

Guide for

Prevention of leaks from hydraulic fluid power systems

Confirmed
July 2009

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- British Hydromechanics Research Association

This British Standard, having been prepared under the direction of the Machinery and Components Standards Policy Committee, was published under the authority of the Board of BSI and comes into effect on 28 February 1991

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The following BSI references relate to the work on this standard:
Committee reference MCE/18
Draft for comment 89/70465 DC

ISBN 0 580 19214 8

Amendments issued since publication

Amd. No.	Date	Comments

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Foreword

This British Standard has been prepared under the direction of the Machinery and Components Standards Policy Committee.

For many years users of hydraulic equipment have identified external leakage as a major problem and in certain areas this can constitute a serious hazard to personnel and plant. Two major surveys confirmed this to be the case and further identified pipe couplings as the major source of leakage.

External leakage from hydraulic systems is always undesirable and can be prevented. The consequences of such leakage depend upon the situation and can vary from being a mild nuisance to a significant safety hazard. Leakage and its effect on the working environment are frequently perceived to be a justification for avoiding the use of hydraulics.

Oil spills are hazardous both as fire risks and in their potential for creating slippery conditions underfoot. Spilt oil is unsightly in most working situations. The cost of replacing lost fluids can be significant in large systems, and frequent addition of replacement fluid is a significant cause of contamination. The maintenance costs consequent upon leakage are an unnecessary expense.

In many environments, such as food processing plants, such leakage is absolutely inadmissible. The users' reaction to leakage is an obstacle to the sales of hydraulic systems and it is in the interests of all concerned in the fluid power industry to prevent it. The major requirements of preventing leakage are acceptance that it can be achieved and the will to ensure that it is done. The techniques are simple and are outlined in this British Standard.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 28, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

0 Introduction

The majority of leaks from hydraulic fluid power systems occur at fittings for the following reasons:

- a) poor pipework design, which leads to over-stressed fittings;
- b) poor accessibility, particularly of fittings, which makes maintenance difficult; this also is a design failure.

The designer usually concentrates his efforts on the critical areas of his design brief, principally related to performance and cost. The pipework is then often delegated to juniors, or even left to the fitters.

If persons wish to buy or sell leak free systems, they should ensure that leakage control is recognized as a significant part of the designer's brief which should appear in the specification so that pipework design and design for maintenance are taken seriously.

Various clauses in this standard refer to the responsibilities of various persons involved in the purchase, design and maintenance of hydraulic equipment. The accountabilities of these persons are described in greater detail in BS 4575-3.

1 Scope

This British Standard provides guidance on the design of hydraulic systems and their installations with a view to minimizing external leakage of fluids and is intended to provide guidance on the way the design specification should define how the customer's requirements in respect of leakage are to be met.

This standard encompasses system specification, circuit design considerations, component specification, pipework design, installation procedures and commissioning.

This standard is not concerned with aspects of systems other than those which relate to leakage and excludes aerospace application and design of hydraulic components.

NOTE The publications referred to in this standard are listed on page 28.

2 Specifications

2.1 General

For a fixed installation, it is usually the customer who writes the performance specification. Therefore, if the customer wants a leak free system, this need should be defined in the performance specification. If leakage is overlooked at this stage, and particularly if the system is ordered from the cheapest quotation, then the customer will have no grounds for complaint if the system is not leak free. Similarly, if the manufacturer specifies the performance, leakage should be included and form part of the inspection requirement.

2.2 Definition of leakage

For the purposes of a specification, it is necessary that the degree of leakage should be defined. A totally leak free system is expensive if only because dynamic seals rely upon a smear of oil for lubrication, so that cylinder piston rods usually run "damp", and strictly speaking this oil is "leakage", if it drips off the rod. Recommended categories of leakage rates are given in Appendix A.

2.3 Operating specification

A leakage specification should be described in terms of what is tolerable. For example, "No oil may be allowed to leak on to the floor either in operation or during maintenance": this form of words would imply the acceptability of drip trays. "Exposed oily surfaces are not allowed": this would be more expensive and would require drain cavities on piston rods and probably rod gaiters; drip trays would be excluded. "Oil usage due to leakage during normal operation must not exceed 1 L per 1 000 h running time": this would, in general, be applicable only to large fixed installations, but would have the advantage of being quantified.

2.4 Conditions applying to maintenance

2.4.1 Since maintenance operations commonly create more spillage than normal running, it may be desirable to specify that certain parts of the system are to be isolated and drained before removing pipes or components.

A study of clauses 5 and 10 may reveal other areas which might be included in the customer's operating specification. The circumstances in which maintenance will be performed may be defined, e.g. at sea, in harbour, in the field, etc. The type of labour available for installation and maintenance should also be a design consideration.

2.4.2 The operating environment should be defined as part of the customer's specification.

2.5 Design specification

2.5.1 If the customer writes the operating requirements or functional specification to describe what is wanted, the supplier would usually write a design specification to define how the customer's requirement is to be met.

2.5.2 Before writing the design specification, it is important that the customer's requirement and its implications for design and manufacture are understood and acceptable. If the customer's requirement is not clearly stated, then it should be clarified and a statement included in the proposal about the leakage standard to which the system will be designed. Some caution should be exercised in the use of "dry" as a description. Areas around static seals, such as sub-plate surfaces, tend in time to become damp with oil, even if there is no measurable oil accumulation. In a dusty environment such dampness becomes very evident. The same comment applies to piston rods, as mentioned earlier. Truly "dry" systems can be achieved, but great attention to detail is necessary.

2.5.3 Having established the customer's requirements in respect of leakage, the design specification should define how the requirements are to be met. It should be appreciated that most requirements can be met by the use of good engineering practice and consequently are not expensive. However, unnecessarily strict requirements result in expensive solutions.

3 Design considerations

3.1 General

3.1.1 Design

System design, as it affects leakage, should be considered in relation to the operating conditions and the environment. The following features will make leakage control more difficult:

- a) high pressure levels, e.g. above 200 bar¹⁾;
- b) sudden pressure changes, e.g. pressure ripple or pressure shocks;

c) high or low temperatures or wide temperature variations, e.g. above 700 °C below – 30 °C or more than 70 °C variation;

d) low viscosity fluids, i.e. 10 cSt²⁾ or less;

e) systems mounted on vibrating or flexible structures;

f) corrosive atmospheres, e.g. marine;

g) abrasive environment (the effect on cylinder rods, pump shafts, etc.)

3.1.2 Contamination control

It is essential that fluid cleanliness should be maintained in a system to avoid contaminants damaging such items as dynamic seals and their sealing surfaces, thereby leading to leakage.

3.2 Number of pipe joints

Extensive analysis of working systems has shown that pipe joints account for the majority of leaks. Much can be done to minimize the likelihood of leaks at pipe fitting, but an obvious approach to the situation is to reduce the number of such joints. In particular, the reduction or elimination of joints that have to be broken and remade in normal maintenance should be a high priority. Valve mounting methods have a strong influence on the proliferation of pipe joints; the various methods are described in 3.3.

3.3 Valve mounting methods

3.3.1 Pipe mounted (threaded body) valves

The pipe connections for such valves have to be disconnected in order to remove them for service; the use of this type of valve normally necessitates the maximum number of pipes and fittings. Such valves should be avoided whenever possible. However, the use of breakaway couplings would allow the removal of valves with minimum disturbance of pipework.

3.3.2 Sub-plate mounted valves

The use of a sub-plate does not reduce the number of pipes or fittings but it does enable the valve to be removed without disturbing pipe joints. It does introduce an additional potential leakage path at the interface, but compared with pipe mounting it is much to be preferred.

¹⁾ 1 bar = 10⁵ N/m² = 100 kPa.

²⁾ 1 cSt = 10⁻⁶ m²/s.

3.3.3 *Manifold valve stations*

A manifold valve station is similar in principle to the sub-plate mounting described in 3.3.2 except that, instead of individual sub-plates having their own valves, all the valves are mounted on a single manifold block within which fluid interconnections between valves are made through drilled passageways.

Manifold blocks range in complexity from simple units that accept two or more directional valves, with series or parallel connections, to blocks containing complete circuits. The former can be purchased as stock items, but the latter have to be made to order. Manifold blocks can make a great contribution to reducing the number of joints and are a major aid to maintenance.

3.3.4 *Cartridge valves*

An alternative to the sub-plate valve is the cartridge valve, which fits into a cavity in a housing. The housing is the equivalent of a sub-plate and accepts the pipe connections.

Cartridge valves are usually either pressure or flow controls, although multiple piloted check valves are often used as high flow directional valves. The cartridge valve is perhaps the most leak free of valve mountings since there is usually only one potential leak path. As with a sub-plate mounted valve, the cartridge valve can be removed without disturbing pipe connections.

3.3.5 *Cartridge valve manifold*

Manifold blocks of widely different degrees of complexity can be made for cartridges, just as for sub-plate valves, and with the same advantages. Mixed cartridge and sub-plate manifolds are common.

3.3.6 *Stacked valve stations*

A variant on the sub-plate valve is the “modular” valve which is sandwiched between a directional valve and its sub-plate. These are available in many combinations of flow, pressure and check valves. These too are helpful in that they reduce the complexity of pipework and simplify maintenance.

3.3.7 *Multiple directional valves*

Multiple spool directional valves with semi-standardized interconnections are available in either mono-block or stackable configurations. Circuit relief valves are commonly incorporated and such valves reduce pipework, although their removal requires pipe connections to be broken.

NOTE Multiple directional valves are particularly suitable for use in mobile systems.

3.4 *Pipe systems*

Careful consideration should be given to choosing the type of pipework, joining, routing and mounting methods. For example, the use of a cold bend in annealed piping [up to 50 mm outside diameter (o.d.)] reduces the number of potential leak paths by two (compared with the use of a fitting) and aids smooth flow. Since a cold bend is difficult to produce, such work should only be carried out by competent personnel.

The use of flexible hose to connect to moving or vibrating components reduces transmitted vibration and movement to a rigid pipework run.

A welded joint between two pipes, although technically a “joint”, can in most systems be regarded as leak free after its initial proof test. (This may be untrue in systems subject to very high pressure peaks, vibration and shocks.)

NOTE A guide to the selection of appropriate fittings for various applications will be added to this standard in due course to take account of a current research programme.

3.5 *Handling*

Suitable lifting and handling points should be provided on equipment heavier than 45 kg (see 8.2.5).

4 *Component choice*

4.1 *General*

The choice of components is governed by a number of factors; potential leakage should be considered as one of those factors.

NOTE Guidance for the selection of components will be added to this standard in due course to take account of a current research programme.

4.2 *Tubing*

4.2.1 *Characteristics*

Too often, tubing is not specified fully. There are many standards of tube available; the following features should be considered:

- a) material type and strength;
- b) production and test method;
- c) wall thickness;
- d) o.d. tolerance;
- e) surface finish;
- f) hardness.

Care should be taken not to mix imperial with metric dimensioned tubing.

4.2.2 *Steel tubing*

Imperial and metric dimensioned tubing may be purchased in accordance with BS 3602-1. The following details should be specified:

- a) method of manufacture, e.g. cold finished seamless (CFS);
- b) material grade, e.g. 430;
- c) test category (category 1 covers ultrasonic testing and category 2 covers leak tightness testing);
- d) tubing dimensions, i.e. o.d., thickness and their tolerances; for metric tubing these are specified in BS 7416³⁾.

NOTE BS 3602-1 is supplemented by BS 7416³⁾ for fluid power systems.

Metric dimensioned tubing is also available to DIN 2391.

Ideally cold drawn tubing should be used in all hydraulic systems; however, it is not widely available larger than 50 mm o.d. As an alternative hot finished tubing may be used provided it is de-scaled and only used for welded joints.

Another suitable alternative to tubing in accordance with BS 3602-1 is cold finished electric resistance welded tubing. This is generally stocked as being in accordance with ASTM A513; it has the advantage of high strength, close tolerances and good surface finish but is not suitable for bending or flaring. Hydrostatic testing is not a general requirement of ASTM A513 but may be carried out by the manufacturer when specified on the order.

4.2.3 Corrosion resistant steel tubing

This is generally available to ASTM A269 grade 316 or 321. Additional requirements of o.d. tolerance and surface hardness should be specified.

4.2.4 Copper-nickel alloy tubing

The copper-nickel alloy tubing most frequently used is designated CN102 (nominally 90/10 copper-nickel-iron) or CN107 (nominally 70/30 copper-nickel) in BS 2871-2. This tubing is seamless and normally available in the size range 6 mm to 44.5 mm diameter though larger sizes are also available. Chemical composition, dimensions and tolerances, mechanical properties and methods of test are specified in BS 2871-2. Information on maximum design stresses at ambient and elevated temperatures is given in BS 1306.

4.3 Tube fittings

4.3.1 General

There are many different types of couplings available falling within two main categories: breakable (generally compression type) and permanent.

In choosing the type of joint to be used, tubing size, working pressure and temperature, the environment, type of tubing to be used, and the skills available should be considered.

4.3.2 Compression couplings

4.3.2.1 General

There are three main types of compression coupling:

- a) bite type (see 4.3.2.2);
- b) flare type (see 4.3.2.3);
- c) sealing ring type (see 4.3.2.4).

These are detailed in BS 4368-1 and BS 4368-3, which specify dimensions for metric couplings.

All fittings are pre-assembled using hardened pre-assembly tools or powered assembly tools.

Manufacturers' retightening instructions should be followed.

If corrosion resistant steel couplings and tubing are to be assembled special anti-galling lubricants should be used to reduce assembly torque and to prevent galling.

4.3.2.2 24° bite type couplings

Details of 24° bite type couplings are as follows.

- a) *Design*: this is a three-piece design, comprising body, tube nut and ferrule, an example of which is shown in Figure 1.
- b) *Available standards*:
BS 4368-1, Type A for low pressure
BS 4368-3, for high pressure
ISO 8434: for high pressure
DIN 2353, LL for very low pressure, L for low pressure, H for high pressure.
- c) *Operation*: as the nut is tightened, the ferrule moves along the tubing and, at the same time, the leading edge cuts into it. The ferrule pushes up a ridge of metal in front of it.
During the making of the joint, the ring is altered in shape and its leading edge becomes embedded in the tube.
- d) *Operating pressure*: the operating pressure depends on size and series.
- e) *Size range*:

- 1) very low pressure, 4 mm to 8 mm o.d.;
- 2) low pressure, 6 mm to 42 mm o.d.;
- 3) high pressure, 6 mm to 38 mm o.d.;

³⁾ In preparation.

f) *Commentary*: different types of ferrule are offered by different manufacturers, whilst bodies and nuts are made to a dimensioned standard; it is therefore not safe practice to mix components from different makers. This is particularly pertinent with respect to product liability.

When using thin walled tubing, inserts should be used to avoid excessive tube collapse.

4.3.2.3 37° flare type couplings

Details of 37° flare type couplings are as follows.

a) *Design*: this is a three-piece design, comprising body, tube nut and sleeve, an example of which is shown in Figure 2.

b) *Available standards*:

BS 4368-1

BS 4368-3, Type B

SAE J514

⁴⁾ISO 8434.

c) *Operation*: the tubing is flared outwards and is clamped between the body nose and sleeve surfaces.

d) *Operating pressure*: the operating pressure is not generally quoted, being based on tube wall thickness.

e) *Size range*: 6 mm to 38 mm o.d.

f) *Commentary*: it is important that the tube end is square and deburred.

If flare length is:

1) too short the flare will be squeezed thin due to the small area of tubing clamped and there will be danger of fracture;

2) too long the tubing may foul on the threads of the nut when assembling the coupling.

It is important that both the inside and outside diameters of tubing are free from surface imperfections and that the tubing is fully annealed to avoid splitting/cracking when flaring.

The joint can be broken and remade.

4.3.2.4 "O"-ring type couplings

Details of "O"-ring type couplings are as follows.

a) *Design*: this is a five-piece design, comprising body, sealing ring, seal support washer, split collet and tube nut, an example of which is shown in Figure 3.

b) *Available standards*: BS 4368-1 and BS 4368-3: Type C.

c) *Operation*: an "O"-ring seals between the tube o.d. and the coupling bore. The split collet has an inner surface with teeth which retains the tube in position.

d) *Operating pressure*: the operating pressure depends on size. Generally "O"-ring couplings, particularly larger sizes, have the highest operating pressure of the three types of coupling in 4.3.2 to 4.3.4.

e) *Size range*: 6 mm to 50 mm is a screwed nut design and 50 mm to 140 mm is a flange design.

f) *Commentary*: the separate sealing and tubing retention makes this design suitable for use in vibration situations. It is important that the correct assembly procedure is followed. The joint can be broken and remade; the "O"-ring should be examined, however, and replaced if necessary. A replacement ring should be of correct size and hardness and preferably obtained from the original supplier.

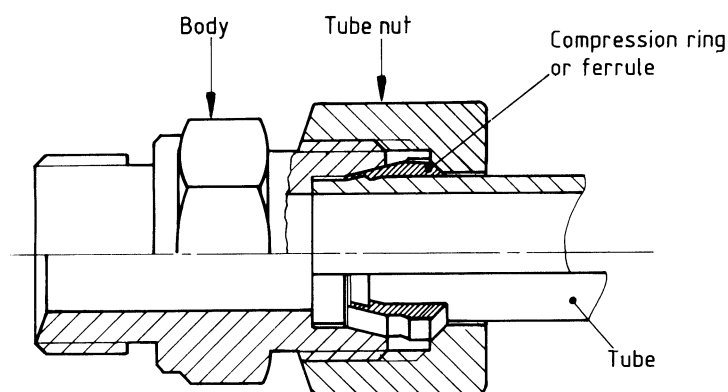


Figure 1 — Example of a 24° bite type compression coupling

⁴⁾ In preparation.