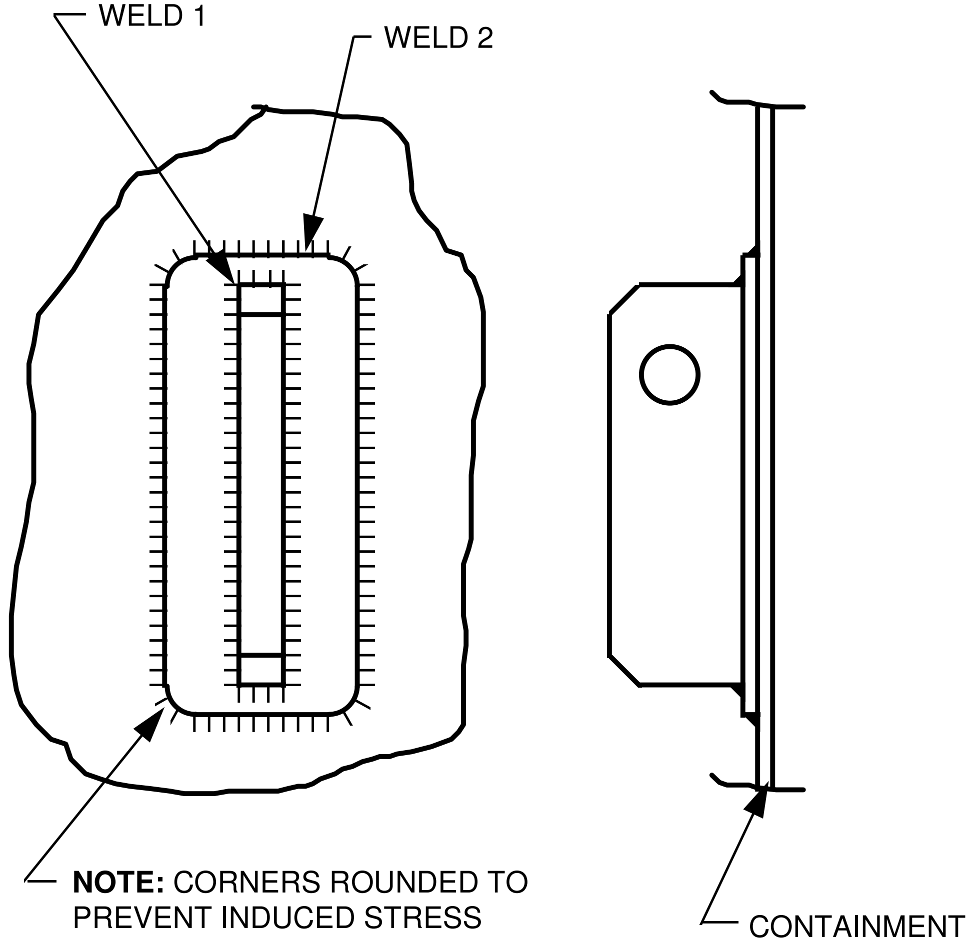
b) Prior to the packaging entering service following a significant alteration or repair.

7 MARKING

The package maximum gross weight must be clearly marked. If the package can be lifted in smaller sub-assemblies, all weight markings must be completely unambiguous to ensure that under no circumstances will lifting gear be used that is insufficiently rated.

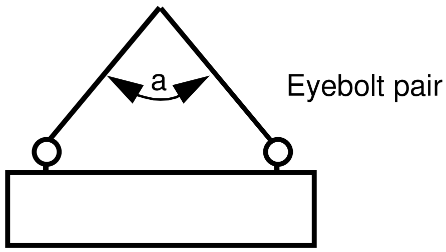
If there is any possibility of confusion, each lifting point must be identified as such. Where necessary the design load may be marked, but this must be done in such a way that there can be no confusion with the overall package weight.

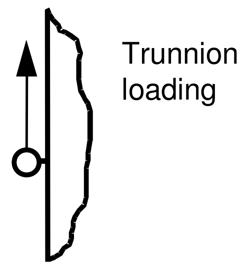
All tapped holes used for lifting must be permanently marked to identify the thread form and diameter. It is good practice to mark the tightening torque adjacent to a bolted lifting point.



Area of Weld 1 is less than the area of Weld 2. Therefore Weld 1 will fail in preference, leaving the containment intact.

Figure 1 Example of how a lifting attachment can be designed to fail without damaging the packaging





Eyebolts to BS 4278:1984	DERATING FACTOR			
	Eyebolt pair, included angle = a			Trunnion loading
	0 °- 30 °	31 °- 60 °	61 °- 90 °	
Collar eyebolts	0.63	0.4	0.25	0.25
Link eyebolts	1.0	0.8	0.63	0.63

Figure 2 (a): Eyebolt ratings

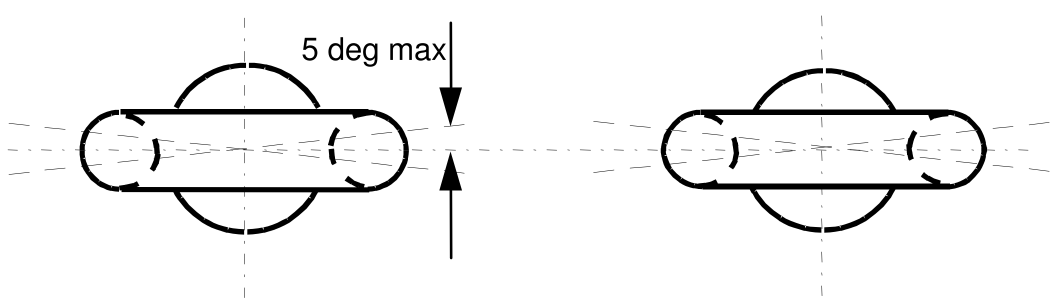
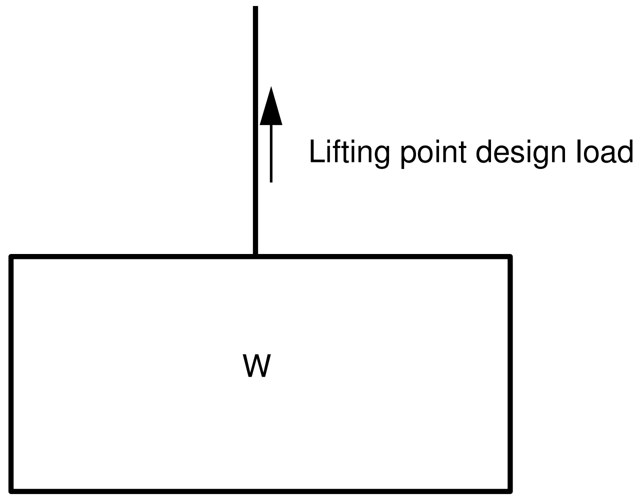


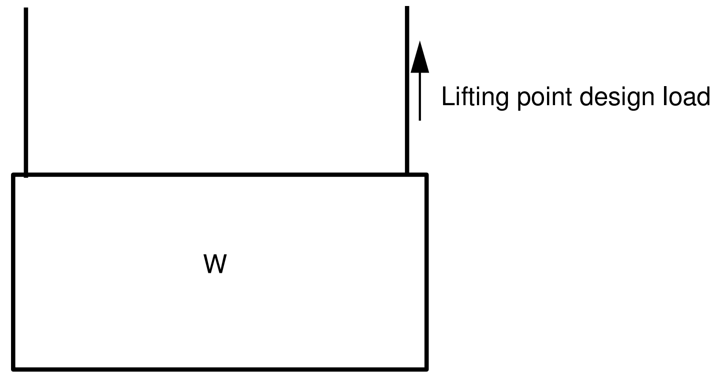
Figure 2 (b): Maximum misalignment of a pair of eyebolts



Package weight	W
Lifting point design load	2W

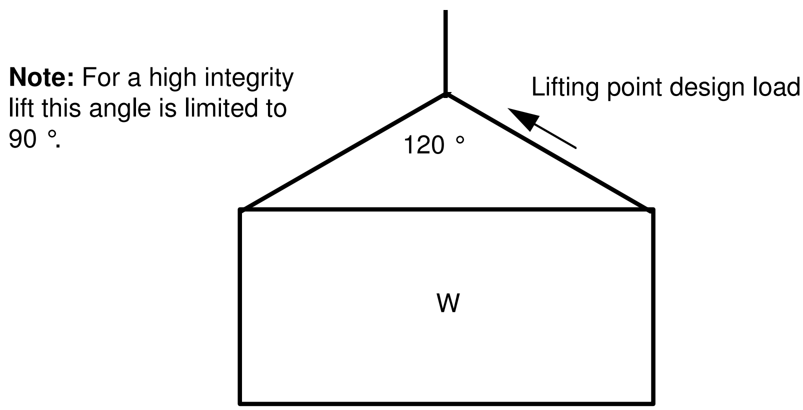
Note: Impact factor = 2.

Figure 3 Single point lift



Package weight	W
Lifting point design load	W

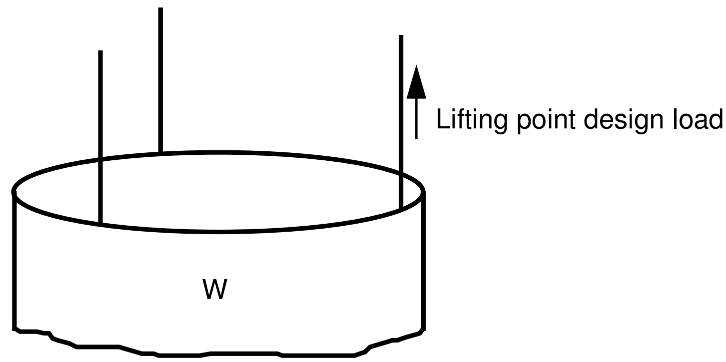
Note: Impact factor = 2



Package weight	W
Lifting point design load	2W

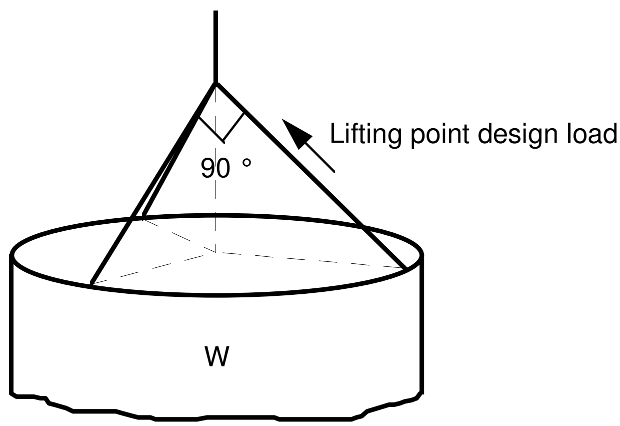
Note: Impact factor = 2

Figure 4 Two point lift



Package weight	W
Lifting point design load	2W/3

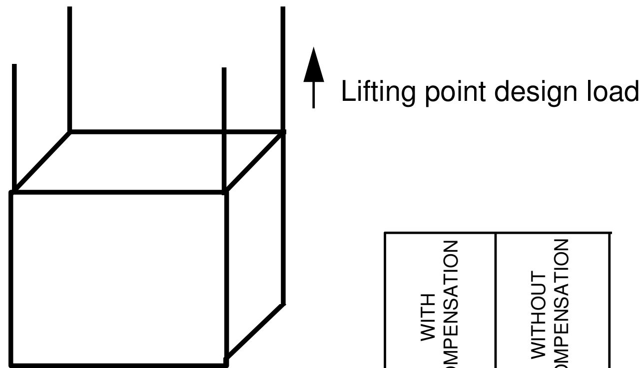
Note: Impact factor = 2



Package weight	W
Lifting point design load	1.15W

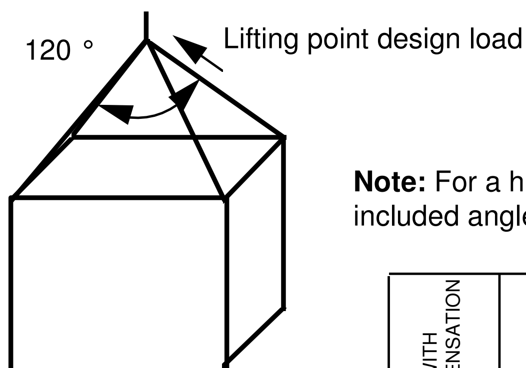
Note: Impact factor = 2

Figure 5 Three point lift



	WITH COMPENSATION	WITHOUT COMPENSATION
Package weight	W	W
Lifting point design load	W/2	W

Note: Impact factor = 2



Note: For a high integrity lift the included angle is limited to 90 °.

	WITH COMPENSATION	WITHOUT COMPENSATION
Package weight	W	W
Lifting point design load	W	2W

Note: Impact factor = 2

Figure 6 Four point lift

APPENDIX

RECOMMENDED METHODS FOR THE DESIGN OF LIFTING LUGS

A1 General

The design code to be used when designing lifting lugs is BS 2573:Part 1.

The following symbols are used in subsequent equations:

a = Fillet weld leg length

A_b = Effective bolt cross-sectional area

AS_n = Thread stripping area

A_w = Weld cross-sectional area.

b = Fillet weld throat thickness = $a/\sqrt{2}$

B = Lifting lug thickness

d_e = Effective bolt diameter, equal to the core diameter

d_{nom} = Bolt nominal diameter

d_m = Distance of a particular bolt from a reference point

D = diameter of lifting lug hole

$D_{s,min}$ = Minimum major diameter of bolt thread

DF = Duty factor, from BS 2573 Table 4

$E_{n,max}$ = Max effective diameter of internal thread

F = Applied load

F_h = Horizontal component of F

F_t = Bolt load

F_v = Vertical component of F

H = Depth of lifting lug in shear

i = A positive integer

IF = Impact factor, normally taken as 2. Otherwise refer to BS 2573 Table 4

I_w = Weld second moment of area

J = Moment arm length on bolted lifting lug

K = Height of lifting lug hole centre line

L = Width of lifting lug

L_e = Length of bolt engagement

n = Number of bolts securing a lug

p = Bolt thread pitch

P_t = Factor to derive basic stress in tension = 0.6. (BS 2573 para 5.1.2)

P_s = Factor to derive basic stress in shear = 0.37. (BS 2573 para 5.1.5.1)

P_{be} = Factor to derive basic stress in bearing = 0.8. (BS 2573 para 5.1.6)

SF = Safety factor; ratio of basic stress to calculated stress; must always > 1

T = Bolt tightening torque

W = Width of lifting lug section under maximum tensile load

Y = Material yield stress or 0.2% proof stress

σ_b = Bending stress

σ_{be} = Bearing stress

σ_s = Shear stress

σ_t = Tensile stress

σ_T = Vectorially combined stress

A2 Stress within the lug

Refer to Fig A1. The safety factors for the various types of loading are found as follows:

(a) Tension:

$$\sigma_t = \frac{F_v.IF}{2.W.B}$$

$$SF = \frac{P_t.Y.DF}{\sigma_t}$$

(b) Shear:

$$\sigma_s = \frac{F_v.IF}{2.H.B}$$

$$SF = \frac{P_s.Y.DF}{\sigma_s}$$

(c) Bearing:

$$\sigma_{be} = \frac{F.IF}{D.B}$$

$$SF = \frac{P_{be}.Y.DF}{\sigma_{be}}$$

A3 Stress in a continuous fillet weld securing a lug

Refer to Fig A2. The calculation proceeds in three stages.

(a) First calculate the peak stress in the weld.

The second moment of area of the weld is:

$$I_w = \frac{\left((B+2.b).(L+2.b)^3\right) - B.L^3}{12}$$

The cross sectional area of the weld is:

$$A_w = \left((B+2.b).(L+2.b)\right) - B.L$$

The bending stress in the weld is:

$$\sigma_b = \frac{F_h.K(L+2.b).IF}{I_w.2}$$

The tensile stress in the weld is:

$$\sigma_t = \frac{F_v.IF}{A_w}$$

The shear stress in the weld is:

$$\sigma_s = \frac{F_h.IF}{A_w}$$

The peak combined stress is:

$$\sigma_T = \sqrt{\left(\sigma_b^{\,2} + \sigma_t^{\,2} + \sigma_s^{\,2}\right)}$$

(b) Now find the basic stress for the weld material.

BS 2573 Table 18 gives the basic stresses for certain grades of steel and welding consumable. Para 6.1.4.4 states that the basic stress shall not exceed either:

0.3 x ultimate tensile strength of the welding consumable

or:

0.3 x ultimate tensile strength of the parent material whichever is the lower.

(c) The safety factor may now be calculated.

$$SF = \frac{Basic\ stress \times DF}{\sigma_T}$$

A4 Stress in bolts securing a lug.

The maximum bolt stress is calculated first. Then if the bolts are screwed into a weaker material an additional calculation should be carried out to ensure that the female thread is not overstressed. The method for determining bolt tightening torque is also given.

(a) Calculate maximum bolt stress.

Refer to Fig A3. The effective bolt cross-sectional area is:

$$A_b = \frac{\pi . d_e^{\,2}}{4}$$

Assume that the lug pivots around point *P*. The maximum tensile load occurs in the two bolts furthest from *P*. The tensile stress in each of these bolts is:

$$\sigma_t = \frac{F.J.d_4.IF}{\left(d_1^{\,2} + d_2^{\,2} + d_3^{\,2} + d_4^{\,2}\right).A_b.2}$$

The general case for two rows of bolts is:

$$\sigma_t = \frac{F.J.IF}{A_b.2} . \frac{d_m}{\Sigma_{i=1}^{m}\left(d_i^{\,2}\right)} \quad where \quad m = \frac{n}{2} - 1$$

The shear load is shared equally, the shear stress is:

$$\sigma_s = \frac{F_h.IF}{n.A_b}$$

BS 2573 para 6.2.1.2.4 states that the following criteria must be satisfied:

$\sigma_t \leq 0.48 . Y . DF$ (non-fluctuating loads, bolt tightened by controlled means)

$\sigma_t \leq 0.4 . Y . DF$ (fluctuating loads, bolt tightened by controlled means)

$\sigma_s \leq 0.375 . Y . DF$

$\sqrt{(\sigma_t^2 + 3.\sigma_s^2)} \leq 1.2 . 0.48 . Y . DF$

(b) Calculate the strength of the female thread.

Since the bolts will almost certainly be screwed into holes tapped in material with a lower strength than themselves the stripping strength of the tapped holes should be assessed. BS 3580 Appendix A gives the following formula for calculating the stripping area of a female Unified thread which is also applicable to ISO metric threads.

$$AS_n = \frac{\pi . L_e . D_{s,\min}}{p} . \left[0.5p + 0.577\left(D_{s,\min} - E_{n,\max}\right)\right]$$

(If a conservative approach is to be taken, then it should be assumed that all the load is taken on the first five engaged threads regardless of the total length of thread engagement. Table A1 gives AS_n calculated on this assumption for a range of bolt sizes.)

The shear stress in the tapped hole is:

$$\sigma_s = \frac{F.J.d_4.IF}{\left(d_1^2 + d_2^2 + d_3^2 + d_4^2\right).AS_n.2}$$

The safety factor is:

$$SF = \frac{P_s.Y.DF}{\sigma_s}$$

Though it may not always be possible to achieve, it is good practice to arrange the failure mode to be by bolt fracture rather than thread stripping.

Table A1: Stripping area for 5 thread engagement

BOLT SIZE (ISO METRIC)	STRIPPING AREA FEMALE THREAD (mm²)
12	289
16	440
20	687
24	989
30	1443
36	1979

(c) Calculate tightening torque.

To avoid bolt fatigue the tightening torque should induce a bolt load in excess of that developed in service. Ideally bolts should be tightened in a controlled manner to a pre-determined torque to give a bolt load of 70 - 80% of the bolt material yield stress. (BS 2573 Section 6.2.1.2.2 (b)). This load may need to be modified if calculation 4(b) shows that the strength of the female thread is the limiting factor. Tightening torque may be calculated from the desired bolt axial load using the following equation:

$$T = \frac{F_t \, . \, d_{nom}}{5}$$

where the units are: T - Nm; F_t - kN; and d_{nom} - mm.

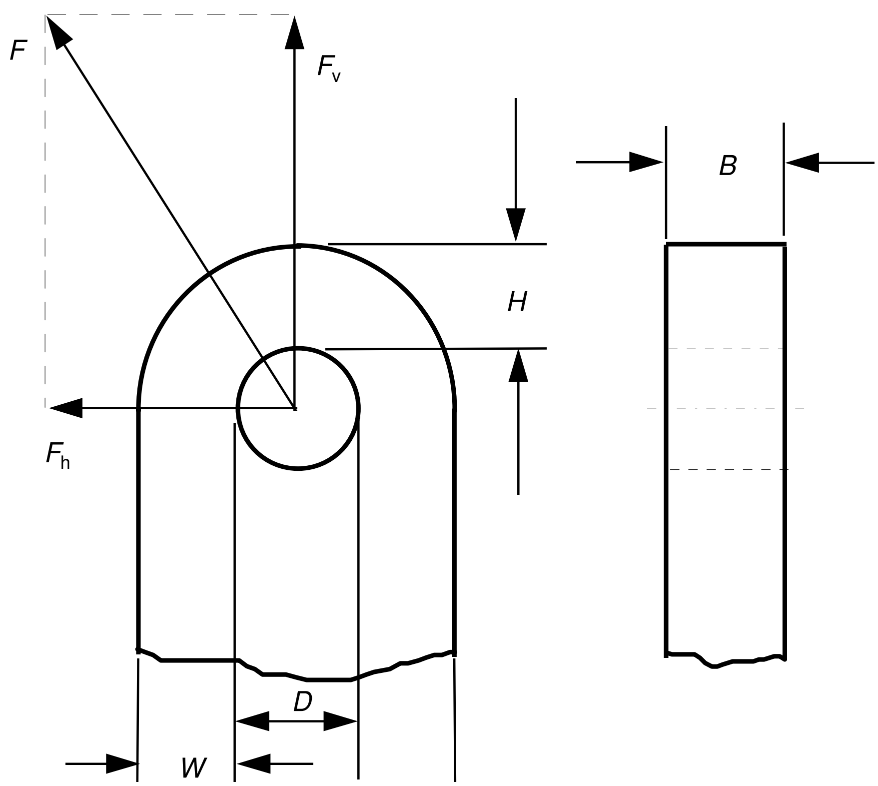


Figure A 1. Generic lug details

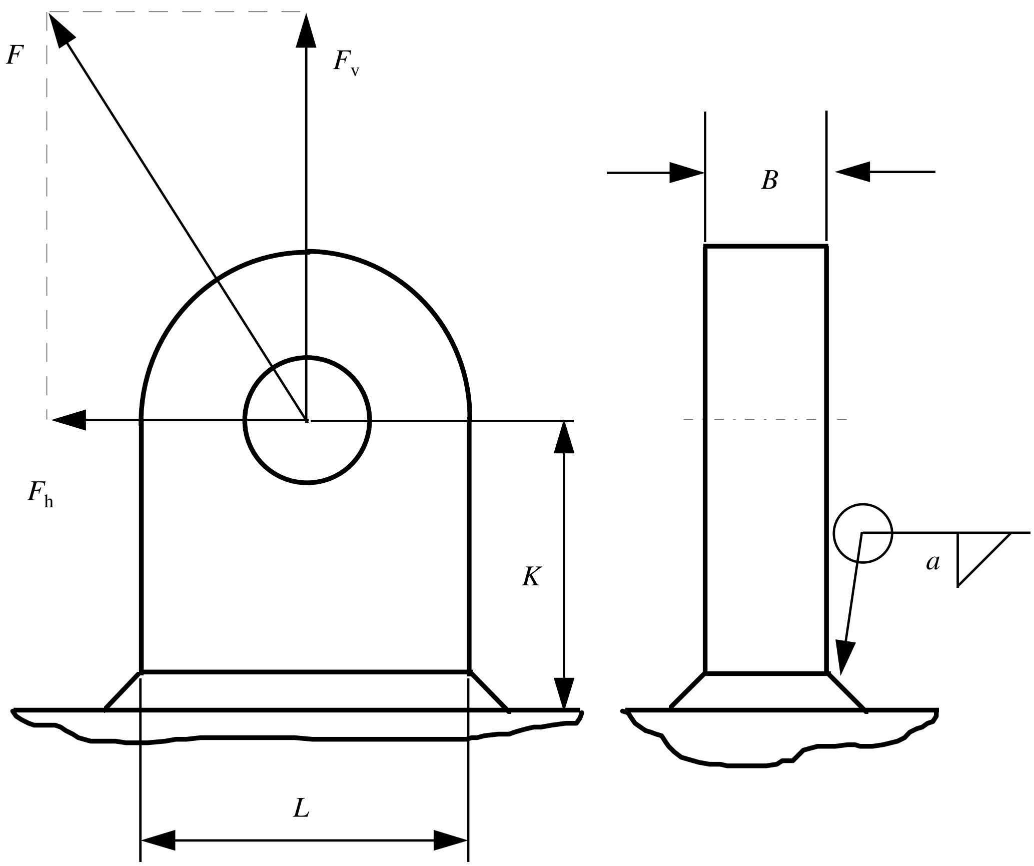


Figure A 2. Welded lug

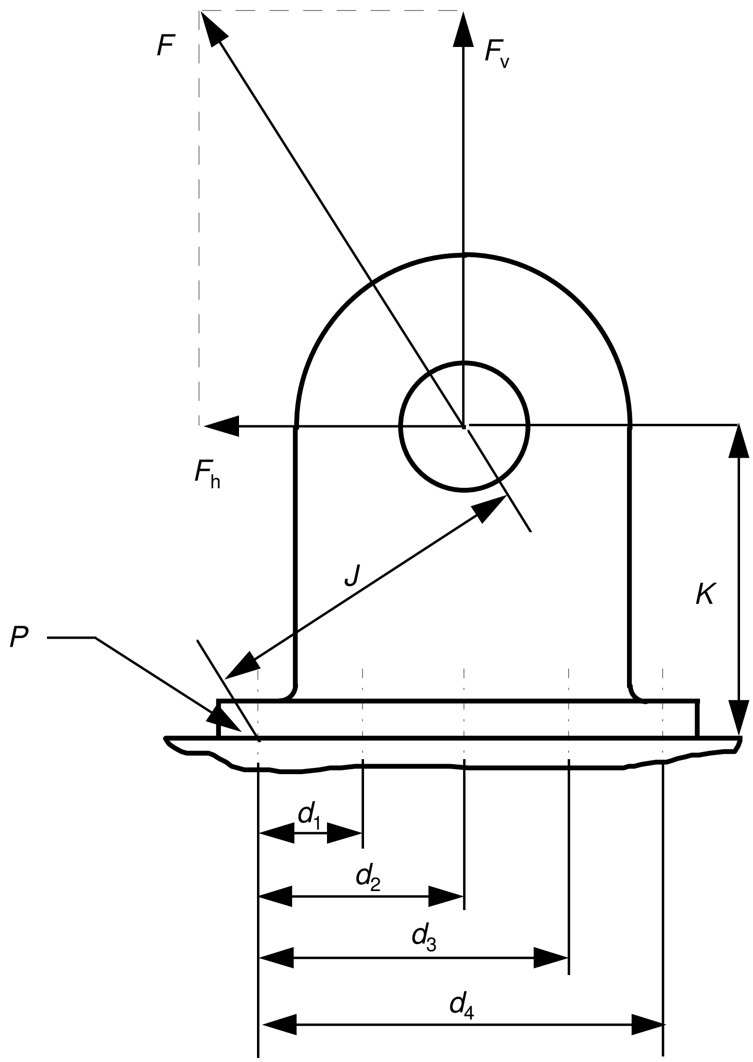


Figure A 3. Bolted lug, secured with 10 bolts