



Specification for

Aluminium piping systems

Part 2. Design

Systèmes de tubes en aluminium
2ème partie. Calcul

Aluminiumrohrsysteme
Teil 2. Konstruktion

British Standards Institution



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Foreword

This British Standard, published under the authority of the Pressure Vessels Industry Standards Committee, is one of a series dealing separately with steel, copper and aluminium pipework.

Hitherto, there has been no British Standard dealing comprehensively with aluminium pipes and components and pipework systems for chemical, cryogenic and pressure purposes, the only guidance available being under the broad heading of 'non-ferrous' and a brief reference to aluminium in BS 3351.

This standard is published in two Parts:

- Part 1 Dimensions, materials and construction of components
- Part 2 Design

In preparing the two Parts of this standard, account has been taken of the provisions of the American National Standards Institute document ANSI B16.31-1971, Non-ferrous Pipe Flanges, where applicable to aluminium.

Future development in design, materials, fabrication and installation procedures may make it necessary for the provisions of this standard to be reviewed periodically and in consequence it is desirable that experience in all aspects of its application be conveyed by users to the BSI Committee for consideration.

For components of steel and materials other than aluminium used in aluminium pipework systems reference should be made to the appropriate British Standards.

British Standard Specification for Aluminium piping systems

Section one. General

1. Scope

This Part of this British Standard for aluminium piping systems specifies the minimum requirements and recommended practice for the selection and application of materials and components for chemical, cryogenic and pressure purposes and the design, fabrication, installation, inspection and testing of these systems.

Piping systems in this standard are interpreted as assemblies of pipe, valves, pipe fittings, flanges, bolting, gaskets and pipe supports and anchors, where the majority of components are aluminium.

General references to aluminium shall be interpreted as including both aluminium and aluminium alloy materials and components covered by Part 1 and Part 2 of the standard.

The standard covers jointing by fusion welding only and other forms of jointing shall be as agreed between the manufacturer and the purchaser.

2. References

The titles of the British Standards referred to in this Standard are listed on the inside back cover.

3. Definitions

For the purposes of this British Standard the following definitions apply.

3.1 process piping. All piping of the unit or plant used in the chemical, cryogenic or pressure applications of the process. The term is taken to apply also to process lines directly interconnecting such units or plants, and to piping and fittings used to connect services, instrumentation and control apparatus to the process pipes and equipment.

3.2 process fluid. This shall be interpreted as covering all gas, vapour, liquid, slurry and granular or powdered material employed in the process or associated services, which have to be conveyed by the process piping system.

3.3 hazardous service. A service or process in which a hazard to personnel or plant could be created in the event of leakage or failure of the pipework and its accessories or the equipment to which they are connected.

3.4 design pressure. The value of pressure to be used for calculations of pipe wall thickness (section five).

3.5 design temperature. The temperature to be used to establish the appropriate value of design stress (table 1).

3.6 nominal size. The nominal size (DN) is a numerical designation of size which is common to all components in

a piping system other than those designated by outside diameter. It is a convenient round number for reference purposes and it is normally only loosely related to manufacturing dimensions.

4. Information to be supplied by the purchaser

The purchaser shall state the following in the enquiry or order:

- (a) the design pressure and temperature, quantities, nature and operating conditions of the process or service fluid(s) to be carried;
- (b) the location and any special features or requirements including environmental conditions;
- (c) the type and extent of non-destructive testing required;
- (d) the quantity of pipework, fittings, components and ancillaries to be covered. The purchaser should further add the information required in clause 3(b) to (f) of Part 1 : 1975 of this standard;
- (e) the name of the inspecting authority, if any;
- (f) whether or not the purchaser (or his authorized representative) desires to:
 - (1) witness the tests;
 - (2) receive signed test certificates;
 - (3) be advised on the welding procedure together with the relevant test results;
- (g) whether painting is required for protection, decoration or colour code identification;
- (h) whether the manufacturer is required to supply a certificate that this standard has been complied with;
- (i) whether the use of backing rings is acceptable;
- (j) the extent of the responsibilities of the manufacturer and any additional requirements not listed in the standard;
- (k) whether bellows type expansion joints are acceptable (see 16.3.3);
- (l) whether a supplementary device is required for correct valve operation (see 21.3).

Section two. Components

5. General

5.1 The components and materials listed shall be in accordance with the reference standards except that, subject to the agreement of the purchaser, this shall not preclude the use of other materials, designs, or methods of manufacture, which can be shown to meet fully the intent of this standard. In any such cases this shall be explicitly stated as a qualification of any claim that the piping system complies with the requirements of this standard.

5.2 Components shall be marked in accordance with the requirements of the reference standards. The marking shall permit the component to be properly identified.

6. Pipe

6.1 Aluminium pipe for process and service pipelines shall be extruded, drawn seamless tube or welded tube of materials and dimensions manufactured in accordance with the requirements of Part 1 of this standard.

6.2 Steel pipe for the construction of supports and anchors for process and service lines shall be in accordance with clause 26.

7. Valves

7.1 Valves shall comply with the requirements of the reference product standards. This does not preclude the use, by agreement with the purchaser, of other valves for which there is no standard provided that they conform, where applicable, to the principles and intent of the reference valve standards and are suitable for the intended service.

7.2 Valves of plastics materials may be used by agreement with the purchaser, but until such time as standards are published to fully cover such valves, it is recommended that the advice of the manufacturer be sought as to the most suitable type of valve for the given application.

8. Fittings and flanges

8.1 Aluminium fittings. Dimensions, materials and construction of aluminium fittings and flanges for pipes shall comply with the requirements of Part 1 of this standard.

8.2 Pipe bends. Pipe bends shall be produced in accordance with section six.

8.3 Expansion components

8.3.1 Expansion bands. Expansion bands formed in accordance with section six should be used in preference to expansion joints where practicable.

8.3.2 Corrugated expansion bands. Subject to the limiting considerations of application specified in 14.1.4(b), they shall be constructed in accordance with section six.

8.3.3 Slip-type and bellows expansion joints. Slip-type and bellows expansion joints are subject to the limitations of application specified in 16.3.2 and 16.3.3 and the recommendations of the manufacturer.

9. Bolting

9.1 Bolting for aluminium pipework and flanges shall be in accordance with materials specified in clauses 5 and 6 of Part 1 : 1975 of this standard.

9.2 Bolting for other components and assemblies shall be in accordance with the requirements of the reference standards.

10. Gaskets and jointing

Brief reference is made in clause 7 of Part 1 : 1975 of this standard to gaskets and jointing which shall be selected from the following materials to suit the process fluid handled and the operating conditions:

- compressed asbestos fibre;
- wire mesh reinforced compressed asbestos fibre;
- natural or synthetic rubber;
- plastics (including PTFE) with or without reinforcement;

- metal jacketed, asbestos filled;
- spiral wound metal filler;
- metal rings, flat or corrugated;
- metal rings, special formed sections;

For limiting dimensions of gaskets see Part 1 of this standard.

Section three. Application

11. General

11.1 The application of all pipes, fittings, components and accessories, and assemblies, is subject to compliance with the requirements of this standard and to their suitability for the process fluids, service and testing conditions, and environment, of the system in which they are to operate.

11.2 The use of dissimilar metals in conjunction, e.g. steel with non-ferrous metals, in a corrosive environment should be avoided. For the guidance of users see 26.2 of this Part of this standard and 5.3 of Part 1 : 1975.

11.3 The relatively low melting point of the metals shall be taken into consideration where it is desired to use non-ferrous metal pipes, fittings and components for locations or services where conditions of fire risk can exist.

12. Application of aluminium pipe

12.1 The application of aluminium pipe shall be limited by the design stress pressure/temperature ratings given in table 1, the requirements of 11.3 and by compatibility with the process fluid.

12.2 Where application of aluminium pipe of the high purity grades is necessary in order to resist corrosion, the low strength of the material shall be recognized and provided for on the detail design.

13. Application of valves

13.1 General

13.1.1 For corrosive or hazardous service where deposits could accumulate, valves with inside screw stems shall not be used.

13.1.2 Where metal valves are trimmed with non-ferrous or non-metallic materials, their permissible temperature range may be limited by the temperature characteristics of the trim material.

13.1.3 When valves with non-metallic trims are to be used, the temperature limitations of the trim material should be taken into account if there is a possibility of a 'steaming-out' or hot-air drying procedure initially or during operation, maintenance or testing of the system.

13.1.4 Where pressure differential is expected to create difficulties in the manual operation of a valve, a bypass should be provided. Alternatively, gear or motor operation may be fitted to the valve.

13.1.5 Drain valves supplied for the drainage of pipework and equipment shall be of the straight through type.

13.2 Non-ferrous metal valves (flanged or butt-welding type)

13.2.1 The use of non-ferrous metal valves shall be subject to the restrictions specified in 11.2 and 11.3.

13.2.2 The application of non-ferrous metal valves shall be limited by the pressure/temperature ratings given in the reference standards. There may be a further limitation

imposed by the range of permissible service temperature of the trim materials (see 13.1.2 and 13.1.3).

13.3 Steel valves (flanged or butt-welding type)

13.3.1 Steel valves shall be used within the pressure ratings specified in the appropriate product standard.

NOTE. Where steel valves are used in conjunction with aluminium pipes and fittings, the pressure/temperature stress rating of the aluminium may determine the maximum conditions at which the system may be operated (see also 13.1.2 and 13.1.3).

13.4 Cast iron valves (flanged)

13.4.1 Cast iron valves may be used for water, aqueous solutions, non-volatile chemicals or air in accordance with the pressure ratings specified in the appropriate product standard. They shall not be used for hydrocarbon or hazardous services.

13.4.2 The use of valves made of special or alloy cast iron developed for specific duties shall receive separate consideration.

14. Application of fittings and flanges

14.1 Aluminium fittings

14.1.1 Butt-welding pipe fittings, in accordance with Part 1 of this standard, are preferred for all applications specified in this standard.

14.1.2 Socket-welding fittings are not recommended for any application covered by this standard.

14.1.3 Fittings with sleeved, screwed, compression, soldered or brazed joints, shall not be used for applications under this standard.

14.1.4 For aluminium pipe bends, if the change of direction does not exceed 30°, subject to the agreement of the purchaser, the pipe ends may be cut to the required angle and prepared and butt-welded direct in accordance with section six.

For greater changes of direction, purpose-made aluminium components may be used as follows:—

(a) Forged or fabricated fittings in accordance with Part 1 of this standard, or formed bends in accordance with clause 36 are recommended.

(b) Proposals to employ corrugated bends shall include consideration of the effect on the system of vibration and the difficulties of drainage. Their use is subject to the agreement of the purchaser and they shall be constructed in accordance with section six.

14.2 Aluminium flanges

14.2.1 *General.* Aluminium flanges shall be manufactured in accordance with the requirements for materials, dimensions, design stresses and pressure/temperature ratings given in Part 1 of this standard.

14.2.2 *Types.* Flanges shall be of the welding pattern selected for each application from the types shown in figures 1 to 5 by agreement between the purchaser and the supplier, and installed in accordance with the appropriate sections of this standard.

14.2.3 *Corrosive or hazardous services.* It is recommended that flanges for corrosive or hazardous services shall be of the butt welding neck pattern (see figure 1).

14.2.4 *Slip-on and fillet-and-back flanges.* Slip-on flanges (see figure 4(a) and 4(b)) and fillet-and-back flanges (see figure 5) shall not be used for corrosive or hazardous services or where cleanliness and the facility for complete draining down of the system are essential requirements.

14.2.5 *Aluminium socket-welding flanges.* These are not recommended for any application covered by this standard.

14.3 Composite flanges

14.3.1 Lapped pipe end flanges (weld-on stubs) in conjunction with steel backing flanges may be used by agreement between the purchaser and the fabricator. The welding-ends of the stub and pipe shall provide full weld penetration and shall be butt-welded true and square in accordance with section six of this Part of this standard. The dimensions of the joint shall be in accordance with table 6/6 or 10/6 of BS 4504 : Part 1 : 1969 as appropriate, but it is to be noted that the maximum operating conditions of the assembly may be determined by the pressure/temperature rating of the aluminium. The grade of steel (e.g. stainless) for the backing flanges and bolting shall be selected to suit the service conditions of the application. The possibility of dissimilar metal corrosion should also be taken into account (see 11.2).

14.3.2 By agreement between the purchaser and the fabricator, tafted flanges may be formed on the ends of the aluminium pipe after pre-assembly of steel backing flanges. The dimensions of the joint shall be in accordance with table 6/6 or 10/6 of BS 4504 : Part 1 : 1969 as appropriate but it is to be noted that the maximum operating conditions of the assembly may be determined by the pressure/temperature rating of the aluminium. The face of each tafted flange shall be finished flat and square and the removal of metal by machining or grinding when trueing up shall not reduce the pressure rating of the joint below the design pressure of the system. The grade of steel (e.g. stainless) for the backing of flanges and bolting shall be selected to suit the service conditions of the application.

14.3.3 Other flanges employing special forms of sealing (e.g. ring-joint facing) may be used where requested by the purchaser. Where such other methods of jointing are used of differing dimensions to those specified in Part 1 of this standard, then it will be necessary to verify the flange design thicknesses. Where these are specified, they shall be subject to the requirements for dimensions, materials, etc. of clause 3 and tables 3 to 10, as appropriate, of BS 1560 : Part 2 : 1970.

14.3.4 Where a blind (blanking) flange is required it shall be formed by welding to the pipe a standard aluminium flange selected in accordance with the recommendations and restrictions given in 14.2.1 to 14.2.5 and prepared and welded in accordance with section six. To this shall be bolted a blind flange plate in conjunction with an appropriate gasket (see clause 17). The dimensions, materials and pressure/temperature ratings of the flange and blind plate shall be in accordance with Part 1 of this standard.

14.4 *Plastics metal flanges.* Composite flanges comprising plastics-to-metal flanges shall have plain (flat) facings in conjunction with full-width gaskets.

15. Bolting applications

15.1 Materials for flange bolting to suit the service conditions of the application shall be selected from those given in clause 5 of Part 1 : 1975 of this standard, or by prior agreement between the purchaser and the fabricator.

15.2 Where dissimilar materials (e.g. stainless steel/aluminium) are involved in bolting flanged joints on systems subject to temperature variations, the differential expansion/contraction may cause joints to leak when under

pressure at low temperatures and compensating washers shall be employed as specified in clause 6 and figure 1 of Part 1 : 1975 of this standard. Furthermore, stainless steel bolts may relax on cooling down to sub-zero temperatures, therefore bolts which cannot be re-tightened should be made from materials having a stable metallurgical structure.

16. Expansion components

16.1 General. The application of components to absorb expansion in the system shall be subject to the recommendations and restrictions set out below. Expansion bends shall be employed in preference to expansion joints.

16.2 Expansion bands

16.2.1 Plain pipe bends. For expansion purposes plain pipe bends, a lyrate full loop, or a square loop with long radius bends, fabricated and installed in accordance with the requirements for pipe bends in sections six and four respectively, should be used.

16.2.2 Corrugated pipe bends. See 14.1.4(b).

16.3 Expansion joints

16.3.1 General. Expansion joints are not to be used where the nature, pressure or temperature of the fluid carried could create a hazard to personnel or equipment in the event of leakage or failure of the joint or any of its components. The manufacturer shall be made fully aware of the conditions of the proposed application and his recommendations are to be strictly observed.

16.3.2 Slip-type expansion joints. Such joints shall not be used on process lines and may only be used on other services by agreement of the purchaser. Installation shall then be in accordance with section four.

16.3.3 Bellows type expansion joints. Such joints may give rise to vibration and introduce difficulties in proper cleaning and draining, and shall only be used by agreement of the purchaser. Installation shall then be in accordance with section four.

17. Gaskets and jointing

17.1 Gaskets of appropriate dimensions shall be of materials selected from those listed in clause 10 to withstand the required bolting loading without injurious crushing and suitable for the pressure, temperature and nature of the fluid carried and the service conditions and environment in which they are to operate (see ASME B31.3 table UA-49.1).

17.2 Soft rubber gaskets are recommended for use where possible with glass-lined valves to prevent damage to the glazed faces of the valve flanges when tightening up to pipework and equipment. For applications where soft rubber is unsuitable or the available thickness is adequate, the most resilient material which satisfies the requirements of the application shall be selected from clause 10.

17.3 Rubber jointing material with canvas insertion may be used only in water lines at temperatures up to 65°C.

17.4 Compressed asbestos fibre jointing materials of the appropriate grade may be used for service conditions as follows, subject to the limitations on operating temperature which may be fixed by the aluminium.

- (a) Grade A complying with the requirements of BS 2815 or BS 1832, for use with water, inert gases and liquids and steam up to a temperature of 400°C.

- (b) Grade B complying with the requirements of BS 2815, for use with water, air and steam services up to a pressure of 19 bar* and temperature of 260°C.

- (c) Oil resistant grade complying with BS 1832, for use with hot oil, oil vapour and gas service up to a temperature of 400°C.

- (d) For severe conditions, wire mesh reinforced or PTFE enveloped compressed asbestos fibre, metal jacketed or spiral wound asbestos filled, or metal ring gaskets may be used as required by the service conditions and by agreement between the purchaser and the supplier.

18. Low temperature service

The following requirements shall apply in regard to design, materials and testing of all piping systems which may be in service at sub-zero temperatures.

18.1 Design

18.1.1 Design temperature. The temperature defined in 3.5, may, where this is not known, be determined in one of the following ways.

- (a) For components that are thermally insulated the minimum temperature of the fluid contents shall be used.

- (b) In the case of components not thermally insulated the minimum temperature of the fluid contents may be used. However, attention is drawn to the effect that the ambient temperature may have upon the contents under c. rating conditions and for this purpose, in the absence of more certain data, the minimum ambient may be taken as the lowest one-day mean ambient temperature.

- (c) Where there is evidence to show that because of radiation, adiabatic or other effects and methods (a) or (b) may not provide a reliable estimate of the temperature, then under such conditions the method of assessment shall be subject to agreement.

18.1.2 Attachments. Any attachments to piping and components (e.g. anchors, support stools, brackets, etc.) shall be designed to avoid creating stress concentrations or corrosion at the point of attachment. Clamp type arrangements should be used wherever possible or the attachment welded to a loose sleeve around the pipe or fitting. All welded attachments to the pipe should be of the same nominal composition as the pipes.

18.1.3 Slip-on type welded flanges. Attention is drawn to the restrictions on the use of slip-on type welded flanges in 14.2.4.

18.1.4 Butt welding. Full penetration butt welding shall be used for all longitudinal and circumferential joints in pipes.

18.2 Materials

18.2.1 General. The user shall satisfy himself by consultation with the supplier, or other authoritative sources that the materials proposed to be used for cryogenic applications are suitable for the service intended.

18.2.2 Metallic materials. The materials specified in clause 4 of Part 1 : 1975 of this standard for pipes, flanges and fittings and clause 5 of Part 1 : 1975 of this standard for flange bolting, do not normally become embrittled at sub-zero temperatures and shall not be subject to additional requirements such as impact testing, unless specifically requested by the purchaser.

*1 bar = 10⁵N/m² = 100kPa

18.2.3 Non-metallic materials. The choice of non-metallic materials for jointing gaskets and for components of valves, etc., shall be given special consideration as to their suitability for operation at the design temperature. In particular, consideration must be given to the hardening effect and/or embrittlement of plastics and rubber-like materials and the cold flow of plastics.

18.3 Testing. On completion, low temperature systems shall be inspected and tested in accordance with section seven unless agreed otherwise with the purchaser.

Attention is drawn to the requirements for thorough draining and drying of the system after testing given in 41.6.12 and 41.6.13.

Section four. Installation

19. Pressure relief arrangements

19.1 Pressure relief arrangements shall be provided in the following circumstances.

- (a) On piping where thermal expansion or vaporization of the contents can cause the internal pressure rise to exceed 133% of the design stress.
- (b) On the downstream side of any pressure reducing valve where the pipework and/or equipment connected thereto is not designed or constructed to adequately withstand the full supply pressure.

19.2 If the provision for pressure or vacuum relief is to be in the form of bursting discs, these shall comply with the requirements for discharge capacity, selection, application and installation, of BS 2915.

20. Arrangement of stop valves

There shall be no intervening stop valves between piping being protected or between the protective device(s) and the point of discharge, except in the following circumstances.

- (a) A full-area stop valve may be installed on the inlet side of a pressure relieving device. A full-area stop valve may be placed on the discharge side of a pressure relieving device when its discharge is connected to a common header with other discharge lines from other pressure relieving devices. Valves of less than full area may be used on both the inlet and discharge sides of pressure relieving devices as outlined in the foregoing, if the stop valves are of such type and size that the increase in pressure drop will not reduce the relieving capacity below that required, nor adversely affect the proper operation of the pressure relieving device. All such stop valves shall be so arranged that they can be locked or sealed in both the open and closed positions.
- (b) Stop valves may be used where they are so constructed, or positively controlled, that the closing of the maximum number of block valves possible at one time will not reduce the pressure relieving capacity provided by the unaffected relieving device(s) below the required relieving capacity.

21. Arrangement of valves

21.1 General. The arrangement of piping should permit easy operation and maintenance of valves. Valves should be grouped together wherever practicable and when operated frequently should be readily accessible. Free access shall be provided to valves installed in pipe tracks and service ducts and, where the latter have to be enclosed, the access covers shall be readily removable but properly

located to prevent accidental displacement. The installation of valves with their stems inclined below the horizontal should be avoided wherever possible, except that where it is desirable for valves to fail safe, e.g. in relief lines, inverted valves may be permitted. For cryogenic systems valves with their stems below the horizontal are not acceptable.

The use of chain operated valves is not recommended. Where the use of chains is unavoidable, they shall not hang in the path of personnel or mobile equipment and shall be positioned or restrained well clear of instruments and controls.

Extension spindles or attachments shall be provided as follows:

- (a) for valves located in trenches or pits where the hand-wheel would otherwise be more than 150 mm below the trench or pit cover level;
- (b) for valves at high level or for platform operation to avoid complications in pipework layout, subject to the restrictions on the inclination of valve stems.

Platforms and ladders necessary for the operation and maintenance of valves shall be securely fixed and properly constructed and guarded to provide safe access.

21.2 Control valves. Control valves should be placed in horizontal lines with stems arranged vertically except where they are liable to silting when they should be installed in vertical lines with stems horizontal. Where possible, control valves should be so located that maintenance may be carried out without the erection of staging. Where a local indicator is provided the controlled variable should be visible from the control valve.

Piping arrangements at control valves shall be designed to:

- (a) provide sufficient space to ensure that the control valves may be dismantled for overhaul without having to remove the valve body from the line;
- (b) permit the removal of the valve body when required without having to spring the piping unduly, e.g. by providing a removable bend or make-up piece on at least one side between the isolating valve and the control valve;
- (c) Provide sufficient straight length of upstream and downstream pipe either side of the control valve to minimize any turbulence caused by any isolating or block type valves (particularly of the Venturi body shape pattern) installed in a bypass system; under no circumstances should the control valve be bolted direct to isolating valves, elbows, tee-pieces, etc.

Control valves shall be provided with a bypass wherever manual control is essential on failure or during maintenance of the control valve. Alternatively, the control valve shall be provided with a handwheel. Bypass valves and lines shall be sized to give adequate manual control. Control valves which handle flammable fluids should be kept away from hot lines, pumps and other hot equipment in order to minimize the fire risk when valves are removed and lines drained. Drain and bleeding piping shall carry the drainings to a safe location.

Top works on control valves shall be kept away from excessive heat to avoid premature failure of diaphragms and electronic components.

21.3 Check valves. Check valves shall preferably be installed in horizontal flow but where they have to be arranged vertically the flow shall be in an upwards direction or, if downwards flow is essential, a supplementary device shall be fitted to ensure correct

operation of the valves. The purchaser shall be responsible for advising the manufacturer of the supplementary requirements.

22. Connections to equipment

22.1 Vessels and units of equipment which require to be isolated for entry of personnel for cleaning and repairs shall be provided with a lockable block valve or a block valve with a spade or removable spoolpiece.

22.2 Pipework between pumps, process vessels, etc., and their isolating valves preferably should be removable to facilitate dismantling of the plant. Where this is not practicable a removable flanged pipe fitting shall be included adjacent to the machinery.

22.3 For dimensional flexibility and avoidance of unnecessary disturbance of plant items, the overall dimensions of the spoolpiece should be interchangeable with standard fittings.

22.4 Where double valving is unavoidable, a bleed valve shall be provided of not less than 20 mm nominal bore and this valve shall be lockable on toxic and flammable services. One valve shall be directly mounted on the equipment, branch or spoolpiece.

23. Branch connections

23.1 Main branch. Main branch connections to pipelines shall be made by the use of standard forged or fabricated butt welding fittings in accordance with the requirements for dimensions and materials specified in Part 1 of this standard. Alternatively, main branch connections may be made by direct welding of the branch to the main and preference should be given to set-on 'type branches'. 'Set-in' type branches may only be permitted by agreement between the purchaser and fabricator and where the dimensions of the pipe permit access for the completion of the weld from the inside to give full weld penetration (figure 19). Preparation and welding shall be carried out in accordance with section six.

23.2 Subsidiary branches. Subsidiary branch connections:

- (a) for instrumentation and control, sampling, venting or draining, shall be made either by standard forged or fabricated butt-welding fittings or by 'set-on' branches directly welded with full penetration as specified in 23.1 and section six;
- (b) for a drain plug in a pipe or item of equipment, where a screwed opening is required, it shall be provided by a tapped boss located at the low point as specified in clause 25, and prepared and welded with full penetration as in section six.

23.3 Branch angle. It is recommended that no branch connection shall be welded to a main pipeline at an included angle of less than 60°. For smaller angles the use of a suitable forged or weld-fabricated fitting is preferred.

23.4 Reinforcement. Openings in pipes for branches shall be reinforced as and when required by section five.

23.5 Mercury-thermometer pockets. Mercury should not be allowed to come in contact with aluminium and the use of mercury-in-glass type thermometers in aluminium piping systems is not permitted. Where temperature measurement in an aluminium pipeline is to be by means of a sealed capillary system filled with mercury, it is recommended that the temperature sensing probe be enclosed in a pocket, preferably of steel, of a grade to suit the operating conditions (e.g. stainless), inserted in the line by means of a pipe fitting or boss welded in accordance with section six.

Other instrumentation or control devices employing mercury should be installed so that in the event of breakage or spillage the mercury cannot contact and attack the aluminium.

24. Expansion arrangements

24.1 General. Expansion in the system shall be absorbed where possible by the bends normally provided at the changes in direction in the run of the pipelines. Where this would be inadequate or is not practicable, the expansion shall be absorbed by purpose-made bends or joints in accordance with the requirements and restrictions of the other sections of this Part of the standard and installed in accordance with the following requirements as appropriate.

24.2 Expansion bends. Expansion bends of the lyrate full loop or square loop with long radius bends shall wherever possible be installed horizontally with adequate free movement and correct falls for drainage. Where space limitations or other factors necessitate arranging the expansion loop in the vertical plane, the falls shall be arranged with provision for drainage at the low point on the up-stream side of the loop.

24.3 Expansion joints. Where expansion joints of either the slip-type or bellows pattern are to be used, the advice of the manufacturer shall be sought with regard to the installation requirements for the guiding, anchoring and supporting of adjacent pipework. If used in below ground pipelines it is recommended that they be enclosed in a suitable pit which will not interfere with their functioning.

Slip-type expansion joints shall not be used in cryogenic installation.

24.3.1 Slip-type joint. The pipes shall be guided to ensure that, adjacent to the joint, they can move in the axial direction only. Pipe anchorages and attachments shall be positioned and adjusted to relieve the joint and its restraining bolts of axial load due to the pressure of the fluid within the pipe.

24.3.2 Bellows type joint. Movement of piping shall be guided to maintain axiality of the bellows under all conditions. The anchorages and attachments to the piping shall prevent the bellows from being subjected to torsional loads and to axial loads in excess of the design conditions.

Bellows units shall be provided with temporary ties or straps to maintain their set length at the specified temperature at which they are installed in the pipeline.

Where double units are installed consideration should be given to the natural frequency of vibration of the unit.

24.3.3 Expansion bellows. Such bellows installed in lines carrying slurries or process materials in suspension shall be fitted with an internal sleeve and provision for purging to prevent the build up of solids and blockage of the convolutions of the bellows (see also 16.3.3 and 32.2.4).

25. Pipe falls, drainage and venting

25.1 General. The installation of pipework and equipment shall include as necessary, provision of correct falls to pipelines and draining facilities for the collection and removal of the following:

- (a) air, when filling and starting-up;
- (b) condensate or moisture resulting from start-up, running, shutting-down, cleaning or testing;
- (c) process or service fluid as may be required as part of the operation or cleaning procedure.

Table 1. Design stresses for aluminium alloy seamless pipes and tube, rolled plate, and forgings (see notes 1 and 2)

Material (see note 6)	Type	Condition (see note 5)	Minimum 0.2 % proof stress (see note 9)	Minimum tensile strength (see note 9)	Minimum elongation on 50 mm or $5.65 \sqrt{S_0}$ (see notes 7 and 9)	Permissible design stresses for temperatures not exceeding (see note 3)							
						-200 to 25	50 °C	75 °C	100 °C	125 °C	150 °C	175 °C	200 °C
1B	Al 99.5	Annealed H4	N/mm ²	55 to 60 100	22 to 32 6 to 8	N/mm ²	N/mm ²	N/mm ²	N/mm ²	N/mm ²	N/mm ²	N/mm ²	N/mm ²
						13.8	13.4	12.7	11.4	10.2	9.2	8.3	7.3
N4	AlMg2	Annealed H2, H3 H4, H6	60 130 175	160 to 170 200 225	14 to 20 6 to 8 5	42.7	42.7	42.7	42.6	41.0	37.2	32.7	25.7
						53.5	53.5	53.2	52.0	48.6	44.2	39.7	27.0
N51	AlMg3Mn	Annealed H2 H4	85 165 to 180 200 to 225	215 245 to 275 270 to 275	12 to 14 7 to 8 4 to 6	58.6	58.6	58.8	57.5	52.8	47.6	42.8	27.6
						53.5	53.5	53.4	52.3	48.6	37.9	30.3	25.2
N5	AlMg3.5	Annealed	85 to 100	215	16 to 18	62.2	62.2	61.7	58.8	50.3	37.9	30.3	25.2
						67.3	67.3	66.2	61.3	50.3	37.9	30.3	25.2
N8 (see note 4)	AlMg4.5Mn	Annealed	125	275 to 280	12 to 16	53.8	53.8	53.8	53.5	51.6	46.7	—	—
						69.0	69.0	69.0	—	—	—	—	—
H9 (see note 8)	Al-Mg-Si	TE TF Annealed	110 130 to 180 —	150 to 155 150 to 200 100	7 to 8 6 to 10 13 to 15	37.9	36.7	34.7	33.2	31.3	28.2	22.1	15.3
						51.7	50.3	48.3	45.8	41.1	31.1	22.1	15.3
H30 (see note 8)	Al-Mg-Si-Mn	TB (drawn) TB (extruded) TF Annealed	100 to 120 115 240 to 270 —	215 170 to 190 280 to 310 155 to 170	12 to 16 13 to 16 5 to 9 —	29.3	29.2	28.6	27.2	25.8	24.6	19.3	14.0
						50.3	51.0	49.3	47.7	46.1	43.8	39.3	30.7
						44.8	44.0	42.3	41.1	39.6	38.6	34.3	26.1
						72.3	71.4	69.7	67.6	63.5	54.2	43.6	32.3
						41.2	41.0	40.3	38.9	37.1	34.2	29.6	23.2

Notes to table 1

NOTE 1. For extruded tube the maximum thickness for which properties apply is 75 mm.

NOTE 2. Unless otherwise covered in the above table for materials used in the 'M', i.e. 'as manufactured' condition, the stress values for the annealed condition shall apply. For welded constructions, the stress values shall be for annealed materials.

NOTE 3.

- (a) Intermediate values may be obtained by linear interpolation.
- (b) The design stress values in shear shall be 0.8 times the values in the table.
- (c) The design stress values in bearing shall be 1.6 times the values in the table.

NOTE 4. N8 alloy should not be used above 75 °C as it may suffer stress corrosion above this limit under certain circumstances.

NOTE 5. Explanation of nomenclature.

TB — Solution treated and naturally aged

TE — Precipitation treated

TF — Solution treated and precipitation treated

H2, H4 — Strain hardened. Material subjected to the application of cold work after annealing (or hot forming) or to a combination of cold work and partial annealing/stabilizing in order to secure the specified mechanical properties. The designations are in ascending order of tensile strength.

NOTE 6. The references shown in column 1 are the British Standard classifications as follows:

BS 1470 for plate, sheet and strip

BS 1471 for drawn tube

BS 1472 for forgings

BS 1474 for extruded round tube

BS 4300/8 for plate, sheet and strip

/10 for drawn tube

/11 for forgings

/12 for extruded round tube

NOTE 7.

(a) For plate above 12.5 mm thick minimum elongation is evaluated on $5.65 \sqrt{S_0}$.

(b) For drawn tube elongation on $5.65 \sqrt{S_0}$ for tubes with a wall thickness of 3 mm and thinner, and on 50 mm for tubes with thicker walls.

NOTE 8. These materials shall not be used in atmospheres that could initiate crystalline corrosion (e.g. chemical plant atmospheres). Additionally, extreme care shall be taken with weld procedures, otherwise unsatisfactory welds may result.

NOTE 9. The range of figures given in columns 4, 5 and 6 are shown because minimum proof stresses, tensile strengths and elongations vary with form and size. Reference should be made to the appropriate British Standard listed in note 6.

25.2 Pipe falls

25.2.1 Pipelines shall normally be arranged with falls to drain in the direction of flow of the fluid carried.

25.2.2 Certain pipeline systems installed for carrying flammable or corrosive fluids, liquid slurries, etc, may require provision to be made for pumping or draining away from the process plant back to storage, either as part of the normal operation of the plant or in the case of an emergency. Such arrangements shall be by prior consultation and agreement between the purchaser and the installer.

25.3 Drainage and venting. Provision shall be made of either manual or automatic types of drain traps at low level and vents at the high point(s) of the system for clearance of pipelines and equipment. Where these devices are of the automatic type they shall clear the system without loss of the process or service fluid carried.

Discharges from drains, traps and vents shall be led to convenient and safe positions well clear of personnel, equipment and buildings.

SPECIAL NOTE. Attention is drawn to the statutory regulations and requirements for the control, handling and disposal of effluents which shall be strictly enforced where applicable.

25.4 Frost precautions. Where applicable, the system shall be planned and installed with correct layout and provision of facilities for protection, drainage, etc, in accordance with the recommendations and principles of CP 99.

26. Pipe supports and anchors

26.1 All supporting equipment shall be suitable for the service, loading, temperature and ambient conditions and shall be in accordance with BS 3974.

Steel shall be used to the greatest extent possible.

Cast iron may be used for rollers, roller bases, guides, brackets, etc, where the loading is mainly compressive, but it is not recommended for pipe supporting elements subject to impact type loadings resulting from pulsations or vibration. Malleable or nodular iron may be used for pipe clamps, beam clamps, hanger flanges, clips and swivel rings, providing that the metal temperature falls within the range -10 °C to 230 °C.

Wood, with suitable preservative treatment, may be used for load bearing elements between pipe and support for insulated piping in low temperature service.

For sub-zero temperature systems the minimum design temperature and impact requirements for ferritic steels whether wrought, cast or forged shall be not lower than is that indicated in appendix B, and in figures 1 and 2 of BS 3351 : 1971. Attention is also drawn to 18.1.2 regarding pipe attachments.

26.2 Pipe supporting equipment located in a corrosive environment should be suitably protected internally and externally or an adequate material corrosion allowance made. Consideration should be given to the treatment necessary for cases where there is a possibility of local corrosion between pipes, supports and components composed of dissimilar metals in the presence of moisture.

Piping shall be supported and anchored so as to prevent excessive thrusts and movements on connected equipment and, at the same time, permit expansion and contraction between anchors.

Hangers* for the support of piping shall, where necessary, permit of adequate adjustment after erection while supporting the load. Screw or equivalent adjustments shall have suitable locking features. Spring hangers shall be so constructed that complete release of the piping load will be impossible in the event of spring failure.

26.3 Supporting equipment shall be designed and constructed to carry the load caused by the most severe combination that can occur of any of the following:

- (a) weight of pipes and associated equipment;
- (b) weight of operating process fluid or the testing medium whichever is the heavier; alternatively, weight of operating process and fluid only, provided that the pipe is temporarily supported during testing;
- (c) weight of insulation when used;
- (d) expansion or contraction loads or thrusts;
- (e) reaction from branch lines;
- (f) reaction from lines discharging to atmosphere;
- (g) weight of equipment installed to counteract or direct the loads under (d), (e) and/or (f);
- (h) wind or earthquake loads, whichever is the greater;
- (i) snow and ice loads.

Weight calculations for springs and counterweights shall be based on normal operating conditions of the piping system.

The calculated stresses in aluminium piping shall not exceed the maximum permissible design stresses given in table 1. Design stress values 'in shear' and 'in bearing' shall be 0.80 and 1.60 respectively of the values given in this table.

For steel used for supporting equipment, reference should be made to BS 449 : Part 2 for design stresses.

26.4 Contact surfaces between pipe and pipe-bearer should be arranged to avoid water retention.

For those lines in which pocketing of liquid must be avoided it is necessary to support and pitch the line in the direction of flow in such a way that the pipe in any span cannot sag below the elevation of the support at the lower end of that span.

26.5 Anchors for bellows or slip-type expansion joints shall be designed and constructed to withstand the algebraic sum of the following:

- (a) the force necessary to deflect the joint which shall be specified by the manufacturer;
- (b) the force due to pressure of the process material under operating conditions; where not specified by the manufacturer, this force may be taken as the product of the working pressure times the maximum internal cross-sectional area of the joint;
- (c) the force required to overcome the static friction of the pipe expanding or contracting on its supports.

Short branch connections (e.g. for pressure gauges, alarm switches, etc) and blind stubs shall be securely anchored (see warning in 41.2 regarding the danger of air trapped when pressure testing).

27. Pipe insulation

For information concerning the choice of insulating materials, methods of application, etc, reference should be made to CP 3005.

27.1 This standard requires that consideration for the need to insulate piping be given to the following:

- (a) saving of energy by minimizing heat transfer to or from the equipment;

- (b) maintenance of process temperature;
- (c) minimizing the influence of climatic and ambient variations;
- (d) protection of personnel from injury through contact, and to minimize the effect on the temperature of the surrounding space of heat emitted or absorbed by the pipework, affecting comfort or health of personnel or condition of materials;
- (e) prevention of condensation on the surface of pipework carrying process materials at low temperature.

27.2 Insulating materials in accordance with the appropriate standards may be used.

27.3 All metal surfaces at temperatures above 65 °C or below -10 °C which could be touched by personnel in the course of their normal duties should be insulated unless otherwise effectively guarded.

27.4 On pipelines insulated for hot or low temperature service, all flanges, valves and fittings shall be insulated.

27.5 Surfaces to be insulated shall be clean. Where plastics composition insulation is to be used it should be alkali free. To ensure good adherence of the composition the recommendations of the insulation suppliers should be observed.

27.6 The use of preformed removable sections is recommended on surfaces where insulation will be subject to periodic removal for inspection, cleaning or other reasons. On surfaces where the insulation will remain undisturbed a plastics insulating composition producing a monolithic covering may be used. To facilitate taking thickness measurements a removable section of insulation may be provided.

27.7 All cold insulation shall be effectively vapour sealed with no ends left open. The pipe surface shall be dry and free of moisture when fitting cold insulation.

27.8 Insulation exposed to the weather shall be suitably protected from mechanical damage and waterproofed adequately.

27.9 Where necessary, according to the types of insulating material and cladding used, the inner surface of the cladding shall be protected against corrosion. Cladding over soft insulation shall be supported on spacer rings or distance pieces to maintain the correct insulation thickness.

27.10 Flashing or sealing is required to prevent rain from percolating behind cladding and causing corrosion.

27.11 Insulation should not be applied over pipe joints or connections before the completion of pressure testing.

27.12 When flanges and valve bodies require to be insulated, this should be done after commissioning.

28. Painting

Aluminium fittings or components are normally not required to be painted but where specified by the purchaser certain installations may require painting for the purpose of:

- (a) decoration;
- (b) safety and/or to conform to a colour coding for identification of pipes and contents.

As an alternative to complete painting, a system of colour banding or symbols may be employed for identification.

*For guidance on components and typical assemblies of pipe hangers, reference should be made to BS 3974 : Part 1.

All surfaces to be painted shall be properly prepared and the paint applied in accordance with the recommendations of the paint manufacturer. Special attention shall be given to paint priming systems for use on aluminium.

NOTE. For guidance on colours and coding, reference may be made to BS 381C, BS 1710 and BS 2929.

Section five. Design

29. Pipe

29.1 The internal pressure design thickness for a straight pipe shall be not less than that calculated from the following formula when t is less than $\frac{D}{4}$

$$t = \frac{pD}{20S + p}$$

Where

- t is the design thickness (mm);
- p is the internal design pressure (bar)*;
- D is the outside diameter of pipe (mm);
- S is the design stress (N/mm²).

Pipe with t equal to or greater than $\frac{D}{4}$ requires special consideration.

The thickness as calculated above shall be increased, if necessary, to meet the requirements of 29.7, 29.8, 29.9 and 36.2.

For the design of piping systems subject to external pressure, reference should be made to BS 5500.

29.2 The design pressure is the maximum pressure expected in normal operation. Where, in normal operation, a pipe is subjected to more than one pressure/temperature condition, the thickness shall be determined for that condition which results in the maximum value of t .

29.3 The design temperature is the temperature coincident with the design pressure as defined in 29.2. For insulated piping systems, the design temperature for all components shall be the fluid temperature, unless tests or experience substantiate the use of other temperatures. For uninsulated systems the design temperature for the piping shall be the fluid temperature; for flanged valves, fittings and flanges (except lapped joints) it shall be 90 % of fluid temperature; for lapped joint flanges it shall be 85 % of the fluid temperature; for bolting it shall be 80 % of the fluid temperature, or as established otherwise by tests.

29.4 The value of S shall be obtained from and shall not exceed that given in table 1 for the design temperature indicated therein. Linear interpolation for intermediate design temperature is permitted.

29.5 The wall thickness selected, less the manufacturing tolerance, shall be not less than the internal pressure design thickness plus the allowances for threading or grooving.

29.6 Variations in the pressure or temperature, or both, from normal operating conditions are characteristic of certain services. If these variations are infrequent and of short duration, the pressure/temperature ratings (or the allowable stresses) of the piping components may be adjusted as follows:

- (a) if the increased operating conditions will not exceed 10 h at any one time or 100 h per year, it is permissible to increase the pressure rating (or the allowable stress) at the temperature existing during the increased

operating condition by a maximum of 33 %;

- (b) if the increased operating condition will not exceed 50 h at any one time or 500 h per year, it is permissible to increase the pressure rating (or allowable stress) at the temperature existing during the increased operating condition by a maximum of 20 %.

29.7 For large diameter pipe, consideration may need to be given to selecting a wall thickness in excess of that calculated in accordance with the requirements of 29.1 in order to reduce deformation during transportation, handling, fabrication or installation of pipe.

29.8 For pipe of 40 mm nominal size and less, the wall thickness may need to be in excess of the minimum calculated, in order to provide adequate robustness in service.

For the thickness of pipe wall in the bending of pipes see 36.2.

29.9 The term 'material corrosion allowance' as used in this standard is an allowance to cover wastage resulting from chemical action, oxidation, scaling, abrasion and erosion. Where it is known that no significant wastage will occur, no corrosion allowance need be made. Where wastage is anticipated the corrosion allowance should be not less than the total wastage estimated for the desired life of the pipe, which in no case should be less than the period covered by two inspection cycles.

Normally no corrosion allowance is necessary for aluminium piping. Reference should however be made to the requirements under clause 26 for pipe supporting equipment located under conditions likely to cause corrosion.

30. Design conditions

30.1 Preferred pipe sizes. The outside diameter of the pipe shall be selected from the preferred sizes given in table 3 of Part 1 : 1975 of this standard.

30.2 Pipe thickness. The thickness of the pipe selected less any manufacturing tolerance shall in no case be less than that calculated under 29.1 for the internal design pressure plus allowance for corrosion, if any.

Additionally, due allowance shall be made where necessary for any stress, either compressive, tension or shear, which may be imposed on the pipe wall by the supporting arrangements (see clause 26 and 36.2).

31. Valves

31.1 For standard valves reference should be made to the appropriate British Standards for information relating to design and materials.

If for such valves it is necessary to use materials other than those for which pressure/temperature ratings are provided, the manufacturer should be consulted for the appropriate ratings.

31.2 The suitability of the design of valves which are not covered by British Standards shall be determined by tests representative of the intended service conditions in conjunction with the recommendations of the manufacturer.

31.3 For cryogenic applications the valves shall be of a design which incorporates extended spindles in order to remove the gland packing from the zone of low temperature, but not including back seal valves unless a suitable relief device is provided.

* 1 bar = 10⁵ N/m² = 100 kPa.