



BS MA 18: August 1973

UDC 629.12.061 : 621.64/.69

British Standard : Marine Series
Specification for

Salt water piping systems in ships

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Printed in England by Gaylard & Son Ltd., London, SE14 6TY
7308-2.5k

Foreword

This British Standard has been prepared under the authority of the Shipbuilding and Marine Industry Standards Committee. Recommendations and requirements are given in this standard with the object of improving the service life of salt water systems in ships.

Failure of the component parts of salt water piping systems may occur as a result of corrosion/erosion, otherwise known as impingement attack, arising from excessive turbulence. Such a condition may be brought about by poor design and/or poor workmanship, or the use of too high a nominal water speed. Excessive water speed is a major factor and may arise as a result of poor design or of misuse of the system. Failure may also occur by pitting resulting from deposit attack, and cracking due to stress corrosion, or by general wastage in the case of ferrous systems.

Attention should therefore be given to the design, fabrication and installation of systems to ensure minimum turbulence. In particular, abrupt changes in the direction of flow, mismatched pipe bores, tube bore protrusions and other restrictions of flow should be avoided.

All pressures in this standard are in bar* (gauge) unless otherwise stated.

This standard makes reference to the following British Standards:

- BS 309 Whiteheart malleable iron castings
- BS 310 Blackheart malleable iron castings
- BS 449 Welding terms and symbols
- BS 639 Covered electrodes for the manual metal-arc welding of mild steel and medium-tensile steel
- BS 729 Hot dip galvanized coatings on iron and steel articles
- BS 864 Capillary and compression fittings of copper and copper alloy for use with copper tube complying with BS 1386 and BS 3931
 - Part 2 Metric units
- BS 970 Wrought steels in the form of blooms, billets, bars and forgings
 - Part 1* Carbon steels
 - Part 2 Direct hardening alloy steels including alloy steels capable of surface hardening by nitriding
 - Part 3 Steels for case hardening
 - Part 4 Stainless, heat resisting and valve steels
 - Part 5 Carbon and alloy spring steels for the manufacture of hot formed springs
- BS 1387 Steel tubes and tubulars suitable for screwing to BS 21 pipe threads
- BS 1400 Copper alloy ingots and copper and copper alloy castings
- BS 1452 Grey iron castings
- BS 1453 Filler rods and wires for gas welding
- BS 1504-6 Steels for use in the chemical, petroleum and allied industries
 - BS 1504 Castings
- BS 1560 Steel pipes flanges, nominal size $\frac{1}{2}$ in to 24 in, for the petroleum industry
 - Part 2 Metric dimensions.
- BS 1640 Steel butt-welding pipe fittings for the petroleum industry
 - Part 3 Wrought carbon and ferritic alloy steel fittings
- BS 1723 Brazing
- BS 1740 Wrought steel pipe fittings (screwed BSP thread)
- BS 1845 Filler metals for brazing
- BS 1965 Butt-welding pipe fittings for pressure purposes.
 - Part 1 Carbon steel

*In course of preparation

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- BS 1973 Polythene pipe (Type 32) for general purposes, including chemical and food industry uses
- BS 2051 Tube and pipe fittings for engineering purposes
Part 1 Copper and copper alloy capillary and compression tube fittings (for use with fractional o.d. sizes of tubes)
- BS 2579 Solid drawn copper alloy tubes for the manufacture of screwed ferrules, and copper alloy screwed ferrules for condenser, evaporator, heater and cooler tubes
- BS 2591 Glossary for valves and valve parts (for fluids)
Part 1 Screw-down stop, check and gate valves
Part 2 Safety valves and relief valves
Part 3 Plug valves and cocks
Part 4 Butterfly valves
Part 5 Ball valves
- BS 2640 Class II oxy-acetylene welding of steel pipelines and pipe assemblies for carrying fluids
- BS 2789 Iron castings with spheroidal or nodular graphite
- BS 2815 Compressed asbestos fibre jointing
- BS 2870 Rolled copper and copper alloys. Sheet, strip and foil
- BS 2871 Copper and copper alloys. Tubes
Part 1 Copper tubes for water, gas and sanitation
Part 2. Tubes for general purposes.
- BS 2872 Copper and copper alloys. Forging stock and forgings
- BS 2873 Copper and copper alloys. Wire
- BS 2874 Copper and copper alloys. Rods and sections (other than forging stock)
- BS 2875 Copper and copper alloys. Plate
- BS 2901 Filler rods and wires for gas-shielded arc welding
- BS 2971 Class II metal-arc welding of steel pipelines and pipe assemblies for carrying fluids
- BS 3071 Nickel-copper alloy castings
- BS 3072 Nickel and nickel alloys. Sheet and plate
- BS 3075 Nickel and nickel alloys. Wire
- BS 3076 Nickel and nickel alloys. Rods
- BS 3100 Steel castings for general engineering purposes
- BS 3468 Austenitic cast iron
- BS 3600 Dimensions and masses per unit length of welded and seamless steel pipes and tubes for pressure purposes
- BS 3601 Steel pipes and tubes for pressure purposes: carbon steel with specified room temperature properties
- BS 3974 Pipe supports
- BS 4368 Carbon and stainless steel compression couplings for tubes
- BS 4504 Flanges and bolting for pipes, valves and fittings. Metric series
- BS 4622 Grey iron pipes and fittings
- BS 4772 Ductile iron pipes and fittings
- BS 4882 Bolting for flanges and pressure containing purposes
- BS MA26 Weed boxes and suction strainers
- CP 3003 Lining of vessels and equipment for chemical processes
Part 1 Rubber
Part 2 Glass enamel
Part 3 Lead
Part 4 Plasticized PVC sheet
Part 5 Epoxide resins
Part 6 Phenolic resins

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Specification**1. Scope**

This British Standard specifies requirements for the materials, design, fabrication, installation, inspection and testing of salt water piping systems in ships, including all fittings which form parts of such systems, in which the design pressure in the pipes does not exceed 16 bar*. For the purposes of this standard a salt water piping system includes all pipes and fittings from sea water inlet to discharge overboard.

NOTE. Users of this standard should note that while observing the requirements of the standard they should at the same time ensure compliance with such statutory requirements, rules and regulations as may be applicable to the individual ship concerned.

2. Definitions

For the purposes of this British Standard the following definitions, together with those given in BS 499 and BS 2591, apply:

- (1) *Design pressure.* The maximum pressure to which the system can be subjected when in service. It is the value used in design calculations. This pressure may result from a combination of circumstances unlikely to occur under the normal working conditions, e.g. ship at its deep draught, discharge valves fully shut, pumps operating and relief valves set for normal working conditions.
- (2) *Test pressure.* The pressure to which the system and its components are subjected under test conditions (see Clause 10).
- (3) *The piping system.* All pipes, pumps, valves, heat exchangers and fittings from sea water inlet to discharge overboard.
- (4) *Flow conditions.* The expected conditions of water flow in individual parts or sections of the piping system. To meet varying design requirements three conditions are recognized:
 - a. *Continuous flow.* Where the water in a system or part of a system is flowing continuously under the ship's normal operating conditions.
 - b. *No-flow.* For air vents, and where a branch connection to a main pipe has its other end permanently closed under normal operating conditions. The water in such a branch is regarded as having a no-flow condition.
 - c. *Intermittent flow.* All systems and parts of the systems not covered by a and b.
- (5) *Purchaser.* The shipowner or ship operator according to the circumstances of a particular ship.
- (6) *Manufacturer.* The shipbuilder or authorized subcontractor.

3. Rating of system

The design pressure rating of the system shall be not greater than 16 bar*.

4. Materials

4.1 General. Materials used in the piping systems constructed in accordance with this British Standard shall comply with one of the material standards given in 4.2 and 4.3. The materials in this standard are not listed in order of preference and the use of other materials shall be by agreement of the manufacturer and the purchaser.

4.2 Copper alloy components. All copper alloys used in the manufacture of components for salt water piping systems shall comply with the requirements of one of the British Standards or designated alloys given in Table 1.

Attention is drawn to the unnumbered footnote immediately under Table 1 and also to Appendix B.

4.3 Ferrous components (steel and cast iron). The component is described as 'ferrous' if it is entirely ferrous or its main body is made of ferrous material. The materials used for ferrous components shall comply with the following specifications.

* 1 bar = 10^5 N/m² = 0.1 MPa

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4.3.1 Pipes

4.3.1.1 Steel pipes as specified in BS 1387. Steel pipes complying with the requirements of BS 1387 are limited to a maximum working pressure of 3.5 bar* on piping systems subject to survey by regulatory bodies. On systems not subject to survey, higher pressures are permissible.

4.3.1.1.1 BS 3601.

'Seamless (S) or electric resistance welded (ERW) steel pipes of Grades 320, 360 and 410.

Submerged arc welded (SAW) steel pipes, Grade 410, provided they are welded internally and externally.'

4.3.1.1.2 General. Steel pipes may also be fabricated from 'ship quality' mild steel plate.

Pipes which are to be used with screwed fittings may be purchased in the galvanized condition. All other steel pipes shall be ordered in the black unvarnished condition.

4.3.1.2 Grey and ductile iron pipes. Grey and ductile iron pipes shall be as specified in BS 4622 or BS 4772.

4.3.2 Pipe fittings, flanges and bolting

4.3.2.1 Steel. Carbon steel butt-welding pipe fittings shall be as specified in BS 1965 Part 1 (for nominal sizes up to and including 400 mm).

Wrought carbon steel butt-welding pipe fittings (metric units) shall be as specified in BS 1640 Part 3 (for nominal sizes over 400 mm).

Steel flanges and bolting for pipes, valves and fittings (metric series) shall be as specified in BS 4504 or BS 1560 Part 2.

Steel flanges may also be made according to BS 4504 but of 'ship quality' mild steel plate.

4.3.2.2 Wrought steel. Steel plates, sheets, strips and forgings shall be of low carbon welding quality so that no preheating or other special precautions are required.

NOTE: With regard to friction welding of flanges see 7.3.1.1.

4.3.2.3 Cast steel. Carbon steel castings shall be as specified in BS 3100-592, Grade 'A'.
BS 1504-161, Grade 'A'.

4.3.2.4 Grey and ductile iron. Grey and ductile iron shall comply with the requirements of the following standards as applicable:

BS 1452, Grade 12 minimum.

BS 2789, Grade SNG 24/17 or 27/12.

BS 3468, AUS 101 flake graphite austenitic cast iron.

BS 3468, AUS 202 spheroidal or nodular graphite austenitic cast iron.

BS 309, Whiteheart malleable iron castings.

BS 310, Blackheart malleable iron castings.

BS 4772, Ductile iron pipes and fittings.

BS 4622, Grey iron pipes and fittings.

* 1 bar = 10^5 N/m² = 0.1 MPa

Table 1. Copper alloy components



			Castings										Pipe and heat exchanger tube					
			1400	1400	1400	1400		1400	1400	3071	3071	—	1400	2871	2871 Pts 2 & 3	2871 Pts 2 & 3	2871 Pts 2 & 3	2871 Pt 3
British Standard			LG1-C Gunmetal	LG2-C Gunmetal	LG4-C Gunmetal	PB1-C Phosphor-bronze		AB2-C Aluminium-bronze	SCB-4-C Naval brass	NA1 Nickel-copper	NA2 Nickel-copper	70/30 Copper-nickel (1)	CT-1 Copper-tin	Copper	CZ110 Aluminium-brass	CNI02 90/10 Cu-Ni-Fe	CNI07 70/30 Cu-Ni-Fe	CNI08 Cu-Ni-Fe-Mn
Designated alloy																		
Component																		
Piping systems	Pipes													X ⁽³⁾	X	X	X	
	Flanges		X ⁽⁴⁾	X	X			X				X						
	Fasteners												X					
	Cast fittings		X	X	X			X	X	X	X							
	Wrought fittings																	
Valves	Body, bonnet, cover, dish, wedge and ball		X ⁽⁴⁾	X	X			X		X	X	X						
	Disc, wedge, ball, facing rings, body seat rings and other trim components		X	X	X			X		X	X	X						
	Internal fasteners		X	X	X			X		X	X	X						
	Stem, spindle and shaft (9)		X	X	X	X		X		X	X							
Pumps	Body			X	X			X		X	X	X						
	Impeller							X		X	X	X						
	Shaft									X	X	X						
	Shaft sleeve			X	X	X				X	X	X						
	Wear ring (6)																	
	Internal fasteners		X	X	X			X		X	X	X						
Heat exchangers	Tubes and ferrules (7)														X ⁽⁸⁾	X	X	X
	Tube, plates and sheet, general purpose plate			X					X									
	Water boxes, covers			X				X	X									
	Fasteners																	
Strainers	Body		X	X	X			X		X	X	X						
	Mesh frame				X			X										
	Wire mesh																	
	Perforated sheet and plate		X	X	X			X		X								
	Fasteners		X	X	X			X				X						
Weed grids	Grids		X	X	X			X										
	Fasteners		X	X	X			X				X						

X is printed in bold type where α -Cu alloys are quoted. All components in these items which are in contact with sea water are to be of the same material.

NOTE 1. Where no standard is quoted the composition is to be agreed.

NOTE 2. Conforms to specification Al 6.0 to 6.4, Si 2.0 to 2.4, Fe 0.5 to 0.9, Cu balance.

NOTE 3. For air vents only.

NOTE 4. Also acceptable: Sn 3 to 4.5, Pb 6.5 to 9, Zn 8.5 to 11, Ni 2.0, Al 0.01% max Cu balance.

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4.3.3 Couplings. Screwed couplings shall be as specified in BS 1740 Part 1 and compression couplings as specified in BS 4368 Parts 1, 2* and 3†. Where proprietary designs of couplings, which prevent leakage by axial or radial compression of non-metallic sealing rings, are used to connect pipes the materials shall be subject to agreement between the manufacturer and the purchaser.

4.3.4 Valves

4.3.4.1 Body, bonnet, cover, disc (according to type of valve). Any of the materials given in 4.3.2.2, 4.3.2.3 or 4.3.2.4 may be used.

4.3.4.2 Internal fittings and trim. All internal fittings other than those given in 4.3.4.3 shall be selected from the respective copper alloy components given in Table 1. With regard to the use of non-metallic materials see 4.5.

4.3.4.3 Stems, spindles, shafts and internal fasteners. Any of the material given in Table 1 or specified in 4.3.5.3.

4.3.5 Pumps

4.3.5.1 Body. Any of the materials given in 4.3.2.3 or 4.3.2.4 and the following material may be used:

BS 3100-1632, Grade B austenitic chromium-nickel-molybdenum steel castings.

4.3.5.2 Impeller. Any of the materials given in Table 1 or the following may be used:

BS 3100-1632, Grade B austenitic chromium-nickel-molybdenum steel castings.

BS 3468, AUS 101 flake graphite austenitic cast iron.

BS 3468, AUS 202 spheroidal or nodular graphite austenitic cast iron.

4.3.5.3 Shaft. Any of the materials given in Table 1 or any of the following materials may be used:

BS 970, Part 4 { 316S16 Austenitic chromium-nickel-molybdenum steels.
320S17
431S29 Martensitic chromium-nickel steel.

BS 3100-1632 Grade B austenitic chromium-nickel-molybdenum steel castings.

For scroll pumps or for eccentric and shoe pumps, where the shaft works in an elastomeric housing, the shaft shall be made from BS 970, 316S16, 320S17 austenitic rust resisting steel.

Where a shaft sleeve is fitted which prevents all contact between the sea water and the shaft, the shaft may be of any material appropriate to the speed and power requirements of the pump duty.

4.3.5.4 Shaft sleeve. With packed gland seals, shaft sleeves shall be made of one of the following materials:

BS 1400, LG2-C or LG4-C leaded gunmetals.

BS 970 Part 4, { 316S16 Austenitic chromium-nickel-molybdenum steels.
320S17

Where a shaft sleeve is fitted to a shaft which is not corrosion resistant it is important to ensure that there is no contact between the shaft and sea water, initially and in service.

4.3.5.5 Wear rings. Either of the materials given in Table 1 may be used (see also 4.5.2).

4.3.5.6 Internal fastenings

4.3.5.6.1 Nuts. Any of the materials given in Table 1 or BS 970 Part 4, 316S16 or 320S17, austenitic chromium-nickel-molybdenum steels, may be used.

4.3.5.6.2 Split pins, locking pins, etc. Only the materials given in Table 1 shall be used.

4.3.6 Strainers

4.3.6.1 Body. Any of the materials given in 4.3.4.1 may be used.

4.3.6.2 Mesh frame, wire mesh, perforated plate and internal fastenings. The materials given in Table 1 are recommended. Other materials, such as galvanized mild steel, stainless steel and plastics coated materials may be used (see 4.1).

4.3.7 Weed grids. Any of the cast non-ferrous materials in Table 1, or fabricated mild steel protected by galvanizing, may be used.

* BS 4368 Part 2 couplings can be used with BS 1387 dimensions.

† BS 4368 Part 3 is in course of preparation.

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For *fastenings* any of the materials given in Table 1 for strainer fastenings, or the following materials, may be used:

- BS 970, Part 4 { 316S16 Austenitic chromium-nickel-molybdenum steels.
320S17
431S29 Martensitic chromium-nickel steel.
BS 3100-1632, Grade B austenitic chromium-nickel-molybdenum steel castings.

4.3.8 Heat exchangers

4.3.8.1 Tubes and ferrules. Any of the materials given in Table 1 may be used.

4.3.8.2 Tube plates. Any of the materials given in Table 1 may be used. In addition stainless clad mild steel, where the stainless steel cladding is an 18/8 stabilized type, may be used.

4.3.8.3 Water boxes and covers. Any of the materials given in 4.3.2.2 or 4.3.4.1 may be used.

4.3.8.4 Stay bolt cap nuts. Any of the materials given in Table 1 may be used.

4.4 Welding and brazing consumables. The welding and brazing consumables to be adopted in the construction of pipe systems in accordance with this standard shall be selected from one of the following in accordance with the requirements of 6.3 and 7.3:

(1) *Copper alloy welding consumables*

BS 1453, Filler rods and wires for gas welding.

BS 2901, Filler rods and wire for gas-shielded arc welding.

Part 3, Copper and copper alloys.

See also 6.3.1.3.

(2) *Ferrous welding consumables*

BS 639, Covered electrodes for the manual metal-arc welding of mild steel and medium tensile steel.

BS 1453, Filler rods and wires for gas welding.

BS 2901, Filler rods and wires for gas-shielded arc welding.

Part 1, Ferritic steels.

Part 2, Austenitic stainless steels.

Part 5, Nickel and nickel alloys.

(3) *Brazing consumables*

BS 1845, Filler metals for brazing.

Only the following alloys shall be used: AG 1, AG 5 (or AWS A 5.8-69, B-Ag 3 may be used as an alternative).

4.5 Non-metallic components

4.5.1 Pipes. Where plastics and composites are used they shall be subject to agreement between the manufacturer and the purchaser.

Suitable elastomers may be used for flexible units or assemblies (see 9.2).

4.5.2 Pumps. Use is made in certain pumps of elastomers for such purposes as the housing of scroll pumps and shoes of eccentric pumps and non-metallic materials for components for use in mechanical seals. The precise materials shall be chosen by the pump manufacturers for their proprietary products to suit the conditions prevailing.

Wear rings for centrifugal pumps made from fibre reinforced plastics may be preferred to the lead-bronze material now in common use.

4.5.3 Valves. Use is made on certain types of valves of non-metallic materials for separate seat inserts, diaphragms and linings. Plastics valves may be used on non-essential services subject to agreement between the purchaser and the manufacturer.

4.5.4 Orifice plates. Where orifice plates and pressure reducing constrictions are permanently fitted, the materials shall be as agreed between the manufacturer and the purchaser.

NOTE. Attention is drawn to the Note under Clause 1 regarding certain restrictions imposed by the classification societies and regulatory bodies.



5. Design of salt water pipeline systems

5.1 General

5.1.1 In designing a salt water system it should be noted that certain configurations and some types of fitting give an appreciable pressure loss and should be avoided if possible; guidance on the calculation of pressure losses is given in Appendix A. Such measures will have the added advantage of reducing the possibility of failure due to impingement attack, since local high losses in a pipe system will usually result in excessive turbulence in the flow fluid.

5.1.2 The diameter of each pipe run is determined from considerations of the water flow quantities and a permissible 'maximum velocity—pipe diameter' relationship. The latter is usually related to the material of the piping and also depends upon whether the pipe is in a pump suction or discharge line. The suction piping is usually the larger in diameter and the pipe leads and fittings should be arranged to limit the pressure drop and ensure adequate flow of water to the pump suction.

5.1.3 The pressure loss through proprietary items such as coolers may be obtained from the manufacturer's specifications. The extra losses to be determined are those occurring in the pipes, valves, bends and other fittings and are considered in detail in Appendix A.

5.2 Recommended water speeds

5.2.1 The water velocities for pipes should not exceed those given in Fig. 1. It should be noted that excessive turbulence due to poor design and/or fabrication can result in failure at nominal velocities well below the values given. Where other materials are to be used the water velocities shall be subject to agreement between the purchaser and the manufacturer.

NOTE. It is a requirement of the regulatory bodies that a minimum water speed of 2.0 m/s be attained in bilge systems.

Where plastics or plastics lined pipes are to be used the water velocities shall be subject to agreement between the purchaser and the manufacturer.

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"Whilst it is important that the maximum water velocities should be restricted, attention is also drawn to the importance of ensuring that the flow should not be established at such a low figure that, when operating under polluted water conditions, sediment and slime are allowed to build up. This will inevitably lead to corrosion followed by early failure. It is recommended that polluted water should not be allowed to remain stagnant in pipework and equipment for long periods. It is recommended that during construction, fitting out and operation all items of equipment should be regularly run for short periods at least to ensure that a flushing-through can be assured, and attention is also drawn to Appendix B."

5.2.2 The maximum water velocity in heat exchanger tubes depends as much upon design as upon materials and is the responsibility of the heat exchanger designers.

5.2.3 It should also be noted that turbulence inside certain types of valves may result in local water speeds in excess of those in the pipeline of the same nominal bore.

5.3 Venting of systems

5.3.1 Entrained air can cause corrosion and erosion of all parts of the system and particularly components of pumps, valves and heat exchangers, and can also cause air-locking of pumps.

5.3.2 To limit the air in systems careful consideration should be given to the following:

(1) *Position of inlet boxes.* Much can be done to reduce air entrainment by careful attention to positioning of the sea inlet boxes. They should be arranged so that they are not in the way of any line of excessive sea water turbulence due to the hull form nor placed in areas where air is likely to be released and accumulated owing to reduced pressure, e.g. immediately beneath the bilge keel, or where water from other pump discharges will be entrained. The depth of immersion at light draught shall be considered together with the angles of roll expected in adverse weather so that it should not be possible for the boxes to emerge above the water line except perhaps in the most severe weather conditions. Even then the suction pipe shall still be completely immersed.

If possible, the inlets should be placed where the angles of run of the hull towards the stern are small.

(2) *Design of inlet boxes.* Ideally, the inlet box itself should be streamlined as much as possible to reduce turbulence. A large rectangular box will tend to allow air to accumulate at the top and if the system suction is placed there, air will be ingested into the system. On the other hand, the conventional rectangular inlet box can be designed to be an effective separation chamber and it has the advantages of a position at the commencement of the system and flow velocities that are low. An arrangement such as an internal pipe to create a free surface should be fitted and the removal of released air should be accomplished by venting. The top of the chamber shall permit free passage of air to the vent. The use of scoops instead of inlet boxes is to be the subject of agreement between the manufacturer and the purchaser.

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(3) *Weed grids.* Weed grids shall be designed so that any disruption of the flow of water is kept to a minimum. Weed grids shall be fitted at the ship's side on all sea water inlets to prevent large solids fouling the sea strainers. Preferably the grids should be mounted with the bars running in a fore and aft direction. The grid bar spacings should be about 25 mm minimum with the ratio of clear grid area to area of sea inlet valve or valves not less than 2:1. No part of a grid shall stand proud of the hull.

Grids may be of cast or fabricated construction by agreement between the purchaser and the manufacturer. Grids shall be secured in position by copper alloy fasteners, securely locked, but shall be easily dismountable for drydock inspection.

(4) *Sea strainers.* Sea strainers, where provided, shall be fitted to screen out solids which have passed the shipside weed grids. The strainers should be capable of stopping solids larger than 10 mm diameter, but finer filtration may be required and particular attention should be paid to the diameters of tubes and orifices in heat exchanger equipment. The ratio of clear area through the strainer to area of sea inlet valve or valves should be not less than 2:1 and a greater ratio will be required for finer filtration. The strainer shall be capable of being isolated to enable it to be opened up for inspection and removal of trapped solids and a test cock is desirable to ensure isolation of the strainer is effective. Sea strainer bodies may be of cast or fabricated construction with a securely jointed access cover and with a removable perforated screen or cage (see BS MA . . . , 'Weed boxes and suction strainers', in course of preparation).

(5) *Air vents.* Arrangements shall be made for relieving air from the highest point in the inlet box. Air vents are preferred in the form of pipes with steeply inclined runs leading from the highest point in the inlet box to a height above the deepest load line of the ship. A shut-off valve should be fitted between the vent line and the box. The highest parts of the system should also be provided with vents, and any positions where the water speed is low should be vented. Where boxes are not in the bottom, air release may be through holes at the highest point connecting to the sea; preferably vent pipes of adequate size may be used.

Air release arrangements should also be fitted on the pressure side of the system. High points of pipes and heat exchangers are positions to consider for the fitting of vents.

(6) *Position of pumps.* Salt water pumps should be placed as low as practicable, preferably on the tank top, but care should be taken that the motor is kept sufficiently high to minimize the possibility of damage in the event of flooding.

5.4 Piping layout

5.4.1 Permanent records of the piping layout shall be supplied to the purchaser. These records shall include single line flow diagrams showing pipeline sizes and valve type identification. Pumps, heat exchangers, machinery units, special fittings and ancillary services supplied shall be indicated on the diagrams. Information on heat dissipation data, limiting temperature and known flow parameters shall also be provided as part of the permanent records.

5.4.2 The single line flow diagrams referred to in 5.4.1 shall be supplemented by additional records of a type agreed between the purchaser and the manufacturer. These may be isometric sketches or pipe arrangement drawings or photographs of scale models of the piping system, as appropriate.

5.4.3 The piping layout provided should incorporate features to facilitate plant operation and maintenance in service. It should:

- (1) use angled branches and large radii bends in pipelines where possible to avoid or reduce turbulent fluid flow;
- (2) keep the number of joints to the minimum practicable;
- (3) provide firm anchor points for pipelines, where required, also supports in critical positions, e.g. where necessary to avoid imposition of loadings on pump branches or at flexible pipe connections;
- (4) provide pipe flexibility in way of orifice plates or temporary line blanks to facilitate removal for service adjustments;
- (5) provide easily portable sections, e.g. short bends or make-up pieces, to facilitate removal of heat exchanger water boxes, etc.;
- (6) provide clearances from all equipment, e.g. for tubestack removal, motor access and equipment maintenance; and for access to machinery parts, e.g. main engine holding down bolts;

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(7) provide accessibility to all other system components which may require manipulation, inspection and maintenance;

(8) allow a straight length of pipe of not less than 6 diameters downstream of any orifice plates used for permanent control of flow.

6. Copper alloy systems

6.1 Pipes, flanges, bolting and fittings

6.1.1 Pipes. The standard outside diameters shall be in accordance with Table 2.

The minimum thickness of pipes subjected to pressures in excess of 7 bar* shall be calculated according to the requirements of the regulatory bodies. For other services the minimum thicknesses in Table 2 shall be used.

Larger pipes may be fabricated from rolled sheet or plate to suit standard flanges in accordance with 6.1.2.

Table 2. Preferred sizes for salt water pipelines

(Extract from BS 2871 Part 2)

Tube size	O.D. max.	O.D. min.	Preferred standard thickness	Other standard thickness	Other standard thickness
	mm	mm	mm	mm	mm
6	6.045	5.965	0.8	1.0	0.6
8	8.045	7.965	0.8	1.0	0.6
10	10.045	9.965	0.8	1.0	0.6
12	12.045	11.965	0.8	1.0	0.6
16	16.045	15.965	1.0	1.5	—
20	20.055	19.975	1.0	2.0	—
25	25.055	24.975	1.5	2.0	—
30	30.055	29.99	1.5	2.0	—
38	38.07	37.99	1.5	2.0	—
44.5	44.57	44.49	1.5	2.0	—
57	57.20	57.12	1.5	2.0	—
76.1	76.30	76.15	2.0	2.5	—
88.9	89.15	89.00	2.5	3.0	—
108	108.25	108.00	2.5	3.0	—
133	133.50	133.25	2.5	3.0	—
159	159.50	159.25	2.5	3.0	—
193.7†	194.50	194.25	3.0	3.5	—
219.1	219.90	218.30	3.0	4.0	—
267	268.00	266.40	3.0	4.0	—
323.9	324.90	323.30	4.0	4.5	—
368	369.00	367.40	4.0	4.5	—
419	420.00	418.40	4.0	4.5	—
457.2	458.20	455.20	4.0	4.5	—
508	509.00	506.00	4.5	5.0	—

NOTE. Tubes for pipelines are usually required suitable for cold bending or other fabrication processes and unless otherwise specified, are, at the manufacturer's discretion, supplied in either the temper annealed (T.A.), half hard ($\frac{1}{2}$ H) or annealed (O) condition appropriate to material and size.

* 1 bar = 10^5 N/m² = 0.1 MPa

† Valves are not available in 193.7 mm size.

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Certain thicknesses listed may be unsuitable for use with non-manipulative type couplings.

On systems using copper alloy piping in accordance with Table 2, premature failure may occur if mismatch or misalignment of the bores is excessive. To avoid excessive mismatch it may be necessary to machine the end flanges of valves and fittings and this will be subject to agreement between the purchaser and the manufacturer.

The external diameters of pipe flanges shall be concentric with their bores.

6.1.2 Flanges and bolting. Flanges and bolting used in piping systems constructed in accordance with this British Standard shall be in accordance with BS 4504 and BS 4882, except in certain types of proprietary equipment where a special design of flange may be essential. In such cases, mating flanges should be supplied by the manufacturer.

6.1.3 Fittings

6.1.3.1 Fittings for joining small diameter pipes. For the assembly of smaller sizes of copper alloy pipes up to and including 57 mm nominal diameter, proprietary types of fitting in materials in accordance with 4.2 may be used. These can be either capillary or compression types with socket diameter tolerances complying with the requirements of BS 864 Part 2 or BS 2051 Part 1 as appropriate; the capillary may be of either integral solder ring type or end feed. The manufacturer's recommendations for the procedure to be adopted for cleaning, fluxing and heating should be adhered to in order to ensure the production of sound joints.

Compression fittings may be either the non-manipulative type in which a ring is compressed on to the outside surface of the tube in the joint, or the manipulative type which requires the end of the tube to be flared for the production of a sound joint. Non-manipulative type couplings are not recommended for continuous flow conditions. When aluminium-brass tube ends are flared for use with these joints they should be stress relieved prior to fixing in accordance with 6.2.5. Because of the danger of stress corrosion cracking, non-manipulative types shall not be used with aluminium brass pipes.

6.1.3.2 Branch and tee-pieces. These may take the form of castings, forgings, extrusions or fabricated pipework. Designs leading to a more streamlined flow into the branch will reduce turbulence and thus decrease the risk of corrosion by impingement attack. Swept or angled branches are therefore preferred to the right angled type. For branches of 57 mm diameter and below, proprietary types of tee-piece fitting may be used. For methods of fabrication see 6.3.1.9.5 and 6.3.2.2.

6.1.3.2.1 Castings. Any of the cast materials in 4.2 are suitable. Where it is impracticable or uneconomic to fit swept or angled branches, tee-connections may be used having internal radii at the junction of not less than $d/3$ (where d =diameter of branch). The bore finish should be smooth and free from any flash, protrusions or sharp edges. For branches of 57 mm diameter and below, proprietary types of tee-piece fitting may be used.

6.1.3.2.2 Forged fittings. Any of the wrought materials which are listed in 4.2 may be used to produce fittings by forging in a press or by stamping. The minimum thickness at any part of the fitting shall be not less than the wall thickness of the branch pipe to which it attaches.

The finished fitting shall be free from internal stresses or in the annealed condition (see 6.2.5).

6.1.3.3 Deck and bulkhead fittings for small pipes. For copper alloy pipeline deck and bulkhead penetrations in sizes 57 mm and below, proprietary types may be used provided the connections to the deck and bulkhead piece are in accordance with 6.1.3.1.

For larger bulkhead pieces see 6.4.2.

6.2 Manipulation and fabrication of copper alloy pipes

6.2.1 Limits of pipe bending and other bends

6.2.1.1 Bends (general). The centre line radius for bends formed from straight pipes shall be as large as practicable. It is recommended that the minimum radius be not less than three times the outside diameter of the pipe for continuous flow conditions as defined in 2.1.

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Subject to agreement between the purchaser and the manufacturer however, a centre line radius of less than the preferred minimum radius may be used, in which case consideration should be given to an increase in wall thickness.

1 Proprietary seamless or seam welded bends in copper alloys or bends in cast copper alloys in accordance with 4.2 may be used. For pipe sizes up to 57 mm, proprietary fittings according to 6.1.3 may be used.

6.2.2 Cold bending of pipes

6.2.2.1 *Machine bending.* It is recommended that tubes should be bent on a machine preferably with a mandrel attachment or on a machine using the principle of an internal rotary cold rolling head. All tools used in the process shall be of the appropriate size to the tube being bent, and be in a good, clean operating condition, free from damage, cracks and other defects. The tools should preferably be confined to use with copper alloys only. A suitable water soluble oil or soap should be used to lubricate the mandrel during bending.

For the larger sizes of pipe, where no mandrel is available, a filler material such as sodium thiosulphate ('hypos') or a synthetic wax should be used.

Because of the difficulty of ensuring complete removal of deleterious residues of resin, or mixtures of resin and pitch fillers, such fillers shall not be used. For removal of filler residues, see 6.2.2.4.

6.2.2.2 *Press bending.* Where bending machines are not available, or where bends are required in larger diameter pipes than can be catered for by a machine, press bending and manual coppersmithing techniques may be adopted. The filler material used shall be as prescribed in 6.2.2.1. With this bending technique it may be necessary to carry out intermediate (i.e. interstage) annealing to complete the bending; if so, this shall be carried out in accordance with 6.2.5.

6.2.2.3 *General treatment.* Bends made on machines, with or without mandrel attachments, shall be smooth and free from wrinkles. Wrinkles formed on filled tubes bent on a machine or by a press shall be dressed before the filler is removed. Bends containing sharp wrinkles that cannot be dressed back to form a smooth surface in the throat are not acceptable. Dressing, which should be kept to a minimum, shall be carried out by appropriate coppersmithing tools in good condition.

6.2.2.4 Following the completion of all bending and dressing operations, *all* traces of filler material or mandrel lubricant shall be removed. Residues of water soluble lubricant and sodium thiosulphate filler may be removed by thoroughly flushing the pipe through with clean water. If synthetic wax fillers are used, the maker's instructions should be followed in order to remove all residues. Attention is drawn to the possibility of toxic vapours being released when some types of synthetic wax fillers are heated.

6.2.2.5 After all the procedures in 6.2.2.4 have been carried out, all cold formed bends in aluminium-brass shall be stress relieved in accordance with 6.2.5. The stress relieving of bends in copper-nickel alloys formed on a machine is not mandatory, but shall be subject to agreement between the purchaser and the manufacturer.

NOTE. To minimize the possibility of subsequent cracking, if any silver brazing or welding operations are to be carried out adjacent to a bend in a copper-nickel alloy which has not been stress relieved, the bend shall be stress relieved in accordance with 6.2.5 before these operations are carried out.

Bends formed by press bending techniques, however, which normally require dressing, shall be stress relieved. The stress relieving of bends in copper-nickel alloys shall be carried out in accordance with 6.2.5.

6.2.3 Hot bending of pipes

6.2.3.1 Copper-nickel alloy pipes shall not be subjected to hot bending.

6.2.3.2 Aluminium-brass pipes may be hot bent although the adoption of this technique is usually restricted to pipe sizes up to and including 108 mm outside diameter. The pipe shall be filled with clean, dry silica sand, free from metallic or carbonaceous contamination. Hot bending of aluminium-brass should be carried out at a temperature of 600 °C to 650 °C as measured by pyrometer or temperature indicating paints or crayons. Bending shall not be attempted within the range of 250 °C to 550 °C or above 750 °C due to the risk of cracking.

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6.2.3.3 The dry sand filler should be firmly compacted; this operation may be carried out by tapping the outside of the tube with rubber or wooden mallets. The sand may also be compacted by mechanical means preferably by standing the tubes on a vibrator table. This technique is recommended for all pipe sizes particularly for the 108 mm size pipeline or larger if hot bending is to be used. Unless the sand is adequately compacted poor quality bends will result.

6.2.3.4 Because of the difficulty of dressing back wrinkles in sand loaded tubes, the wrinkles should be kept as shallow as possible during bending. Slight opening out of the bend again at the bending temperature will remove moderate to shallow wrinkles, but the sand filler should be recompacted before continuing the hot bending operation. Any shallow wrinkles remaining on completion of the bend may be dressed back at below 200 °C (or cold) as described in 6.2.2.3. Bends containing sharp wrinkles that cannot be dressed back to form a smooth surface in the throat are not acceptable.

6.2.3.5 The limits of pipe bending are that the centre line radius for bends formed by hot bending techniques shall be in accordance with 6.2.1.

6.2.3.6 On completion of the dressing operation the cold worked portions shall be stress relieved in accordance with 6.2.5.

6.2.4 *Welded copper alloy segmented (or gusseted) bends.* Segmented bends are not in general recommended but where their use is unavoidable they shall preferably be fabricated from tubes, and be confined to pipelines of 219.1 mm outside diameter and larger. Alternatively, for pipelines of 368 mm outside diameter and larger, the segments may be fabricated from sheet, cut and rolled to shape.

Segmented bends shall consist of a recommended minimum of three segments and be constructed in accordance with the recommendations in 6.3.1 and Fig. 14. The centre line radius shall be as large as conditions on board permit. The recommended radius is not less than three times the outside diameter of the pipe, for continuous flow conditions as defined in 2.1.

6.2.4.1 Segmented bends, consisting of less than three segments and a centre line radius of less than three times the diameter of the pipe may only be used for continuous flow conditions subject to agreement between the purchaser and the manufacturer.

6.2.4.2 Segmented bends consisting of a minimum of two segments and a centre line radius of 1½ times the outside diameter of the pipe or less, may be used only for intermittent flow conditions, as defined in 2.1.

6.2.4.3 Segmented bends shall have at least one end flanged to facilitate the removal of any excessive weld bead penetration, globules, etc., and also to permit the internal weld bead and general construction of the bend to be inspected in accordance with 10.1.

6.2.4.4 'Cut-and-shut' bending technique is not acceptable for copper alloy salt water piping systems.

6.2.5 *Heat treatment of copper alloys*

6.2.5.1 *Stress relieving.* This treatment does not soften the pipes appreciably but reduces the stresses induced by cold working operations to a safe level. It shall be carried out, preferably in a pyrometrically controlled furnace, at the following temperatures:

Aluminium-brass	350 °C to 400 °C
90/10 Copper-nickel-iron	350 °C to 450 °C
70/30 Copper-nickel	400 °C to 500 °C

The temperature of the pipes should be maintained within the above ranges for not less than 30 minutes. Stress relieving may also be carried out between the stress relieving and annealing temperatures and for appropriate times quoted in 6.2.5.1 and 6.2.5.2 by agreement between the purchaser and the manufacturer.

6.2.5.2 *Annealing.* This treatment softens the pipes and shall be carried out wherever practicable in a pyrometrically controlled furnace at the following temperatures:

Aluminium-brass	600 °C to 650 °C
90/10 Copper-nickel-iron	750 °C to 800 °C
70/30 Copper-nickel	800 °C to 850 °C

The temperature of the pipes shall be maintained within the above ranges for not less than 10 minutes.

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6.2.5.3 Method of heating. If no suitable pyrometrically controlled furnace is available, the pipes may be stress relieved or annealed with one or more suitable torches which shall be adjusted to give an appropriate size of neutral to slightly reducing flame that is large enough to heat the pipe up to the required temperature uniformly and moderately quickly.

If torch heating is used, temperature indicating crayons, optical or contact pyrometers shall be used to measure the temperature of the pipe.

For copper-nickel alloys, the sulphur content of the furnace atmosphere shall not exceed 0.25 g/m³.

NOTE 1. If fairly heavily cold worked sections of copper-nickel alloy are subjected to sudden intense heat 'fire cracking' may result.

NOTE 2. Because of the possibility of the collapsing of large diameter pipes, particularly in aluminium-brass during annealing, it is advisable to use supports in the ends of the tubes where necessary.

6.2.5.4 Pickling (acid cleaning). After all hot and/or cold forming, cleaning and stress relieving operations have been completed the tubes may be pickled if agreed between the purchaser and the manufacturer.

Should pickling or acid cleaning be necessary it shall be carried out in a solution of 5 % to 10 % sulphuric acid to which potassium dichromate has been added in the proportion of 25 g/l to 50 g/l. After pickling, the tubes shall be thoroughly rinsed in hot, fresh water. Other pickling processes may be used subject to agreement between the manufacturer and the purchaser.

6.3 Permanent joining

6.3.1 Welding of copper alloys

6.3.1.1 Filler materials. Filler materials for arc welding copper alloys shall be in accordance with 4.4(1) and Table 4.

6.3.1.2 Arc welding processes. The appropriate arc welding process shall be selected from Table 3.

6.3.1.3 Gas welding. Gas welding is not recommended.

NOTE. BS 1453 does not list any suitable materials but commercial consumables are available for use in an emergency. Gas welding of aluminium-brass is possible using a matching (or 2 % to 3 % greater) Zn filler if obtainable with a fused borax and boric acid flux. The technique is even more difficult with tin-bronzes and aluminium-bronzes. Matching filler can be used in an emergency but for aluminium-bronze it is necessary for the flux to contain fluorides.

Table 3. Arc welding processes

Alloy	Backing gas		Process	Root run		Filler run (if necessary)	
	Internal access to root	No access to root		Current supply	Electrode	Current supply	Electrode
Cu-Ni	not mandatory*	Argon preferred	TIG†	d.c.	—ve	d.c.	—ve
			MIG§	not recommended		d.c.	+ve
			Manual metal arc	d.c.	+ve	d.c.	+ve
Al-brass	not mandatory†	not mandatory†	TIG†	a.c.		a.c.	
			MIG§	not recommended		d.c.	+ve

* Backing gas is preferred. Refractory backing rings may be used.

† Painting the inside of the joint with a slurry of silver brazing type flux aids formation of a good under-bead profile by deterring zinc volatilization and oxidation.

‡ A tungsten electrode diameter of 3 mm or less is recommended.

§ For the pipe thickness permitted by this standard a 1.6 mm diameter wire should be the maximum used.

|| Direct current with electrode positive is sometimes possible on the thin wall thickness pipes.

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6.3.1.4 Edge preparation. Edge preparations shall be such as to permit a satisfactory weld to be made with the selected welding process or processes. In the case of copper-nickel alloys the preparation shall be such as to allow, where possible, at least 50 % of filler to be added to the weld in order to avoid excessive dilution and resultant porosity.

The following butt-weld preparations are presented for guidance:

(1) *Copper-nickel alloys.* For thicknesses up to 2 mm the pipe ends to be welded may be cut square and close-butted. For pipe thicknesses over 2 mm the pipe ends may be prepared to give either a single V of included angle 70 ° with a feather edge and no root gap or a V preparation with a 1.5 mm root face.

Where fusible inserts are used there shall be a root face.

(2) *Aluminium-brass.* Up to 1.5 mm, a square edge preparation with a gap of 1.5 mm to 2.5 mm is acceptable. For thicker pipe an edge preparation giving a 45 ° included angle single V with a 1.5 mm root face and 1.5 mm root gap is recommended.

6.3.1.5 Edge precleaning. Immediately prior to welding or tacking, all copper alloy surfaces shall be scratch-brushed to brightness with a clean, stainless steel brush used only for copper alloy and then degreased with a non-toxic non-flammable solvent. The same treatment, using stainless steel wire wool in place of a scratch brush, shall be applied to all filler wire used with the TIG process.

6.3.1.6 Jigs and fixtures. Internal or external backing rings or clamps may be necessary and tack welding is permitted. The tack welding should be done observing the precautions for general welding described in 6.3.1.4, 6.3.1.5 and 6.3.1.7.

6.3.1.7 Welding procedure (general)

6.3.1.7.1 Copper-nickel alloys. The welding procedure shall be such as to introduce a minimum of 50 % of filler wire into the joint. Preheat shall not be used. Interpass temperature shall be kept below 150 °C to prevent any lowering of fatigue strength. Between passes the weld shall be cleaned as specified in 6.3.1.5.

6.3.1.7.2 Aluminium-brass. The procedure shall be such as to ensure as short a time at high temperature as possible. Between passes the weld shall be cleaned as specified in 6.3.1.5.

6.3.1.8 Weld quality. The weld metal as deposited shall be free from cracks, gross slag inclusions and porosity, cavities and other deposition faults. The weld metal shall be properly fused with the parent metal without serious undercutting or overlapping of the toes of the weld. Tests on completed welds shall be in accordance with the requirements of this standard (10.1).

6.3.1.9 Requirements for special joints

6.3.1.9.1 Pipe to pipe butt welds. Butt welds between pipes shall be made in accordance with 6.3.1.1 to 6.3.1.8.

6.3.1.9.2 Copper alloy flanges welded to copper alloy pipes. Butt welds made to attach flanges to pipes shall be made in accordance with 6.3.1.1 to 6.3.1.8 for the appropriate alloy. In the case of fillet welds the leg length should be not less than 1.5 times the thickness of the pipe. Welds shall be made on both sides of the flanges and flanges shall be concentric with the pipe.

6.3.1.9.3 Steel flanges welded to copper-nickel pipes. 6.3.1.1, 6.3.1.2 and Table 3 apply. The welding procedure adopted shall be such that there are no iron-rich surfaces in contact with the liquid in the pipe. The join shall be finished by the removal of excess weld metal. After completion of all welding and machining operations of the join the following surfaces shall be checked for iron content by the ferricyanide test (see 10.1.1):

- (1) The face of the weld and down to the pipe bore.
- (2) The inside surface of the pipe in the vicinity of the fillet welds.

NOTE. For the guidance of fabricators the following procedure is known to be satisfactory. Prepare the flange as in Fig. 12. Shot blast or peen the machined surface of the flange and degrease; this minimizes iron pick up. Do not scratch-brush. Before mounting the flange on the pipe make welds 1, 2 and 3 (see Fig. 13), using any process appropriate to copper-nickel alloys (6.3.1.2) for filler runs. Welding conditions should be such as to keep dilution to a minimum. Any overfilling at this stage should appropriately be machined back. The flange may now be mounted on the pipe and the remaining welds completed (Fig. 13) including the fillet weld on the back of the flange. Care should be taken with this fillet to avoid burning through the pipe wall. Deviations from this procedure are acceptable provided that the mandatory requirements of 6.3.1.9.3 are still met.

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6.3.1.9.4 Fabricated bends and branches (including attachment for branches). The welding procedure for the manufacture of these items and their inclusion in the pipework system shall comply with the requirements of 6.3.1.1 to 6.3.1.8 for the appropriate alloy.

6.3.1.9.5 Welded connections.

6.3.1.9.5.1 General. The appropriate welding consumables are given in 4.4 and Table 4. Welding shall be in accordance with 6.3.1. Immediately before welding the formed section of the pipe shall be stress relieved in accordance with 6.2.5.1. Inspection in accordance with 10.1.1 shall be carried out. In the case of aluminium-brass, stress relieving shall be repeated in the same manner.

6.3.1.9.5.2 Preparation of pipes, branches and bosses for welding. For the guidance of fabricators the following descriptions of methods of preparing pipes, branches and bosses for welding are given:

(1) For continuous, intermittent and no-flow conditions

- a. **Butt-welded saddle.** With the swept type of branch it is necessary to form the end of the pipe to the required angle. With this type, and the right angled branch, when it is required to manipulate the end of the branch pipe to form a saddle to fit to the main pipe, it may be necessary to carry out inter stage annealing for which the temperatures given in 6.2.5.2 will apply. Care has to be taken in forming the saddle not to reduce the thickness below the minimum specified thickness of the branch pipe. A corresponding hole is then cut in the main pipe to the same shape and size as the profile of the saddle portion of the branch pipe. Both profiles are then prepared for butt-welding in accordance with 6.3.1.4. An external view of a swept-type branch and a section of a tee-type branch are shown in Figs. 2 and 3 respectively.
- b. **Butt-welded stub (right-angled, tee-type only).** For this type of branch (see Fig. 4) a hole is drilled in the main pipe smaller in diameter than the branch pipe and the area surrounding the hole is locally annealed. A stub is then manipulated out. The stub so formed shall match the branch pipe to enable a butt weld to be made. Depending upon the size of the stub, it may be necessary to carry out inter-stage annealing. Care has to be taken in forming the stub not to reduce the wall thickness below that of the branch pipe. The profiles of the stub and branch pipe are then prepared for butt-welding in accordance with 6.3.1.4.
- c. **Penetration.** In both 6.3.1.9.5.1(1)a and 6.3.1.9.5.1(1)b the penetration into the bore of the pipe shall not exceed the following limits:
1 mm for branch pipes having a wall thickness up to 1.5 mm, or 80 % of branch pipes wall where this is above 1.5 mm.

(2) For intermittent and no-flow conditions

- a. **Branch connections.** Branch connections for these conditions only may be of the set-on type and are prepared by cutting the end of the branch pipe to the appropriate profile to set on the main pipe as shown in Fig. 5. A hole is then cut in the main pipe to match the bore of the profiled end of the branch. For branch pipes having a wall thickness of 2.5 mm and above, the weld preparation of the branch end shall be in accordance with Fig. 5b.
- b. **Penetration.** The penetration into the bore of the pipe shall not exceed 80 % of the branch wall thickness.

(3) For no-flow conditions

- a. **Branch connections.** Branch connections of the type described in this clause shall only be used in no-flow conditions.
- b. **Set-on branch.** This type of connection may be prepared and welded as shown in Fig. 6a or b. When the thickness is 2.5 mm or above, the preparation for the fillet weld shall be in accordance with Fig. 6b. A pad may be built up on the main pipe to suit the face of the branch. A fillet weld is then made between the branch and the built-up pad.

6.3.1.9.6 Fabricated bulkhead pieces. Of the designs of these items shown in Fig. 11b the joints which are relevant to copper alloy welding are the fillet welding of a copper alloy flange, of a steel sleeve and of a steel flange to copper alloy pipe. Descriptions of the various joints and attachments are given in Fig. 11c (to be used in conjunction with Fig. 11b). Welding shall be in accordance with 6.3.1.7, 6.3.1.8 and 6.3.1.9.

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6.3.1.10 Heat treatment. After severe cold working and before welding, stress relieving shall be carried out in accordance with 6.2.5.1. Aluminium-brass shall also be stress relieved at the completion of all welding and fabrication.

6.3.2 Brazing of copper alloys

6.3.2.1 Brazing consumables. Consumables shall be chosen from 4.4(3).

6.3.2.2 Brazing clearances. With tubes, as supplied, up to and including 57 mm nominal outside diameter specified in 6.1.1 and proprietary capillary fittings in accordance with 6.1.3, the capillary gap is satisfactory for the production of sound joints.

For pipe sizes above 57 mm and where proprietary capillary fittings are not used and for flanging, the gap between the fitting and the external diameter of the pipe at any point shall be not less than 0.1 mm nor greater than 0.2 mm.

6.3.2.3 Methods of achieving gap tolerance

6.3.2.3.1 Flanges. Flanges shall have their bores machined. If the flange bore and pipe outside diameter does not meet the tolerances of 6.3.2.2 the tube may be expanded by means of a mandrel or roller expanders. If circumstances prevent expansion by these methods careful hammering is allowed. With composite flanges hammering of the pipe end shall not be carried out with the inner ring fitted on the pipe.

6.3.2.3.2 All other fittings

6.3.2.3.2.1 If the gap between any of the fittings given in 6.1.3 and the pipe exceeds the tolerances of 6.3.2.2 the pipe shall be manipulated to achieve the tolerances. This situation will most commonly arise with set-on type branches both swept and tee, and bosses, both set-on and socketed (Scotch) type. The gap filling brazing alloy AWS A5.8-69 BAg-3 is preferred after such manipulation.

6.3.2.3.2.2 For the guidance of fabricators the following descriptions of methods of preparing pipes, branches and bosses for brazing are given:

(1) *Set-on saddle type.* With the swept type branch, it is necessary to form a bend that is cut to the required angle. With this type and the right angled branch, it is then required to manipulate the end of the branch pipe to form a saddle to fit snugly on the main pipe; it may be necessary to carry out inter-stage annealing, for which the temperatures given in 6.2.5.2 will apply. In forming the saddle, care should be taken not to reduce the thickness below the minimum specified thickness of the branch pipe. A corresponding hole is then cut in the main pipe to the same shape and size as the bore of the saddle portion of the branch pipe. The periphery of this hole is then manipulated so that there is a satisfactory capillary space between the saddle and the main pipe. Sections of swept and tee branch joints are shown in Figs. 7 and 8 respectively.

(2) *Connections.* Connections of the type described in this clause shall only be used where there is no flow through the branch, e.g. thermometer and air vent connections.

a. *Set-on type.* This type of boss connection should be prepared and brazed as shown in Fig. 9.

b. *Socket (or Scotch) type.* To form this type of connection a hole is drilled in the main pipe and the area surrounding the hole is locally annealed. A socket is then manipulated out with a 'bent pin', or with a pear shaped bobbin and steel cable which are pulled through the hole from the inside. Depending upon the size of the socket, it may be necessary to carry out inter stage annealing. The thickwalled branch is machined with a spigot which is inserted into the socket to a distance equal to 6 times t (where t is the thickness of the main pipe). The arrangement is illustrated in the sections in Fig. 10.

6.3.2.3.2.3 For no-flow conditions.

Table 4. Filler metals for arc welding copper alloy

The table is to be read within a given section along any horizontal row. For example, CN102 90/10 copper-nickel-iron may be welded to CA104 both on top of and backing the weld, by the tungsten inert gas or MMA.

Parent metals*

CN102 90/10 Cu-Ni-Fe	W e l d e d	CN102 90/10 Cu-Ni-Fe
CN102 90/10 Cu-Ni-Fe CN107 70/30 Cu-Ni-Fe		Weldable steel flanges as detailed in 4.3.2 and bulkhead pieces as in 6.4.2.2
CN102 90/10 Cu-Ni-Fe CN107 70/30 Cu-Ni-Fe		Cu-Al-Si-Fe (see Table 1, Note 2)
CN102 90/10 Cu-Ni-Fe CN107 70/30 Cu-Ni-Fe		BS 1400 AB2 Cu-Ni-Al-Fe CA104 Cu-Al-Ni-Fe CA105 Cu-Al-Ni-Fe-Mn CA106 Cu-Al-Fe
CN107 70/30 Cu-Ni-Fe		CN107 Cu-Ni-Fe
CZ110 Cu-Zn-Al		CZ110 Cu-Zn-Al BS 1400 Cu-Al-Ni-Fe CA104 Cu-Al-Ni-Fe CA105 Cu-Al-Ni-Fe-Mn CA106 Cu-Al-Fe Cu-Al-Si (see Table 1, Note 2)
CA104 Cu-Al-Ni-Fe Cu-Al-Fe		Weldable steel bulkhead pieces as in 6.4.2.2

TIG: tungsten inert gas
MIG: inert gas metal arc
MMA: manual metal arc

* Except where otherwise shown, copper alloys are as specified in BS 2870 to BS 2879.
† MMA electrodes are not covered by British Standards, but electrodes are commercially available, except for C12/C12Fe. The Cu—10 % Al—1 % Fe MMA electrode can be used for use in contact with sea water because of the risk of preferential corrosion.

‡ Normally MMA electrodes would only be used for the filling runs in which case oxygen-free nitrogen has been used for backing welds in CN107, although argon pool, where it will cause porosity.

NOTE 1. Shaped fusible inserts of composition identical to the filler metal composition. Some ceramic backing systems have been shown to be excellent on some copper-nickel-iron dissimilar metal combination.

NOTE 2. A recent commercial filler of the following compositions 6.5 to 7.5 Sn and 0.5 to 1.0 Cu.

NOTE 3. CN108 is a heat exchanger tube alloy and connections between this and the same range of alloys as CN107 using similar processes and consumables.

NOTE 4. Other alloy combinations given in Table 1 may be welded but the filler

y pipelines

lpath.

2A105 aluminium-bronze by C20 copper-aluminium-bronze with argon or helium shielding metal inert gas process.

Filler metals	Welding process	Shielding gas	
		Torch	Backing
BS 2901:Part 3 C16 90/10 Cu-Ni-Fe-Ti BS 2901:Part 3 C18 70/30 Cu-Ni-Fe-Ti † 70/30 Cu-Ni-Fe-Ti	TIG MIG TIG MIG MMA	Ar, He Ar, He —	Ar Ar Ar†
BS 2901:Part 3 C18 70/30 Cu-Ni-Fe-Ti BS 2901:Part 5 NA33 30/70 Cu-Ni-Mn-Ti † 30/70 Cu-Ni-Mn-Fe † 70/30 Cu-Ni-Mn-Fe	TIG MIG TIG MIG MMA MMA	Ar, He Ar, He — —	Ar Ar Ar† Ar†
BS 2901:Part 3 C12 Cu-Al BS 2901:Part 3 C12Fe Cu-Al-Fe	TIG MIG TIG MIG	Ar, He Ar, He	Ar Ar
BS 2901:Part 3 C18 70/30 Cu-Ni-Fe-Ti BS 2901:Part 3 C12 Cu-Al BS 2901:Part 3 C12Fe Cu-Al-Fe BS 2901:Part 3 C20 Cu-Al-Ni-Fe † 70/30 Cu-Ni-Mn-Fe † Cu-Al-Ni-Fe	TIG MIG TIG MIG TIG MIG TIG MIG MMA MMA	Ar, He Ar, He Ar, He Ar, He — —	Ar Ar Ar Ar Ar† Ar†
BS 2901:Part 3 C18 70/30 Cu-Ni-Fe-Ti † 70/30 Cu-Ni-Mn-Fe	TIG MIG MMA	Ar, He —	Ar, N ₂ § Ar†
BS 2901:Part 3 C12 Cu-Al BS 2901:Part 3 C12 Cu-Al BS 2901:Part 3 C12Fe Cu-Al-Fe BS 2901:Part 3 C20 Cu-Al-Ni-Fe	TIG MIG TIG MIG TIG MIG TIG MIG	Ar, He Ar, He Ar, He Ar, He	Ar Ar Ar Ar
BS 2901:Part 3 C20 Cu-Al-Ni-Fe † Cu-Al-Ni-Fe	TIG MIG MMA	Ar, He —	Ar Ar†

BS 2875.

commercially available which will deposit weld metal equivalent to the inert gas-shielded filler metals given in the table can be used for joining copper-aluminium alloys to steel or to copper-nickel alloys, but it is not recommended for use in the case of aluminium.

case backing is not necessary. However, for foot runs, gas backing is recommended as desirable.

argon is preferred. It is important to avoid too high a backing gas pressure to prevent nitrogen entering the weld.

composition may be used. Only C18 and NA33 specifications are currently known to be commercially available. Copper-nickels. Not all the combinations of materials in the table have been tried with ceramic backing.

Sn, 1.0 to 1.5 Ni, 0.4 to 0.6 Si, P and Mn, remainder Cu may be used as an alternative to C12 and C12Fe for

alloy and other components of heat exchangers are normally by roller expansion. It can, however, be welded to

filler wires should be specially selected.

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6.3.2.4 Procedure. The brazing procedures shall be generally in accordance with BS 1723 except where these are altered or restricted by the details given in 6.3.2 of this standard.

6.3.2.5 Inspection and testing. Brazed components shall be visually inspected and shall meet the requirements of 10.1.1.

6.4 Bulkhead pieces

6.4.1 General. Where a pipe has to pass through a watertight, gastight or oiltight bulkhead it is necessary to attach the pipe to it while maintaining the integrity of the bulkhead. Typical approved types are described in 6.4.2 and the choice of design depends upon accessibility and the space available on the bulkhead itself.

6.4.2 Bulkhead pieces for copper alloy pipes

6.4.2.1 Cast bulkhead pieces. Any of the materials given in Table 1 are suitable. The sketches in Fig. 11a Types A, B, C and D show the typical approved types. Type D uses less bulkhead space than the others but care has to be taken to ensure a watertight joint at the threads.

6.4.2.2 Fabricated bulkhead pieces. Typical approved types of construction are shown in Figs. 11b and 11c Types E1, E2, F and G and an explanation of the joint to be made is given in Fig. 11c.

For Type E1 the pad piece may be of a cast or wrought 90/10 or 70/30 copper-nickel alloy as given in 4.1, capable of being welded on site directly to the steel bulkhead using a manual metal-arc process given in Table 4. Type E2 pad pieces are designed for copper alloys which are not easily welded by this process but, nevertheless, may be used provided the pad piece is first shop-welded into a steel flange of similar thickness to that of the bulkhead, when other welding processes given in Table 4 may be used. For this type of pad piece, the flange should be of such a diameter as to prevent the heat generated during welding the flange into the bulkhead from overheating the shop welds.

For Type F, all the welds shall be made in the shop, and in the case of welding the steel sleeve over the wrought copper alloy pipe, care shall be taken to limit the leg length of the fillet weld to be not more than the thickness of the pipe to ensure that the weld does not penetrate the pipe wall. If the pipe is of 90/10 or 70/30 copper-nickel, then the terminal flanges may be of steel and prepared and attached in accordance with 6.3.1.9.3.

Type G is similar to Type F except that this method uses the least bulkhead space, but involves site welding of the steel sleeve into the bulkhead and a loose terminal flange of 90/10 and 70/30 copper-nickel. The latter welds shall be in accordance with one of the manual metal-arc processes given in Table 4.

In Types F and G where the steel sleeve is brazed to the pipe, the sleeve should be of length and/or thickness sufficient to prevent the heat, generated during welding to the flange or to the bulkhead, from destroying the brazed joint. The site attachment of flanges or sockets by brazing is only recommended for sizes up to and including 57 mm. Above this size all flanges shall be shop-brazed.

6.5 Weed grids and strainers. Any of the materials given in Table 1 are suitable. See 5.3.2 for general comments.

7. Ferrous systems

7.1 Pipes, flanges, bolting and fittings

7.1.1 Pipes

7.1.1.1 Steel. The standard outside diameters and recommended thicknesses of steel pipe are listed in Table 5. It should be noted that the use of thinner or thicker pipe may depend upon the service conditions, the requirements of the regulatory bodies and on any agreement between the purchaser and the manufacturer. Where thicknesses different from those given in Table 5 are required, such thicknesses should be selected from BS 3600 Table 1.

7.1.1.2 Pipes for compression couplings. Pipes for compression couplings shall be in accordance with BS 4368, Part 1 or 3.

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7.1.1.3 Grey and ductile iron. Grey and ductile iron pipes shall be in accordance with 4.3.1.2. The thickness and external diameters are listed in Table 6.

7.1.2 Flanges and bolting. Dimensions shall be in accordance with the appropriate table of BS 4504 or BS 1560 Part 2 when specified.

7.1.3 Fittings

7.1.3.1 Steel. Steel fittings shall be in accordance with the following:

- (1) *Butt welds.* Dimensions shall be in accordance with BS 1965 Part 1 or BS 1640 Part 3, as applicable.
- (2) *Screwed.* BS 1740 Part 1.
- (3) *Compression.* BS 4368 Parts 1, 2 and 3 as appropriate.

7.1.3.2 Grey and ductile iron. Grey and ductile iron fittings shall be in accordance with 4.3.2.4.

Table 5. Steel pipe sizes

Nominal size	Outside diameter	Thickness*
mm	mm	mm
15	21.3	3.2
20	26.9	3.2
25	33.7	4.0
32	42.4	4.0
40	48.3	4.0
50	60.3	4.5
65	76.1	4.5
80	88.9	5.0
100	114.3	5.4
125	139.7	5.4
150	168.3	5.4
200	219.1	5.4
250	273	6.3
300	323.9	6.3
350	355.6	6.3
400	406.4	6.3
450	457.2	6.3
500	508	6.3
600	609.6	6.3
700	711.2	8.0
800	812.8	8.0
900	914.4	10.0
1000	1016	10.0
1200	1220	12.5
1400	1420	14.2
1600	1620	16.0
1800	1820	17.5

* For bends in pipes 150 mm nominal size and above the use of thicker pipes may be required to avoid puckering during bending (see Note to Table 7).

NOTE. The above pipe diameters and thicknesses have been selected from Table 1 of BS 3600.

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Table 6. Dimensions of grey and ductile iron pipes

Metric size pipe

Nominal internal diameter	Mean external diameter	Mean thickness			
	All classes	Grey iron		Ductile iron	
		Class 1 Socket and spigot pipes	Class 3 Socket and spigot and flanged pipe	Class K9 Socket and spigot pipes	Class K12 Flanged
mm	mm	mm	mm	mm	mm
100	118	7.5	9.0	6.1	7.2
150	170	8.3	10.0	6.3	7.8
200	222	9.2	11.0	6.4	8.4
—	—	—	—	—	—
250	274	10.0	12.0	6.8	9.0
300	326	10.8	13.0	7.2	9.6
350	378	11.7	14.0	7.7	10.2
—	—	—	—	—	—
400	429	12.5	15.0	8.1	10.8
450	480	13.3	16.0	8.6	11.4
500	532	14.2	17.0	9.0	12.0
—	—	—	—	—	—
600	635	15.8	19.0	9.9	13.2
700	738	17.5	21.0	10.8	14.4
800	842	—	—	11.7	15.6
900	945	—	—	12.6	16.8
1000	1048	—	—	13.5	18.0
1100	1152	—	—	14.4	19.2
1200	1255	—	—	15.3	20.4

NOTE. Pipe diameters and thicknesses have been selected from Table 8 of BS 4622 and BS 4772.

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Table 7. Recommended minimum bending radii for steel pipes

Nominal size	Outside diameter	Radii measured to centre line of pipe
mm	mm	mm
15	21.3	45
20	26.9	65
25	33.7	75
32	42.4	100
40	48.3	115
50	60.3	150
65	76.1	190
80	88.9	230
100	114.3	305
125	139.7	380
150	168.3	460
200	219.1	710
250	273.0	1020
300	323.9	1220
350	355.6	1500
400	406.4	1730
450	457.2	2030

NOTE. There is a practicable minimum thickness for each size below which larger radii shall be used.

By agreement between the purchaser and the manufacturer smaller bending radii than those given in Table 7 may be used provided that the necessary allowance is made in tube thickness. As an alternative in these cases it is recommended that the use of forged bends be considered.

7.2 Manipulation and fabrication of steel pipes

7.2.1 Limits of bending. The recommended minimum bending radii for pipes are given in Table 7.

7.2.2 Cold forming. Bending machines or presses employed in cold forming bends shall be equipped with forming dies or rolls. Where internal mandrels are used they should be fully hardened to avoid seizing and pick-up. Care shall be exercised during bending to avoid producing excessive scratching, grooving, die marks or contamination with non-ferrous material on the surface of the pipes. Water soluble extreme pressure lubricants should be used on mandrels or any surfaces where sliding friction occurs. Attention is drawn to 7.6.2 with regard to stress relieving before galvanizing.

7.2.3 Hot forming. The pipe shall be filled with dry silica sand free from metallic contamination, especially non-ferrous contamination. Heating shall be carried out in a furnace under slightly oxidizing conditions, the sulphur content not exceeding 0.75 g/m³. The temperature of the pipe shall be raised to a maximum of 1050 °C and as much bending as possible shall be completed before the temperature of the pipe has fallen below 850 °C. Bending may be continued below 850 °C but all work on the pipe shall cease before the temperature has fallen to 750 °C.

Where puckers have to be removed, use shall be made of a suitably shaped cress. Direct blows with a hammer are not permitted.

7.2.4 Fabricated bends. Fabricated bends may be either of the segmental or cut-and-shut type as described in BS 2971.

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7.3 Permanent joining

7.3.1 Welding. The welding, preparation and joining procedure for pipelines, pipe assemblies and flanges shall be in accordance with:

- (1) BS 2971, except that permanent backing rings shall not be used; or
- (2) BS 2640.

In addition to the manual metal-arc process specified in BS 2971 the following welding processes may be used:

- (1) TIG (Inert gas tungsten arc).
- (2) MIG (Inert gas metal arc).
- (3) CO₂.

NOTE. Refractory tapes and ceramic coated backing system may be used subject to their removal after welding where necessary to meet other requirements of this British Standard.

The filler metal and electrodes to be adopted in the welding of pipelines, by arc or gas welding, shall be as set out in Table 8.

Table 8. Filler metals and electrodes; steel

Welding process	Filler metals and electrodes	
Manual metal-arc welding Oxy-acetylene welding	BS 639	
	BS 1453	Type A2
TIG welding	BS 1453	Type A2
	BS 2901 Part 1	Type A15 Type A17 Type A18
MIG and CO ₂ welding	BS 2901 Part 1	Type A15 Type A17 Type A18

NOTE. By agreement between the purchaser and the manufacturer, low carbon steel fusible inserts may be used in conjunction with the TIG process. Attention is drawn to the need to verify that the bore matching tolerances of the pipe ends are suitable in these cases.

Friction or other welding processes may be adopted subject to agreement between the manufacturer and the purchaser. The 'flash' in the bore shall be removed in all instances on completion of the welding.

7.3.2 Brazing. Steel pipes shall not be brazed.

7.4 Bulkhead pieces

7.4.1 General. Where a pipe has to pass through a watertight, gastight or oiltight bulkhead, it is necessary to attach the pipe to it while maintaining the integrity of the bulkhead. Typical approved types are described in 7.4.2 and the choice of design depends upon accessibility and the space available in the bulkhead itself.

7.4.2 Fabricated steel bulkhead pieces. The typical approved types are shown in Fig. 11d, Types H, J, K and L. All fabrication welds may be made in the shop, the attachment to the bulkhead being made by welding or bolting as required. It is recommended that the body of the bulkhead piece be made of slightly heavier material than for normal pipes to include a corrosion allowance.

7.4.3 Grey and ductile iron bulkhead pieces .. Typical approved types are shown in Fig. 11e.

7.5 Weed grids and strainers. Any of the materials given in 4.3.6 or 4.3.7 are suitable.

7.6 Protective coatings for service

7.6.1 For screwed pipes and fittings, galvanizing shall comply with the requirements of BS 1387.

7.6.2 All other steel pipework and fabricated components in the finished condition prior to installation shall normally be hot dip galvanized in accordance with BS 729, except that the minimum weight of coating shall be 610 g/m² for all thicknesses. Cracking can occur as a result of galvanizing heavily cold worked pipe. This can be avoided by stress relieving at 600 °C to 650 °C prior to galvanizing.

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7.6.3 There are many non-metallic protective coatings available but service experience to date is inadequate for recommendations to be made. Any such protective coating shall be subject to agreement between the purchaser and the manufacturer, and attention is drawn to CP 3003.

8. Mixed ferrous and copper alloy systems

Where systems use different materials which are in contact with each other, e.g. non-ferrous pipes with cast iron valves, accelerated corrosion of the ferrous component will occur.

The problems involved are outlined in Appendix B.3.

9. Pipework flexibility, support and installation

9.1 Flexibility of piping systems

9.1.1 Piping systems are to be designed with adequate flexibility so that expansion of the piping and machinery and vibration and working of the ship will not result in overstress of the system or leakage at joints.

9.1.2 Flexibility can be provided where practicable by the use of plain piping bent to a suitable radius.

9.1.3 Alternatively, or where space limitations prevail, use may be made of flexible pipes, flexible joints or bellows expansion pieces, and these are essential for connection to resiliently mounted machinery. They shall be installed in an undistorted condition.

9.1.4 Pressure of fluid in a piping system can result in distortion particularly in way of bends and flexible units if adequate anchorage is not provided. Attention is drawn to the necessity of making such provision as stated in 9.2.

9.2 Flexible piping units or assemblies

9.2.1 The design and construction of flexible piping units or assemblies shall be suitable for the pressure, vacuum and temperature under all conditions likely to occur in service, including ambient temperature, and shall also be capable of absorbing the movements imposed by attached machinery and pipework.

9.2.2 The material of these components, including end fittings if separately attached, shall be suitable for containing sea water and be compatible with the material of the piping system to which they are attached.

9.2.4 Elastomer assemblies shall not be painted.

9.3 Pipe supports

9.3.1 General design

9.3.1.1 Pipelines should be routed to enable the surrounding structure to provide logical points of support, anchorage, guidance or restraint. Supporting of the largest of critical piping systems should take priority over others and the location of supports and anchors should be shown on arrangement drawings.

9.3.1.2 The design of supports shall be capable of adequately supporting the piping system without undue distortion. In addition to pipeline gravitational loads the supports shall provide for concentrated loads imposed by valves and risers, for axial loadings due to expansion and the pressure of fluid, and for inertia effects due to ship movements. Hangers or supports shall be provided close to concentrated weights, at horizontal changes in line direction, and on or adjacent to pipe risers.

Where grey or ductile iron pipes are fitted with a flexible joint incorporating an integrally cast socket, one anchored pipe support per pipe is required and it shall be positioned immediately behind the socket.

9.3.1.3 Pipework adjoining flexible units shall be supported as closely as possible to the flexible unit. The supports shall be designed to prevent the pressure loads transmitted by the flexible unit distorting the attached pipework and equipment.

Where steel or cast iron pipes are connected by proprietary couplings allowing some flexibility, their installation, supports and anchorage shall be such as to accommodate changing alignment in service. The couplings shall only be used subject to agreement between the manufacturer and the purchaser.

9.3.1.4 Plastics pipes should be supported continuously where possible, otherwise at distances not greater than those shown in Table 4 of BS 1973.

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9.3.1.5 All pipework shall be examined during the sea trial to determine whether additional supports are necessary due to unforeseen vibrations.

9.3.2 Detail design

9.3.2.1 BS 3974 may be used as a guide for the design of supports.

9.3.2.2 Supports for non-ferrous pipes shall be lined with a soft packing strip, free from ammoniacal compounds, to prevent chafing and stress corrosion and to permit free expansion and contraction between anchors.

9.3.2.3 The use of toe hangers or supports, where the stressed leg is welded directly to the supporting structure without flanging, is not recommended due to the weakness of this type of attachment.

9.3.2.4 If plastics pipes are used, the type and spacing of supports shall be the subject of special consideration and agreement between the purchaser and the manufacturer.

9.4 Piping installation

9.4.1 Pipe jointing material

9.4.1.1 General. Jointing material should preferably comply with the requirements of BS 2815. Other materials may be adopted provided they are suitable for the application.

Jointing material for flanged joints should preferably be precut and shall be so dimensioned that it will not project into the bore of the pipe.

9.4.1.2 Jointing materials in fire mains. Jointing materials in fire mains are subject to the requirements of certain national authorities and classification societies. Accordingly only guide lines in respect of UK practice can be given for these items on the choice of appropriate materials to be adopted, as follows:

(1) Compressed asbestos fibre complying with the requirements of BS 2815 Grade A for jointing not greater than 2 mm thick.

(2) Other material not greater than 1 mm thick. Chloroprene or materials having similar melting points shall not be used.

9.4.2 Pipe erection

9.4.2.1 Flange faces shall be closely mated and bolt holes aligned before making up the joint. The pipes shall not be strained into position in order to make them fit. Pipes which do not fit satisfactorily shall be corrected and then re-stress relieved where necessary.

Care shall be taken with the alignment of piping before making any screwed, brazed or welded joints.

9.4.2.2 Mating pipes, valves and fittings shall be installed with their bores concentric and in line, and care taken to ensure that any jointing fitted does not protrude into the bore.

9.4.2.3 The installation of bellows pieces or flexible units should be carefully carried out to ensure that they are not distorted.

9.4.2.4 The closing length of piping shall be manufactured to a sufficient degree of accuracy so that it can be fitted in place without undue manual effort, and so that the flanges are closely mated and the bolts can be inserted freely. If there is any misalignment which cannot be corrected manually, the pipe shall be removed for correction and subsequent stress relieving if of non-ferrous material.

9.4.2.5 Closing lengths shall not be finally connected until the system has been inspected as under **10.2**. Flange joints should be left unfastened with bolts loosely in place.

10. Inspection and testing

10.1 Component inspections and tests before installation

10.1.1 Inspection. The following inspections shall be carried out before pressure testing:

(1) All components shall be checked to ensure that they are correct and in accordance with drawings, especially details of terminals and materials.

(2) All components shall be visually examined for faults and irregularities and shown to be clear of scale or internal deposits. Instruments shall be available for internal inspection of branch attachments.

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(3) Welded and brazed joints shall be examined to ensure that fillets are regular and continuous in form. Wherever practicable it shall be established that there is no lack of root penetration, evidence of lack of fusion, burn through or excessive penetration of the pipe in way of the joint.

(4) In the case of steel flanges welded to cupro-nickel pipework, penetration of iron to the surfaces in contact with sea water shall be checked by means of the 'ferricyanide test', after cleaning the area to be considered, according to the following procedure:

- a. Swab with dilute hydrochloric acid (HCl).
- b. Swab with a solution of potassium ferricyanide ($K_3Fe(CN)_6$).

Aqueous solutions are used and the concentrations are unimportant. A ratio of 1:4 of concentrated hydrochloric acid to water and a 10 % solution of ferricyanide is suitable.

Iron penetration is shown by a blue discolouration and any indication of the presence of iron is unacceptable. Simple washing is adequate to remove residue from acceptable joints. Where a number of sample tests show that a satisfactory standard of workmanship is established, the percentage of production testing shall be by agreement between the purchaser and the manufacturer.

10.1.2 Hydraulic test. Each completed pipe and fitting subject to a pressure of 7 bar* and over shall be hydraulically tested according to the requirements of the regulatory body.

The completed pipes and fittings shall be tested with fresh mains water with filling, air evacuation and test gauge connections provided. The test pressure shall be maintained for not less than 2 minutes after the filling valve is closed to demonstrate the integrity of all connections. The test shall be repeated after the rectification of any defects.

10.2 System inspections and tests after installation

10.2.1 System inspections after installation. Before any testing is carried out the system shall be inspected to check that:

- (1) the systems are in accordance with the pipe diagrams;
- (2) where polluted water is admitted for basin trials consideration should be given to inhibitive chemical treatment;
- (3) the location and fitting of supports and hangers are adequate;
- (4) alignments of flanged joints are correct;
- (5) the fittings are installed correctly for the required direction of flow, especially valves and strainers;
- (6) the valves are accessible for operation and maintenance;
- (7) all valves and necessary remote controls can operate through their full limits open-shut-open;
- (8) all bellows pieces and flexible pipes are installed correctly within the operating limits specified;
- (9) all continuity strips, if specified, are installed;
- (10) instrumentation is fitted as specified;
- (11) valves are correctly labelled.

10.2.2 System tests after installation. After all inspections have been carried out and rectifications made the complete system shall be tested. Where feasible the testing should be in accordance with the following procedure:

(1) In order to protect surfaces of copper alloy systems the first filling of a new system shall be with clean sea water or, if not available, fresh mains water. Distilled water or contaminated dock or river water shall not be used.

(2) Each pump shall be primed before starting basin trials.

(3) The system shall be circulated with water at the maximum pressure attainable by the pumps under existing conditions.

(4) All air valves and air ejectors shall be operated to ensure that air is released from high points.

(5) The system shall be examined for leaks from joints and glands.

(6) A note shall be made of undue noise and vibration, and additional supports fitted where necessary.

(7) After completion of the basin trials the system shall be flushed with mains water and drained as far as practicable.

* 1 bar = $10^5 \text{ N/m}^2 = 0.1 \text{ MPa}$.

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10.2.3 Records. It is desirable that records signed by appropriate inspectors should be kept of all inspections and witnessed tests.

10.3 Sea trials

10.3.1 System tests. The system shall be tested in accordance with the following procedure:

- (1) Each pump shall be primed before starting.
- (2) The system shall be circulated with water at the maximum pressure attainable by the pumps under normal service conditions.
- (3) All air valves and air ejectors shall be operated to ensure that air is released from high points.
- (4) The system shall be examined for leaks from joints and glands.
- (5) A note shall be made of undue noise and vibration and, where appropriate, remedial action taken.

10.3.2 Setting up correct flows in salt water circulating systems. In spite of all precautions taken during design and installation considerable trouble may be experienced at sea by failures of pipes and fittings due to corrosion/erosion. It is therefore very important that the system should be correctly adjusted during sea trials so that design flows are achieved through the various pipelines.

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Appendix A

Pressure losses

A.1 Losses in pipes, bends, fittings and valves

A.1.1 Pipe losses. Pressure losses in straight pipes have usually been calculated from the following equation:

$$p = f \times \frac{l}{d} \times \rho \times \frac{V^2}{2} \dots \dots \dots \text{Equation (1)}$$

where p = pressure loss (kN/m²),
 f = friction coefficient,
 l = pipe length (m),
 d = pipe bore (mm),
 V = fluid velocity (m/s),
 ρ = density (kg/m³).

The friction coefficient is dependent upon the Reynolds number and the relative roughness of the pipe inner surface. Over the range of Reynolds number for flow of water in pipes, drawn tube such as the copper alloys may be regarded as hydraulically 'smooth' and the graph of friction coefficient against Reynolds number is a single curve applicable to all pipe diameters, as shown in Fig. 16. For steel pipes, separate curves of friction coefficient against Reynolds number are obtained for each pipe diameter. Some representative values are illustrated in Fig. 16.

However, to correspond with the method to be used with respect to valves, etc., as described below, the values to be used for straight pipe are presented as a loss coefficient per unit length of pipe. These values of loss coefficient are shown in Figs. 17 and 19 for smooth and steel pipes respectively and apply to pipes when new; increasing corrosion and fouling of the pipe surface with time, particularly with steel pipes, increases the pipe roughness and consequently the pressure loss. Correction factors for the effect of water temperature are given in Figs. 18 and 20.

A.1.2 Losses in bends, fittings and valves. Here two methods are currently in use to express these losses. One method, which is only approximate, determines the system loss by inserting a total equivalent length in Equation (1).

The other method uses a loss coefficient K , thus:

 $p = K \times \frac{V^2}{2} \times \frac{\rho}{1000} \dots \dots \dots \text{Equation (2)}$

where p = pressure loss (kN/m²),
 K = loss coefficient,
 V = fluid velocity (m/s),
 ρ = density (kg/m³).

The latter method has been adopted in this standard, and all following data are in the form of loss coefficients.

Fig. 21 presents a convenient means for determining the dynamic $\left(\frac{V^2}{2} \times \frac{\rho}{1000}\right)$ pressure for salt water.

A.1.2.1 Bends. Values of loss coefficient for both smooth and new steel pipes, each for several values of bend radius/diameter ratio, are shown in Fig. 22. This loss is referred to as the 'excess' bend loss, i.e. it is additive to the loss in a straight pipe of length equal to the mean circumference of the bend. These values only pertain to the loss in 90° bends. A correction factor is included for use with a bend of any other deflection. These values of loss may be applied to the total deflection of two bends in series provided that the length of straight pipe between the two bends does not exceed 15 pipe diameters. This latter is independent of the orientation of the plane of the second bend with respect to the first.

A.1.2.2 Branches. Figs. 23 to 26 show the loss coefficients for 45° and 90° branches for both dividing and uniting flow. In all cases the reference velocity is that of the combined flow in the main.

A.1.2.3 Sudden enlargement and contraction. Values of loss coefficient for sudden enlargement and contraction are shown in Fig. 26 expressed as a function of the diameter ratio. In each case the reference velocity is that in the smaller pipe. The most common instances of these arrangements are for a value of diameter ratio of zero, i.e. when discharging to, or drawing from, a reservoir of fluid such as a tank.

A.1.2.4 Valves. A number of different types of valve are used in water systems and results of tests on several of these have been published. In most instances there is a considerable variation in these results for nominally similar valves. This is largely due to physical differences in design of the products of the various manufacturers. It is therefore recommended that when data are available from the actual manufacturer of a specific valve, this should be used. In the absence of such data, values of loss coefficient for several common types of valve are given in Fig. 27. These results are in effect mean values of the data quoted by a number of sources. For valves having bores greater than 300 mm the values at 300 mm should be adopted.

Some versions of the globe valve have the spindle at an angle of 60° or 45° to the direction of flow. With such a valve, the loss coefficient is the same as that for a right-angle valve.

The values given in Fig. 27 for parallel bore gate valves apply equally to versions where the 'gate' itself is parallel or wedge-shaped. With some valves the area at the gate is less than at the flange and the valve body contains corresponding convergent and divergent sections. The effect of this is to increase the loss through the valve, compared with the parallel-bore type, by a factor of:

- 2, when the included angle of these sections is 8° to 10°,
- 3, when this angle is 20° to 25°.

In designing a salt water pipe system care shall be taken in selecting the valve sizes to ensure that the valve bores match as closely as possible the bores of the adjoining pipes.

A.2 Flow in parallel branches. It is common in many systems for the flow from the pump discharge to split into two, or more, branches. The pressure loss through each branch should be the same, otherwise the flow quantities through each branch will not conform to the design requirements. If, however, the pressure losses corresponding to the design flows are not the same for each branch, an approximation to the flow distribution which will occur may be made by assuming that the pressure loss is dependent only upon the square of the fluid velocity.

The following relationships are obtained for the case of two branches:

$$\frac{1}{q'_1} = 1 + \left(\frac{1}{q_1} - 1 \right) \left(\frac{p_1}{p_2} \right)^{1/2} \quad \text{and} \quad q'_2 = 1 - q'_1$$

The actual pressure drop through each is given by:

$$p' = p'_2 = p_1 \times \left(\frac{q'_1}{q_1} \right)^2$$

In the above, q = branch flow/total flow,
 p = pressure loss (kN/m²),
 subscript 1 refers to first branch,
 subscript 2 refers to second branch,
 superscript ' refers to redistributed flow condition.

In practice, orifice plates or special valves may be included in preference to adopting a throttling device.

A.3 Total system loss and pump selection. The total system loss is determined by the addition of the separate losses through all the components of the system. The necessary pump delivery pressure is then the sum of this total loss and the pressure equivalent of displacement between the free surface over the system outlet and that over the system inlet. This figure, together with the flow quantity, gives the design operating condition of the system; that is it gives one point on the characteristic of the required pump. Normal

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practice is to select a pump with a characteristic close to that required. The effect on a system of installing a pump whose characteristic does not pass through the design point may be estimated by plotting, on the same axes, both the pump and system characteristic curves (see Fig. 28). The latter graph is assumed to be a parabola given by,

$$p = \frac{\rho}{1000} \times g \times h + (p' - \frac{\rho}{1000} \times g \times h) \left(\frac{q}{q'} \right)^2$$

where h = static lift (m),

p = pressure head bar (kN/m²),

q = flow (m³/h),

g = gravitational constant (9.81 m/s²),

ρ = density (kg/m³).

superscript ' refers to the designed quantities.



The point of intersection of the two curves gives the resultant equilibrium point. If the difference in flow rate, as between the design and resultant values, is acceptable then this pump may be fitted. If closer matching is required, a pump whose characteristic passes above the design point should be chosen and the tip diameter of the impeller skimmed to lower the characteristic so as to pass through the system design point. The operating point should be in the range of high efficiency of the pump which ensures that cavitation will be minimal. In some instances some variation in flow quantity is required of a pump, and in such a case care should be taken that the operating line again coincides with the region of peak pump efficiency.

It is necessary to check:

(1) that the total of pressure loss and the pressure equivalent of the static lift from suction to pump inlet, added to the vapour pressure of the water (see Fig. 29) does not exceed the permissible value quoted by the pump manufacturers (usually the order of 6 m). To enable this condition to be satisfied it may be necessary to install a suction line of larger diameter than would otherwise be indicated from consideration of maximum permissible velocity;

(2) that the pressure equivalent of the total lift to the highest point of the system does not exceed the maximum delivery pressure of the pump, otherwise the system will not start.

A.4 Example calculation. The vessel considered is a twin-screw ship, powered by four medium-speed engines arranged in a row athwartships, two engines driving each screw. Each pair of engines is served by a single sea water circulating pump, the sea water then dividing to flow through individual charge-air, lubricating oil and jacket water coolers arranged in series, and then uniting to flow through a single overboard discharge. Athwartships cross-connections exist on the pump section and discharge between each pair of engines; however, for normal operation there is no flow in these cross-connections. A diagrammatic sketch of the sea water system is shown in Fig. 30 and an isometric view of the layout is shown in Fig. 31.

The required flow rate for each engine is 100 m³/h so that the combined flow through the common parts of the system is 200 m³/h. The material of the piping is copper-nickel-iron, and the pipe sizes, fixed with regard to this material, are:

- (1) Suction, nominal bore 150 mm ($q = 200$ m³/h) $\therefore$ water velocity = 3.12 m/s.
- (2) Delivery, nominal bore 150 mm ($q = 200$ m³/h) $\therefore$ water velocity = 3.12 m/s.
- (3) Delivery, nominal bore 100 mm ($q = 100$ m³/h) $\therefore$ water velocity = 3.47 m/s.

The vessel was designed for operation in temperate waters and the maximum sea water inlet temperature is taken as 20 °C. The temperature rise of the cooling water through the successive coolers gives outlet temperatures of 23 °C, 26 °C and 38 °C respectively.

The losses in the system may be evaluated as follows:

Suction. 150 mm diameter. Dynamic head = 0.50 m.

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Fitting

	Loss coefficient
Inlet from sea-box; sudden contraction, $d/D = 0$	0.50
Sea valve; screw-down, angle valve	2.60
Branch; 45 ° uniting flow, no flow from branch	0.00
Butterfly valve	0.47
T-junction; flow from main to branch	1.00
Two 90 ° bends in series; $r/d = 1.0$	$0.29 \times 1.55 = 0.45$
Straight pipe; length 5 m	$0.089 \times 1.00 \times 5 = 0.45$
Strainer	2.40
	7.87

Therefore total loss in suction piping = $7.87 \times \frac{1030}{1000} \times \frac{3.12^2}{2} = 39.5 \text{ kN/m}^2$

Delivery

	Loss coefficient
(1) 150 mm diameter	
90 ° bend; $r/d = 1.0$	0.29
Screw-down, non-return valve	2.60
90 ° bend; $r/d = 1.0$	0.29
T-junction; flow from main to branch	1.00
90 ° bend; $r/d = 1.0$	0.29
Straight pipe; length 2 m	$0.089 \times 1.000 \times 2 = 0.18$
	4.65

Therefore loss up to branch point = $4.65 \times \frac{1030}{1000} \times \frac{3.12^2}{2} = 23.3 \text{ kN/m}^2$

(2) Inboard engine

a. 150 mm diameter

	Loss coefficient
T-junction; flow from branch to main, dividing equally	0.66
Therefore loss = $0.66 \times \frac{1030}{1000} \times \frac{3.12^2}{2} = 3.3 \text{ kN/m}^2$	

b. 100 mm diameter

	Loss coefficient
Contraction $d/D = 100/150$	0.32
90 ° bend; $r/d = 1.0$	0.31
T-junction; flow in main	0.12
Butterfly valve	0.54
90 ° bend; $r/d = 1.0$	0.31
Two 90 ° bends in series; $r/d = 1.0$	$0.31 \times 1.55 = 0.48$
Butterfly valve	0.54
T-junction; flow in main	0.12
90 ° and 30 ° bends in series; $r/d = 1.0$	$0.31 \times 1.22 = 0.38$
45 ° and 90 ° bends in series; $r/d = 1.0$	$0.31 \times 1.31 = 0.41$
90 ° bend; $r/d = 1.0$	0.31
Gate valve	0.14
90 ° bend; $r/d = 1.0$	0.31
Enlargement; $d/D = 100/150$	0.31

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Loss coefficient

Straight pipe

Branch point to air coolers; length 5.5 m

$$0.102 \times 1.00 \times 5.5 = 0.56$$

Air coolers to lubricating oil cooler; length 10.7 m

$$0.102 \times 0.99 \times 10.7 = 1.08$$

Lubricating oil cooler to jacket water cooler; length 0.5 m

$$0.102 \times 0.98 \times 0.5 = 0.05$$

Jacket water cooler to T-junction; length 1.5 m

$$0.102 \times 0.94 \times 1.5 = 0.14$$

Add Air coolers, loss coefficient = 1.8

Lubricating oil coolers, loss coefficient = 2.4

Jacket water cooler, loss coefficient = 0.5

4.7

4.7

$$\text{Total loss coefficient} = 11.13$$

$$\text{Therefore total loss} = 11.13 \times \frac{1030}{1000} \times \frac{3.47^2}{2} = 69.0 \text{ kN/m}^2$$

Loss coefficient

c. 150 mm diameter

T-junction; half-flow from branch to main

0.21

$$\text{Therefore loss} = 0.21 \times \frac{1030}{1000} \times \frac{3.12^2}{2} = 1.1 \text{ kN/m}^2$$

$$\text{Therefore total loss round inboard engine loop} = 3.3 + 69.0 + 1.1 = 73.4 \text{ kN/m}^2$$

(3) Outboard engine

a. 150 mm diameter

T-junction; flow from branch to main, dividing equally

0.66

$$\text{Therefore loss} = 0.66 \times \frac{1030}{1000} \times \frac{3.12^2}{2} = 3.3 \text{ kN/m}^2$$

Loss coefficient

b. 100 mm diameter

Contraction; $d/D = 100/150$

0.32

90° bend; $r/d = 1.0$

0.31

T-junction; flow in main

0.12

Butterfly valve

0.54

90° bend; $r/d = 1.0$

0.31

Two 90° bends in series; $r/d = 1.0$

$$0.31 \times 1.55 = 0.48$$

Butterfly valve

0.54

T-junction; flow in main

0.12

Two 90° bends in series; $r/d = 1.0$

$$0.31 \times 1.55 = 0.48$$

Two 90° bends in series; $r/d = 1.0$

$$0.31 \times 1.55 = 0.48$$

90° bend; $r/d = 1.0$

0.31

Gate valve

0.14

Two 45° bends in series; $r/d = 1.0$

0.31

Enlargement, $d/D = 100/150$

0.31

Straight pipe

Branch point to air coolers; length = 3.4 m

$$0.102 \times 1.00 \times 3.4 = 0.35$$

Air coolers to lubricating oil coolers; length = 11.0 m

$$0.102 \times 0.99 \times 11.0 = 1.11$$

Lubricating oil coolers to jacket water cooler; length = 0.5 m

$$0.102 \times 0.98 \times 0.5 = 0.05$$

Jacket water cooler to T-junction; length = 4.9 m

$$0.102 \times 0.94 \times 4.9 = 0.47$$

Coolers; as in (2), loss coefficient =

4.7

$$\text{Total loss coefficient} = 11.45$$

$$\text{Therefore total loss} = 11.45 \times \frac{1030}{1000} \times \frac{3.47^2}{2} = 71.0 \text{ kN/m}^2$$

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c. 150 mm diameter
T-junction; half flow in main

Loss coefficient

0.32

$$\text{Therefore loss} = 0.32 \times \frac{1030}{1000} \times \frac{3.12^2}{2} = 1.6 \text{ kN/m}^2$$

$$\text{Therefore total loss round outboard engine loop} = 3.3 + 71.0 + 1.6 = 75.9 \text{ kN/m}^2$$

The total loss through each engine loop is very similar. This was to be anticipated since the main sources of loss are duplicated as between the two branches. Only a slight redistribution of the flow will occur to equalize the loss in each branch and the resultant pressure drop may be taken as the mean of the above values, i.e.

$$\text{Pressure loss through each engine system} = 74.7 \text{ kN/m}^2$$

(4) Overboard discharge

150 mm diameter

Sea valve screw-down, non-return, angle valve

2.60

Enlargement; $d/D = 0$

1.00

Straight pipe; length 1.5 m

$$0.089 \times 0.93 \times 1.5 = 0.12$$

 3.72

$$\text{Therefore loss} = 3.72 \times \frac{1030}{1000} \times \frac{3.12^2}{2} = 18.6 \text{ kN/m}^2$$

Summary. The pressure loss in the suction line will be 39.5 kN/m² and the sea water temperature of 20 °C gives a vapour pressure of 2.4. If the maximum suction lift of the pump is, say 6 m, then the pump may be located at a height of not more than 1.8 m above the sea level corresponding to the minimum draught at which the pump will be required to operate.

The total pressure loss in the system will be 156.1 kN/m² provided the overboard discharge is below water level, this figure representing the pressure to be delivered by the pump.

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Appendix B

Measures to minimize corrosion in salt water systems

B.1 General. When components of a system are exposed to a corrosive environment it is necessary to consider the possibility that corrosion will occur, and, if so, the rate at which it will proceed. With materials of relatively low corrosion resistance, such as mild steel or galvanized steel exposed to sea water, corrosion will occur and it is necessary to consider only the effect of various factors on the rate of attack. For example, increasing the velocity of the water flow increases corrosion rates of these materials. In the case of materials that can be passivated in aerated sea water by the formation of thin protective oxide films in close contact with the metal surface, the possibility of attack can vary considerably. It is very low with some of the more resistant copper alloys, but under conditions of high velocity and turbulence tends to increase to some extent. When the normally resistant materials do break down, attack is usually localized and the rate of penetration may be comparatively high.

For most of the materials used in salt water systems it is desirable to avoid high water velocities and turbulence; hence the recommendations to use smooth bends of reasonably large radius, to avoid sharp changes in direction or in pipe section, and to avoid protuberances. Such measures will help reduce rates of attack on materials of low resistance and will also reduce the possibility of attack on materials of inherently high resistance, though with these latter there is a considerable margin of safety.

B.2 Protective film formation. Several copper alloys form good self-healing protective films in salt water, and those most used in salt water systems are aluminium-brass and the cupro-nickels. The requisite amount of iron is an essential ingredient of the cupro-nickel alloys if good corrosion resistance is to be obtained. Although it is not incorporated in the alloy, iron is also important in the case of aluminium-brass, since good protective films on aluminium-brass are always found to contain a significant proportion of iron oxides. This iron is normally derived from the corrosion of ferrous materials in mixed systems, but it is possible in non-ferrous systems to augment the effect by making a deliberate addition of soluble iron salt to the water.

A suitable procedure would be to introduce a strong solution of a cheap iron salt, such as ferrous sulphate, into the system by gravity or through a suitable metering pump. Good results are obtained by intermittent additions for 1 hour per day, during which a concentration of 1 part per million of iron in the water is maintained (i.e., about 5 g of ferrous sulphate per cubic metre of water). After an initial period (say for a few weeks) occasional treatments should suffice to keep protective films in good repair. If the iron salt is introduced in the vicinity of the cooling water intake beneficial results can be expected to spread to all copper alloy components throughout the system, i.e. not only to pipelines, but also to pumps, valves, heat exchanger tubes, etc.

Other recommended precautions are to prevent, as far as possible, the entry of debris into the system, and to avoid leaving stagnant salt water lying in the system for protracted periods. Protective films formed in service may be liable to break down under stagnant conditions, particularly in contact with polluted harbour or estuarine waters. The ferrous sulphate treatment mentioned above is therefore likely to be of most benefit if applied for a period before entering harbour, and again for a period after leaving.

In the commissioning of new systems it has been found beneficial to introduce ferrous sulphate or sodium dimethyldithiocarbamate which assists in the formation of protective films.

B.3 Dissimilar metals in contact. Currents flowing due to potential differences between dissimilar metals in contact with sea water (see Table 9 for guidance) can cause accelerated corrosion of the less noble metal (anode) and protection of the more noble metal (cathode) in the electrolytic or galvanic cell formed. The magnitude of the current flow, which determines the rate of attack of the anode, depends on many factors including the nature of the films and deposits formed on the electrodes (polarization effects), the composition of the sea water, its temperature and rate of flow, etc., as well as on the open circuit potential difference between the two metals. The relative areas of the two electrodes is also important in determining the intensity of attack on the anode.

A mixture of copper alloys with bare or galvanized steel in a salt water system would be likely to lead to significant acceleration of attack of the ferrous components near the points of contact. Apart from direct galvanic effects, increased attack on ferrous materials can occur due to local cells set up when minute amounts of copper picked up in the water from copper alloy components deposit out on the iron or zinc

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surfaces. Use of bare or galvanized steel downstream of copper alloy components should therefore be avoided. Indeed it is preferable to avoid this combination of materials altogether, if possible. Where the combination is unavoidable, it may be useful to fit between the two components an easily accessible and replaceable straight length of steel pipe of length at least 0.5 m or three times the tube diameter (whichever is the greater). This 'corrosion piece' will require renewing relatively frequently; nevertheless there may be some overall advantage if accelerated attack on more vital or less easily replaced components is prevented.

Cast iron is in a similar category to mild steel but has better resistance to corrosion in sea water, and, furthermore, cast iron components are usually of relatively thick section. There is much practical experience of the satisfactory use of cast iron components such as valves and pump bodies in contact with copper alloy pipelines in salt water systems. Corrosion pieces could be used as a precautionary measure if desired, subject to contractual agreement.

The relatively small differences in potential between different copper alloys rarely lead to any difficulties in salt water systems.

B.4 Electrical leakage currents. Electrical leakage currents may flow in sea water piping systems and, if there is any interruption to a continuous metallic path, such as a high resistance joint, corrosion will occur where the current leaves the metal and passes into the water (particularly with direct current). Good electrical continuity throughout the salt water system is therefore desirable and this is usually obtained without taking any special steps. Brass or copper bonding strips may be fitted, for example, across the peripheries of flanged joints of similar metals.

Table 9. The galvanic series in sea water

Noble (cathodic)

Graphite	
Titanium	
18 chromium/8 nickel stainless steel (passive)	
Nickel copper alloy NA13	
18 chromium/2 nickel stainless steel	
70/30 cupro-nickel	}
Nickel-aluminium-bronze	
Aluminium-silicon-bronze	
90/10 cupro-nickel	
Gunmetal	
Phosphor-bronze	
Copper	}
Rolled naval brass	
Aluminium-brass	
High tensile brass	
Tin	}
Lead	
Lead/tin packings, solders, etc.	
Cast irons	}
18 chromium/8 nickel stainless steel (active)	
Carbon steel	
Cadmium	
Aluminium	
Zinc	
Magnesium	

Base (anodic)

For all practical purposes alloys included in brackets are equi-potential and may be used together without special precautions

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Appendix C

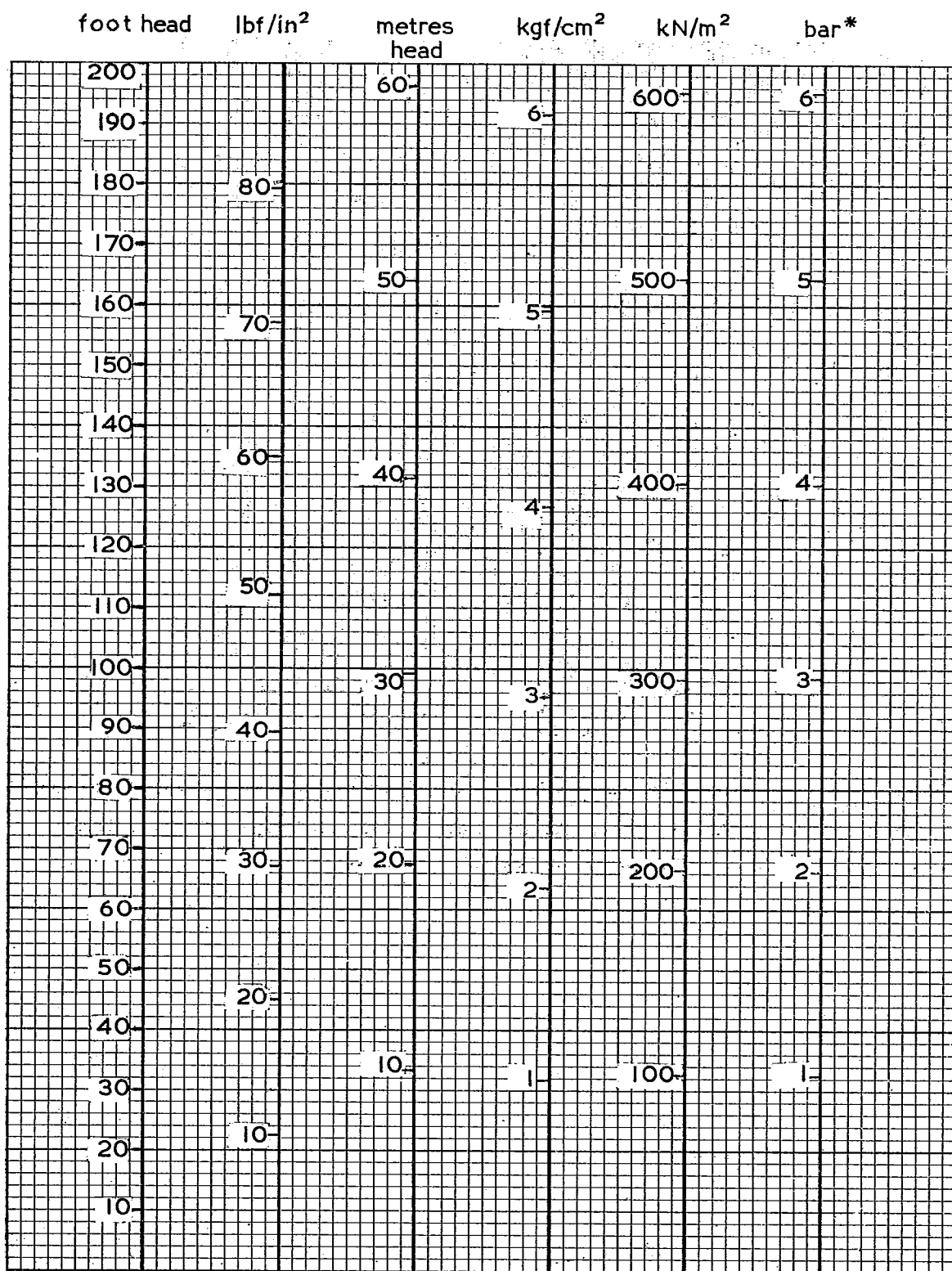
Conversion of sea water pressure units

foot head	lbf/in ²	metres head	kgf/cm ²	kN/m ²	bar*
1	0.4457	0.3048	0.0313	3.0732	0.0307
2.2435	1	0.6838	0.0703	6.8947	0.0689
3.2808	1.4624	1	0.1028	10.0827	0.1008
31.9101	14.2234	9.7262	1	98.0667	0.9807
0.3254	0.1450	0.0992	0.0102	1	0.0100
32.539	14.504	9.918	1.0197	10 ²	1

The above are based on the density of fresh water of 0.998 205 gm/cm³ at 20 °C and the specific gravity of sea water of 1.03.

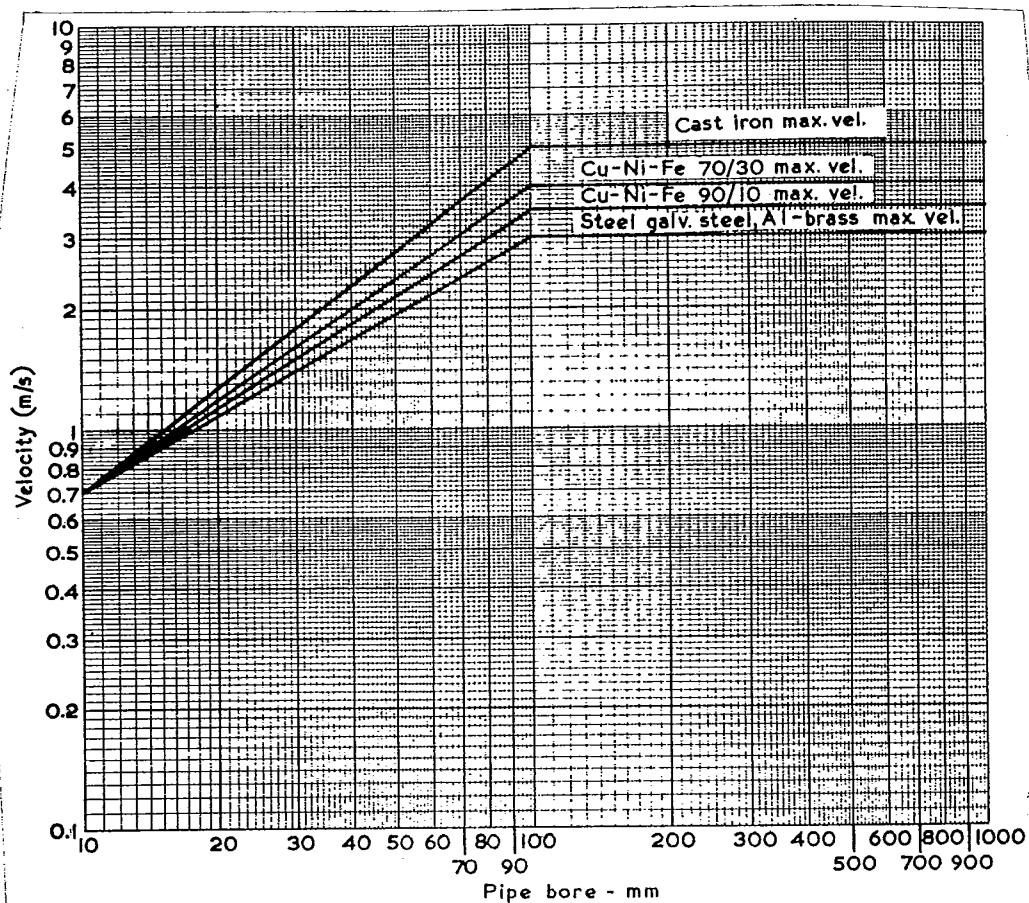
* 1 bar = 10⁵ N/m² = 0.1 MPa.

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*1 bar = 10^5 N/m² = 0.1 MPa.

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NOTE 1. Maximum velocities are based on materials; due regard should be given to design considerations i.e. pressure drops versus pump discharge head.

NOTE 2. Suction velocities would tend to be lower than those indicated, particularly for high suction lift conditions.

Fig. 1. Salt water velocities in pipes; for continuous flow

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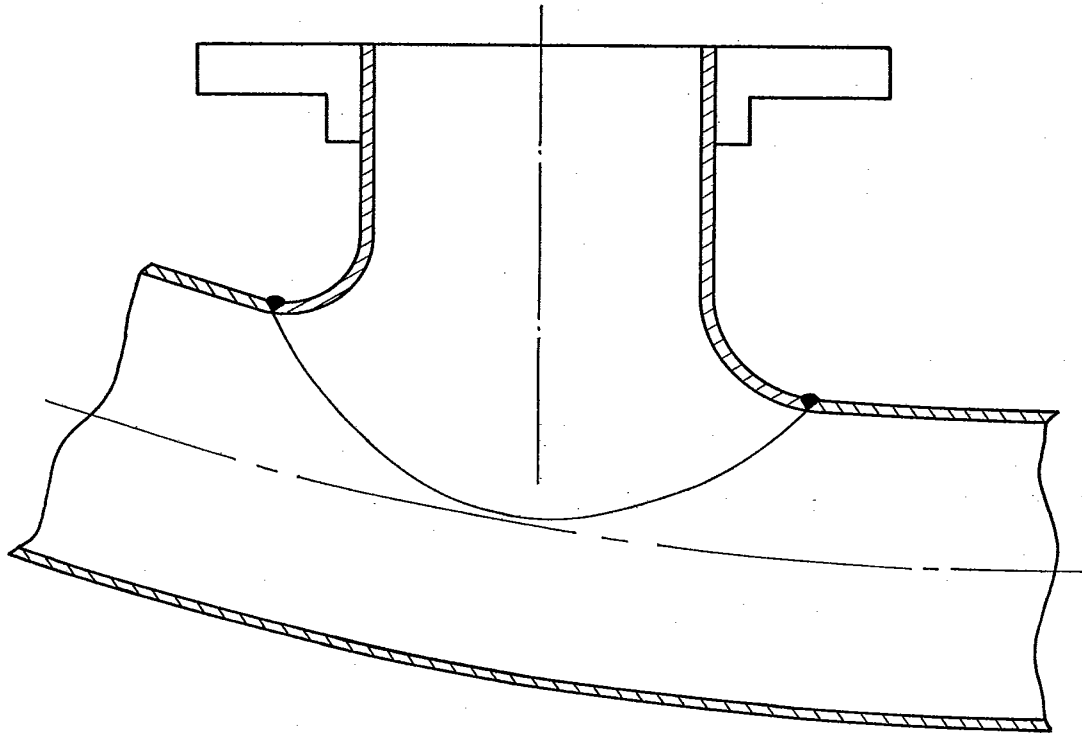


Fig. 2. Swept saddle type branch, welded ; continuous, intermittent and no-flow

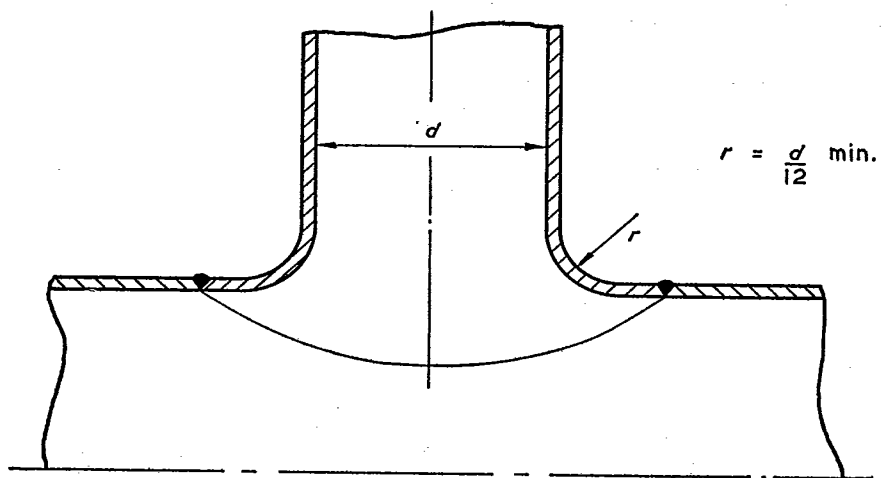


Fig. 3. Saddle branch, welded ; continuous, intermittent and no-flow

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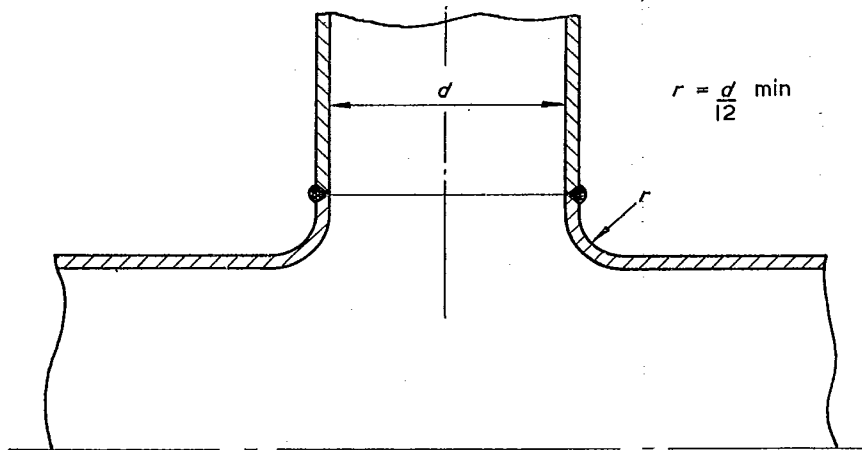


Fig. 4. Welded stub branch ; continuous, intermittent and no-flow

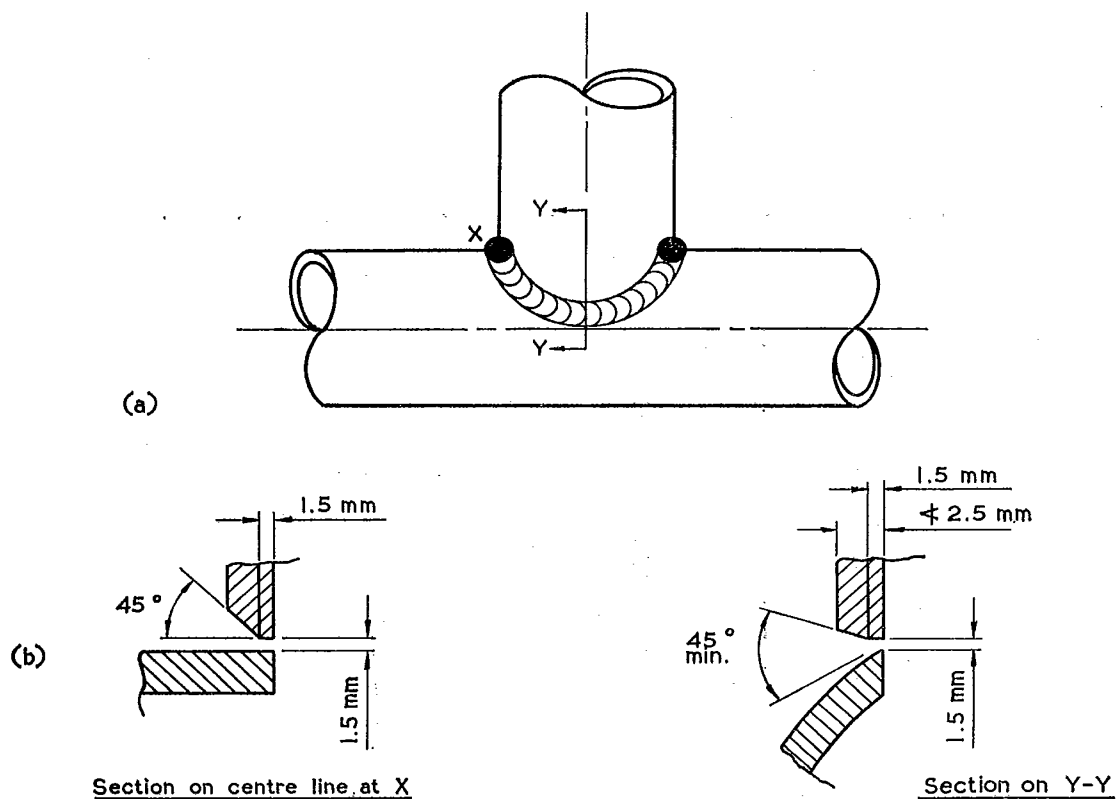


Fig. 5. Set-on branch pipes for 2.5 mm wall thickness and above ; intermittent and no-flow

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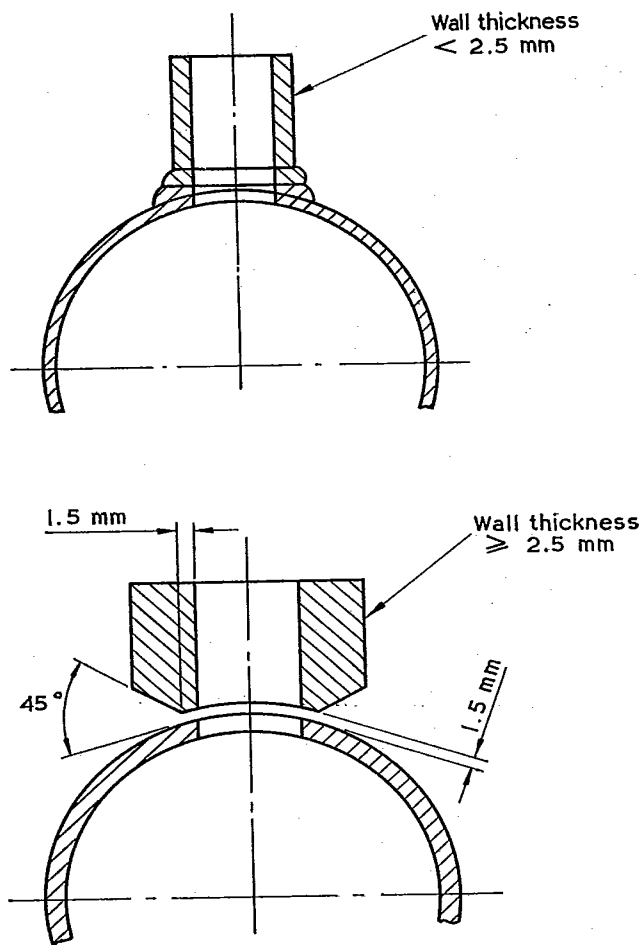


Fig. 6. Set-on branches and bosses, welded ; no-flow

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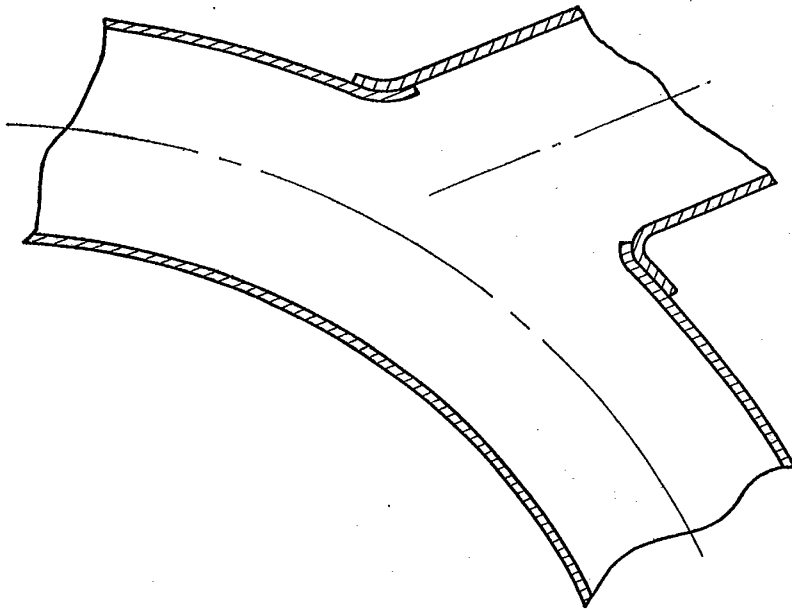


Fig. 7. Swept saddle type branch, brazed; continuous, intermittent and no-flow

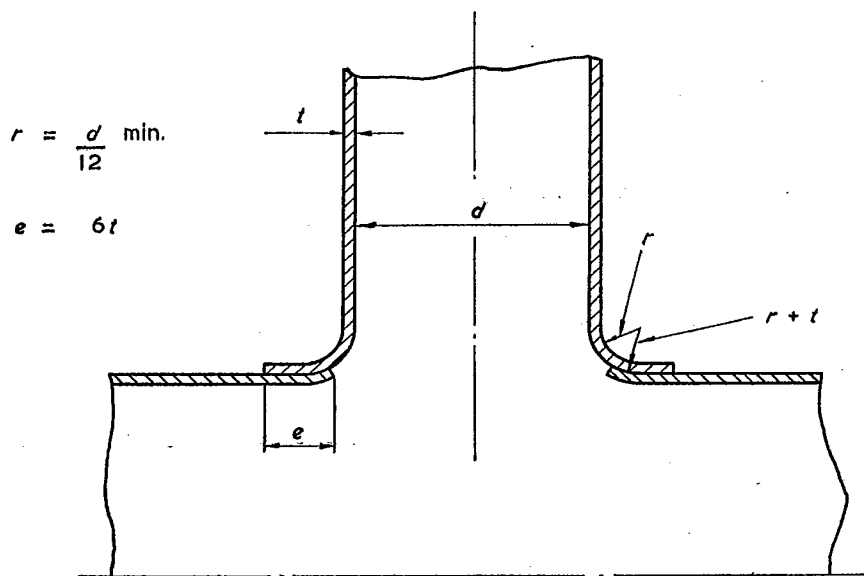


Fig. 8. Saddle branch, brazed; continuous, intermittent and no-flow

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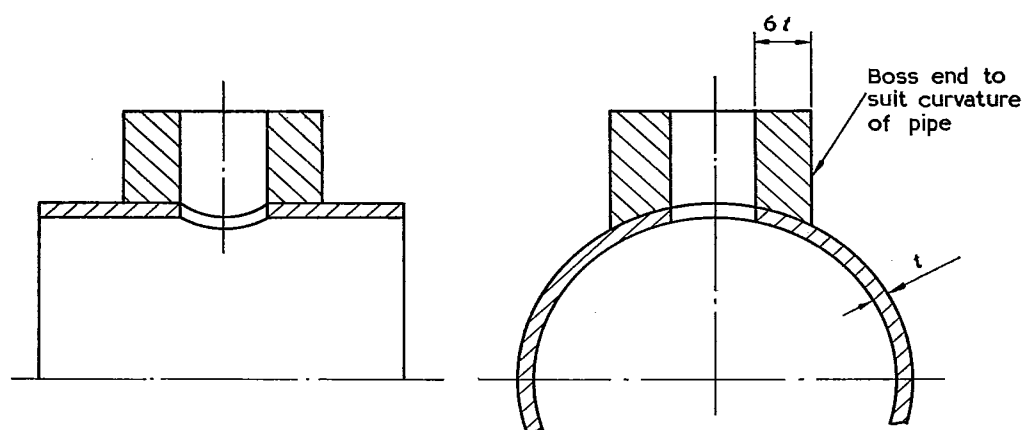


Fig. 9. Set-on boss brazed; no-flow

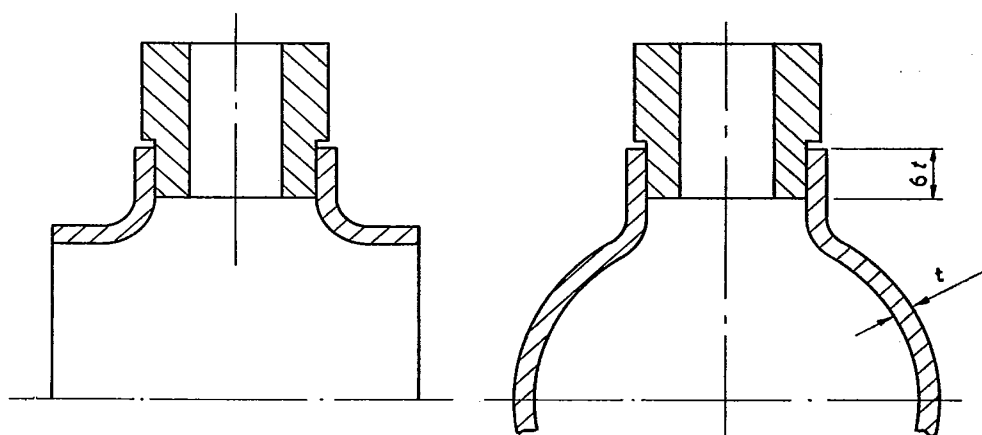
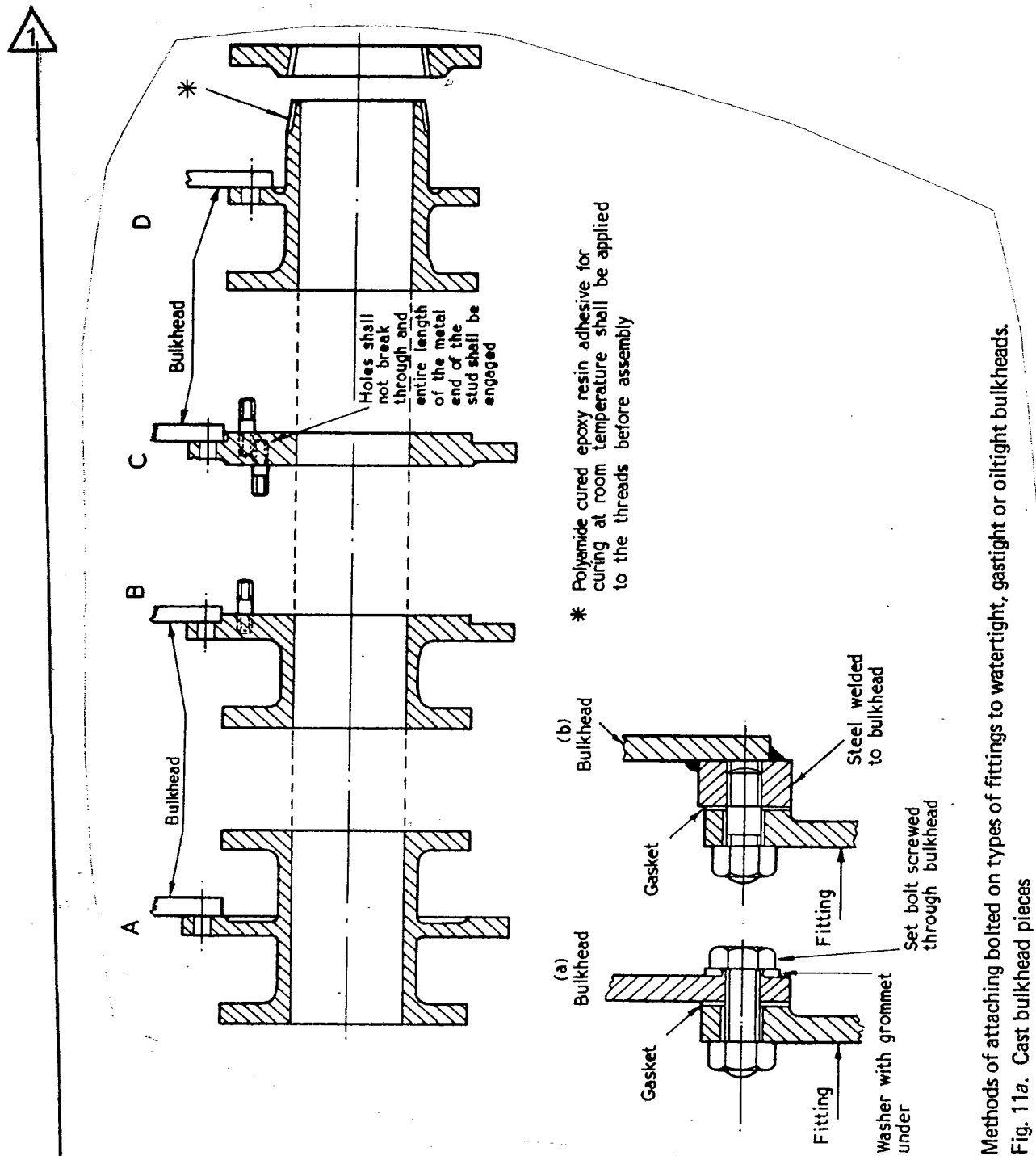


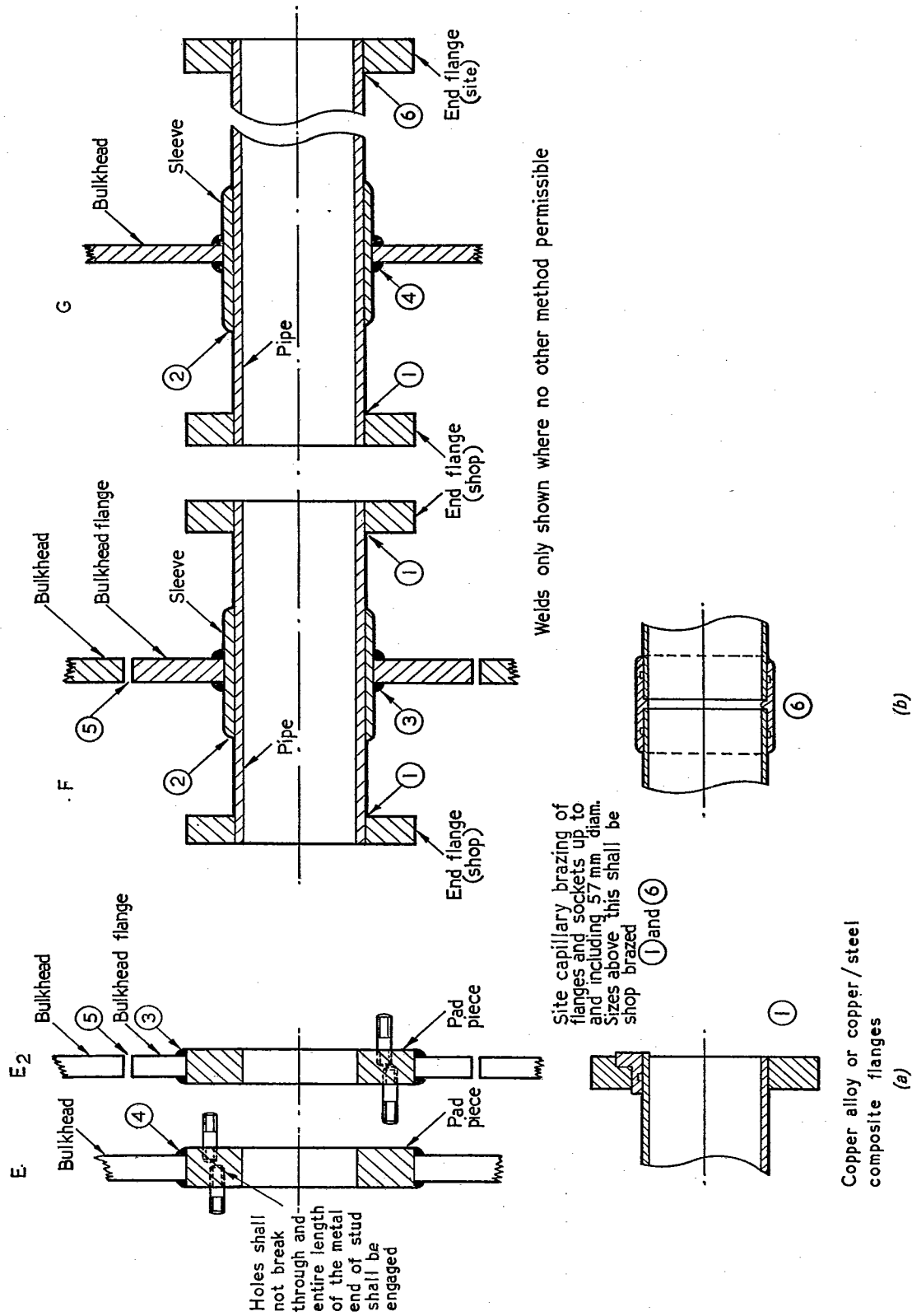
Fig. 10. Set-in socket boss (Scotch type); no-flow

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Methods of attaching bolted on types of fittings to watertight, gastight or oiltight bulkheads.
Fig. 11a. Cast bulkhead pieces

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For an explanation of the various attachments see Fig. 11c. (encircled numbers)

Fig. 11b. Fabricated copper alloy/steel bulkhead pieces

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← Weld or braze IN SHOP → ← Weld or braze ON SITE →

Type	End flanges (1)*	Sleeve to pipe (2)	Pad piece or sleeve to bulkhead flange (3)	Pad piece or sleeve to bulkhead (4)	Bulkhead flange (5) to bulkhead	End attachment (6)
E ₁	NA	NA	NA	Pad piece of 90/10 or 70/30 copper-nickel metal-arc welded to steel bulkhead	NA	NA
E ₂	NA	NA	Pad piece of 90/10 or 70/30 copper-nickel or aluminium-bronze† welded to steel bulkhead flange	NA	Steel bulkhead flange to steel bulkhead (1) Lap or butt welded (2) Bolted see Fig. 11a, (a)	NA
F	(1) Copper alloy flange (see Table 1) welded or brazed to copper alloy pipe	Steel sleeve (1) welded to 90/10 or 70/30 copper-nickel pipe. Test in accordance with 10.1.1	Steel sleeve welded to steel bulkhead flange	NA		NA
G	(2) Steel flange welded to 90/10 or 70/30 copper-nickel pipe (see 6.3.1.9.3)	(2) Brazed to 90/10 or 70/30 copper-nickel or aluminium-brass pipe	NA	Steel sleeve welded to steel bulkhead	NA	(1) Flange of 90/10 or 70/30 copper-nickel metal-arc welded to copper alloy pipe (2) 57 mm and below. Copper alloy flange or socket capillary brazed to copper alloy pipe (see Fig. 11b, (a) and (b))

* Encircled numbers in headings refer to Fig. 11b. NA = Not applicable. † Other materials may be used in due course as appropriate fillers and techniques are evolved.

Fig. 11c. Fabricated copper alloy/steel bulkhead pieces. Methods of attaching components of types shown in Fig. 11b

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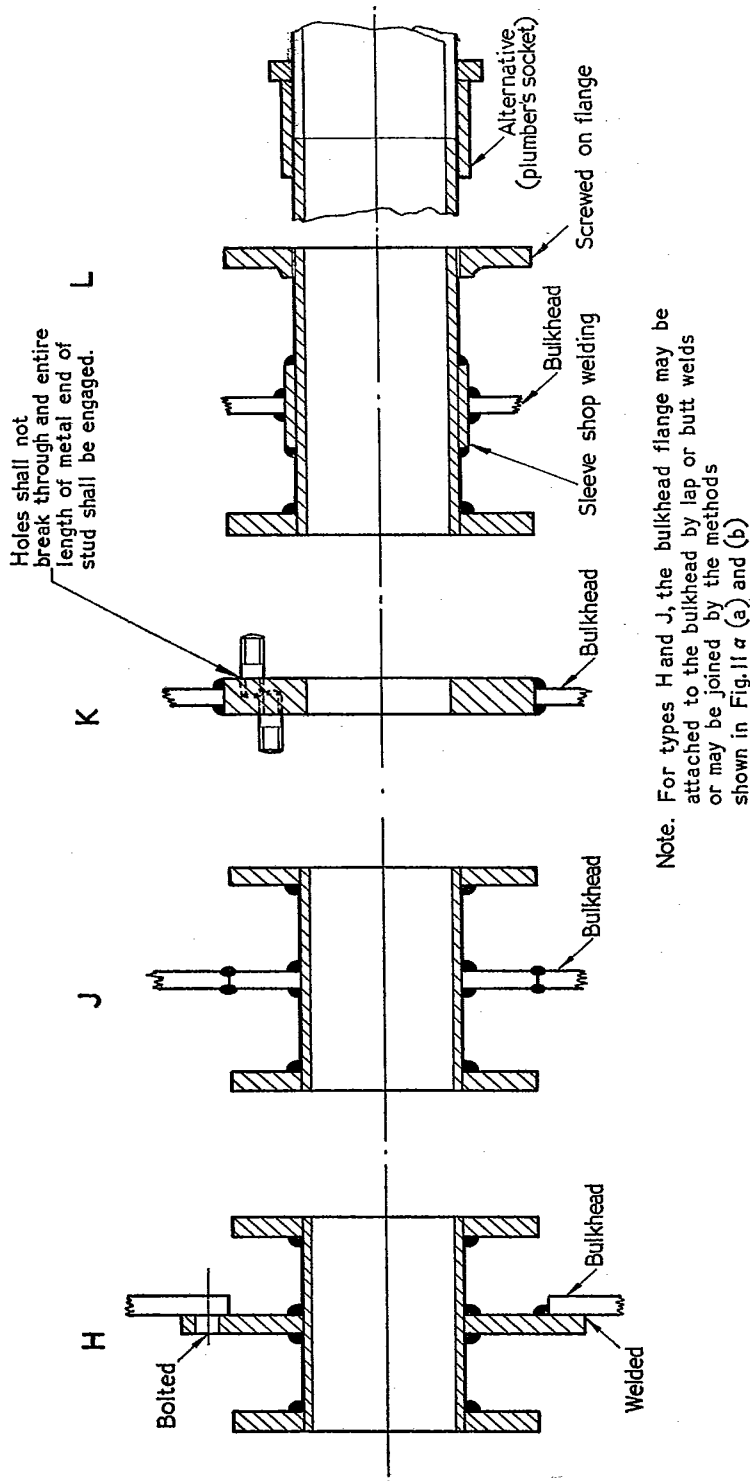


Fig. 11d. Galvanized fabricated steel bulkhead pieces

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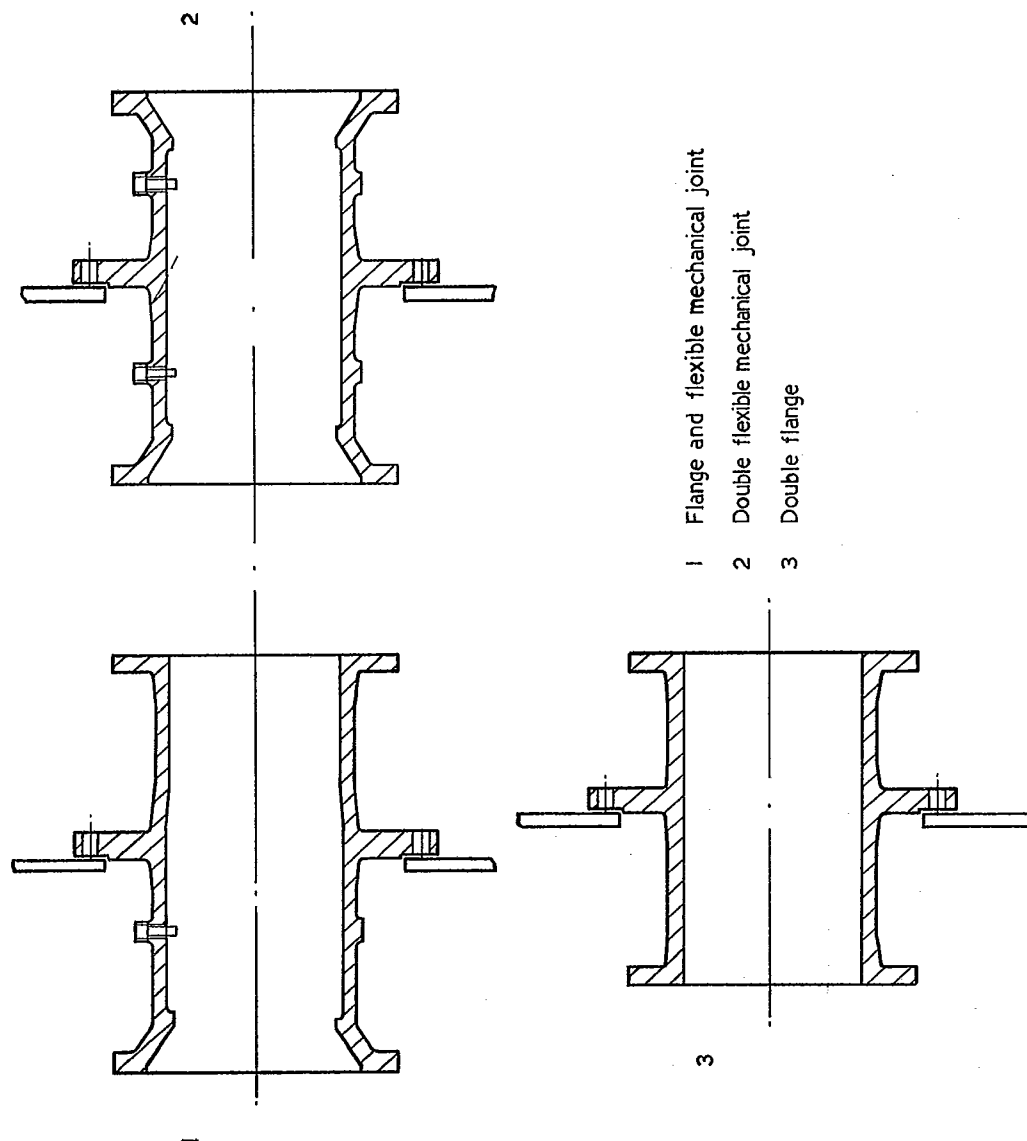


Fig. 11e. Grey and ductile iron bulkhead pieces

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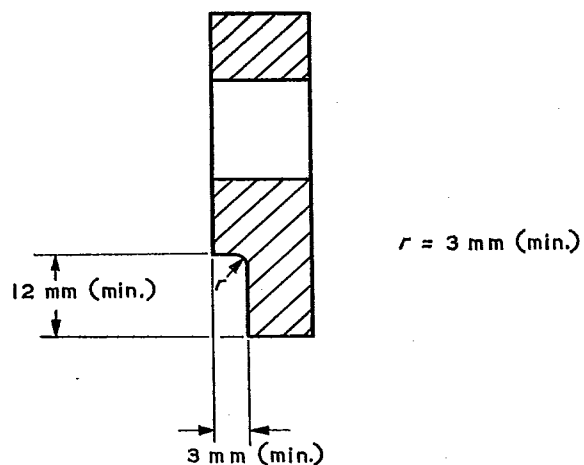


Fig. 12. Recommended steel flange preparation for welding to copper-nickel pipe

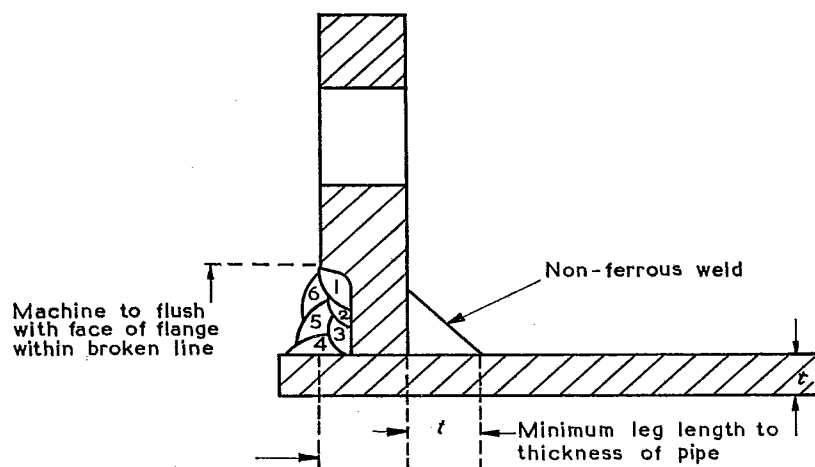


Fig. 13. Typical procedure for welding steel flange to copper-nickel pipe

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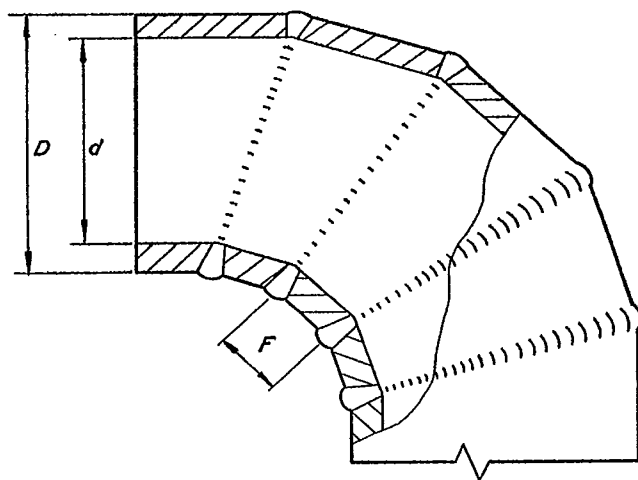


Fig. 14. Gusseted bend

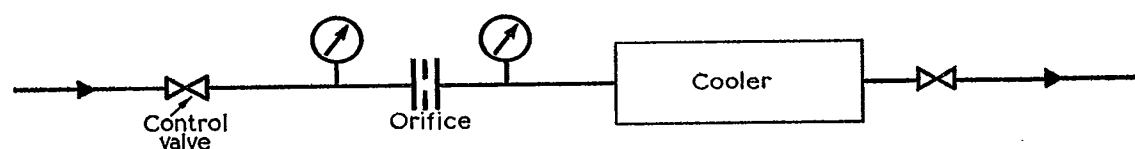


Fig. 15. Setting up correct flows in salt water circulating systems

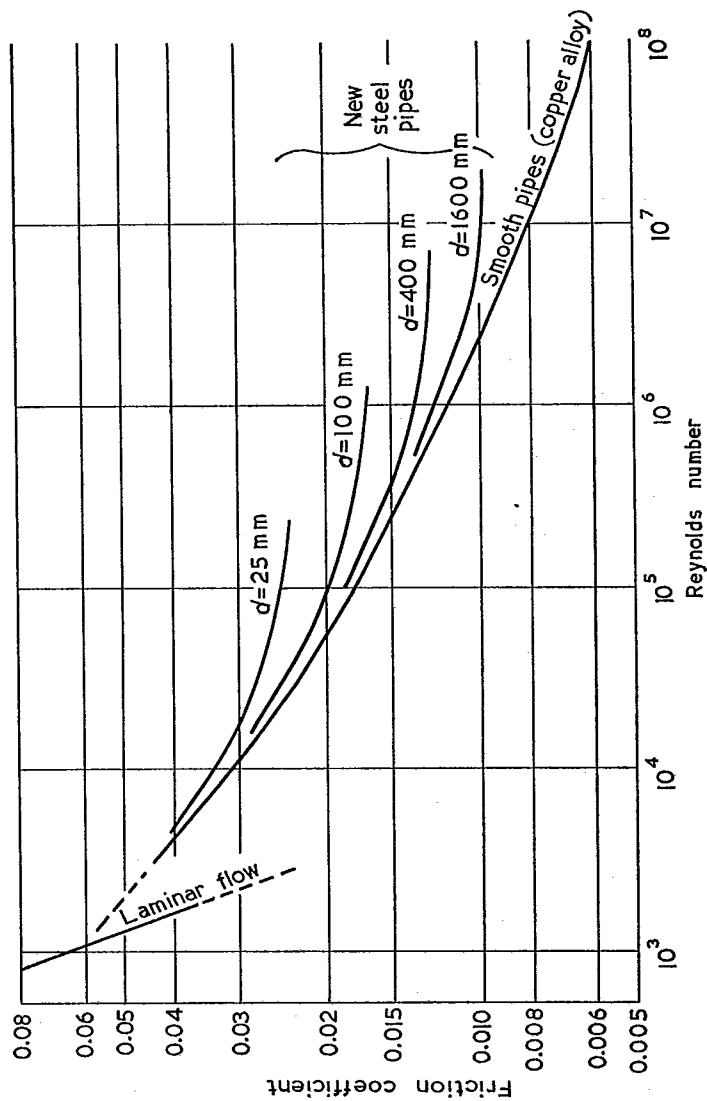


Fig. 16. Pipe friction coefficient

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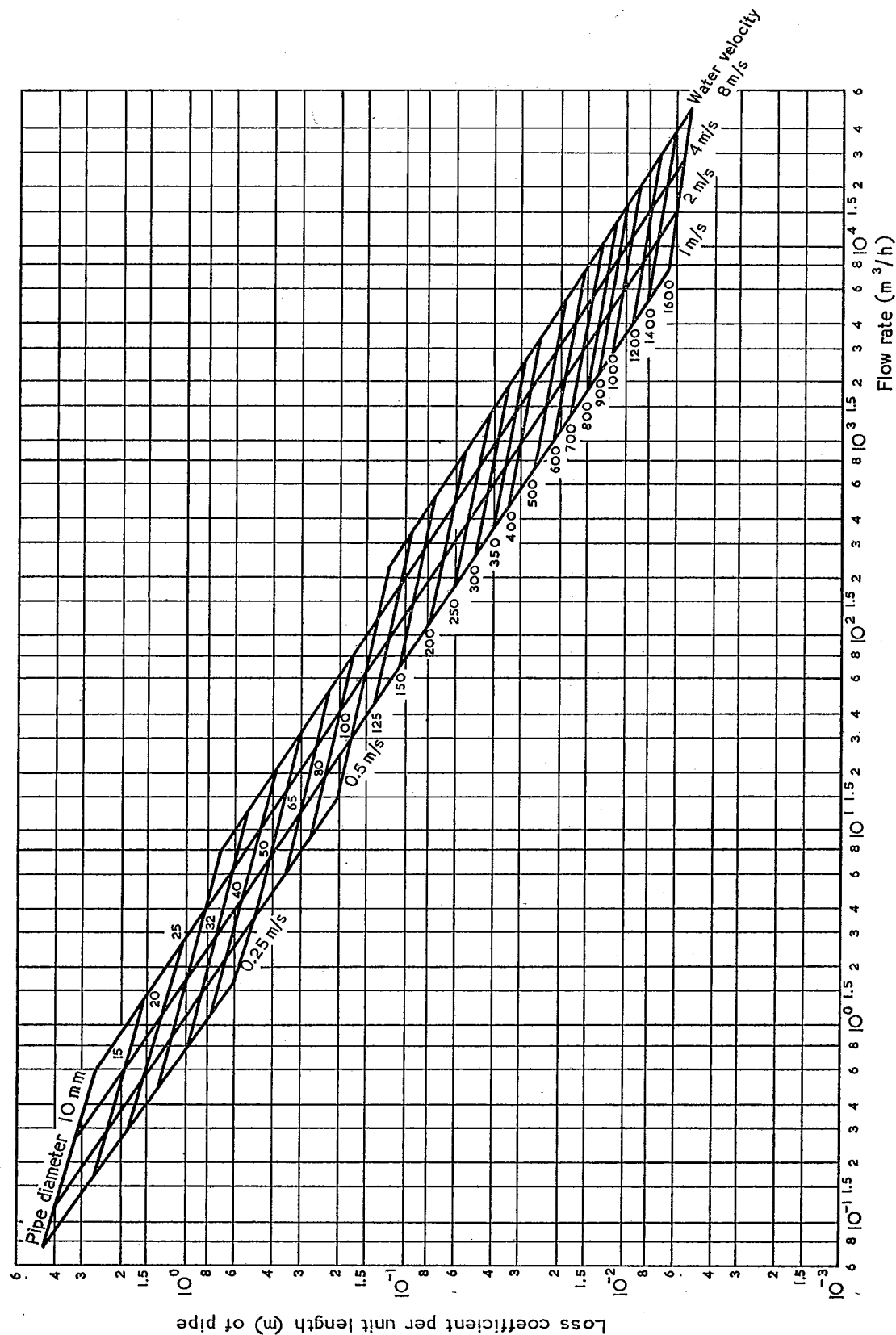


Fig. 17. Friction loss in 'smooth' copper alloy pipes (water 20°C)

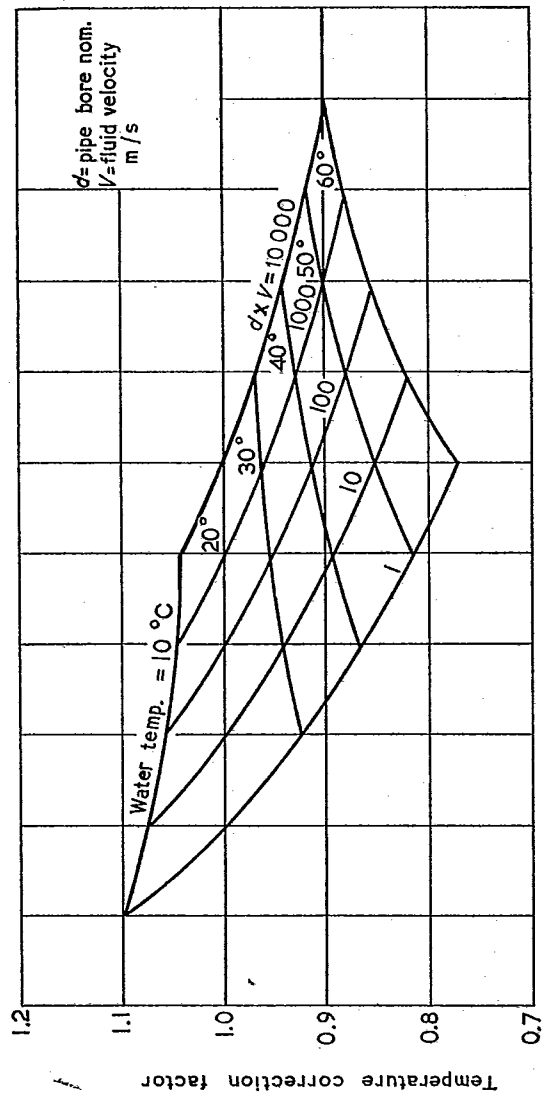


Fig. 18. Temperature correction factor for loss in 'smooth' copper alloy pipes

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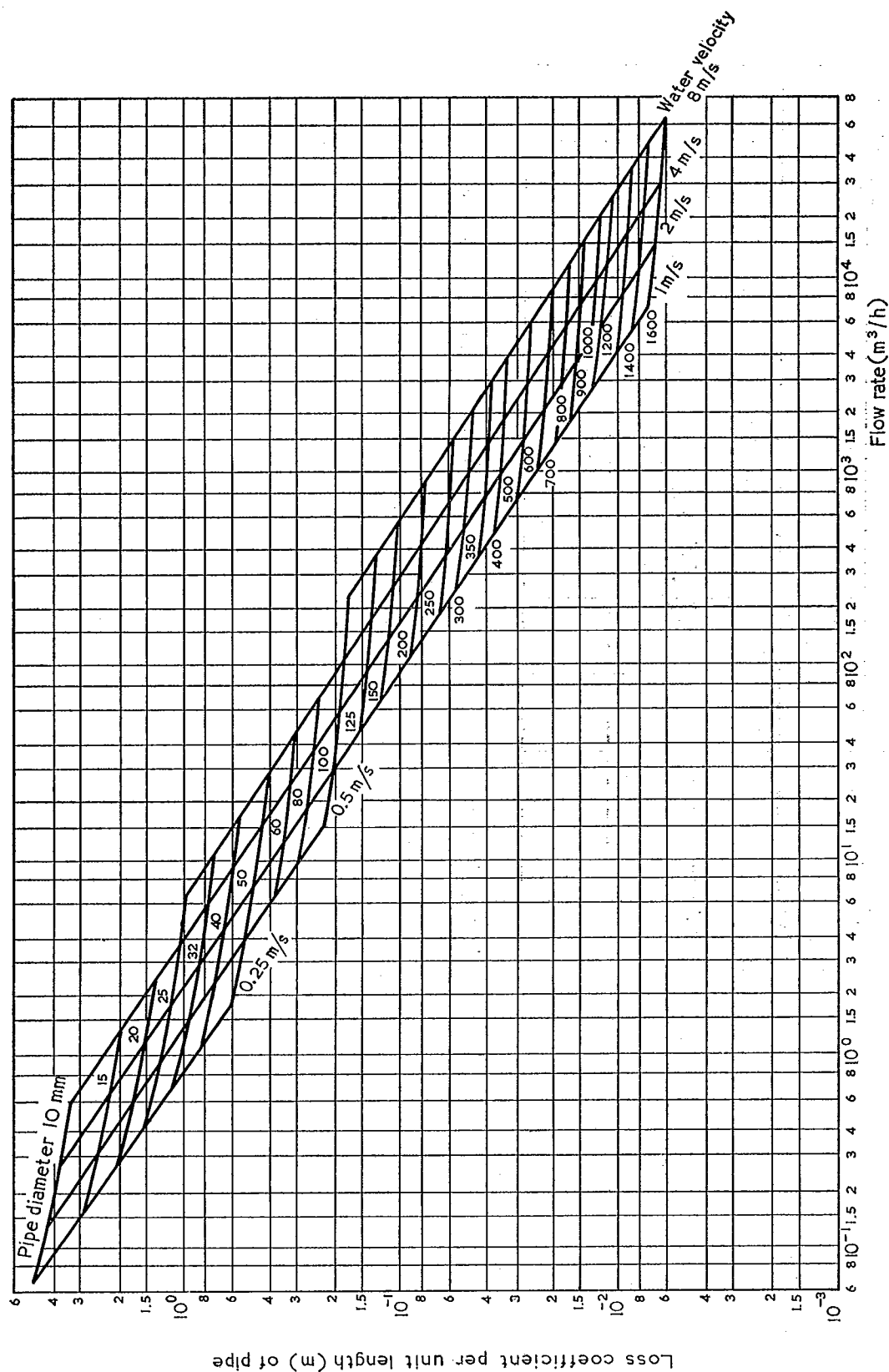


Fig. 19. Friction loss in new steel pipes (water 20 °C)

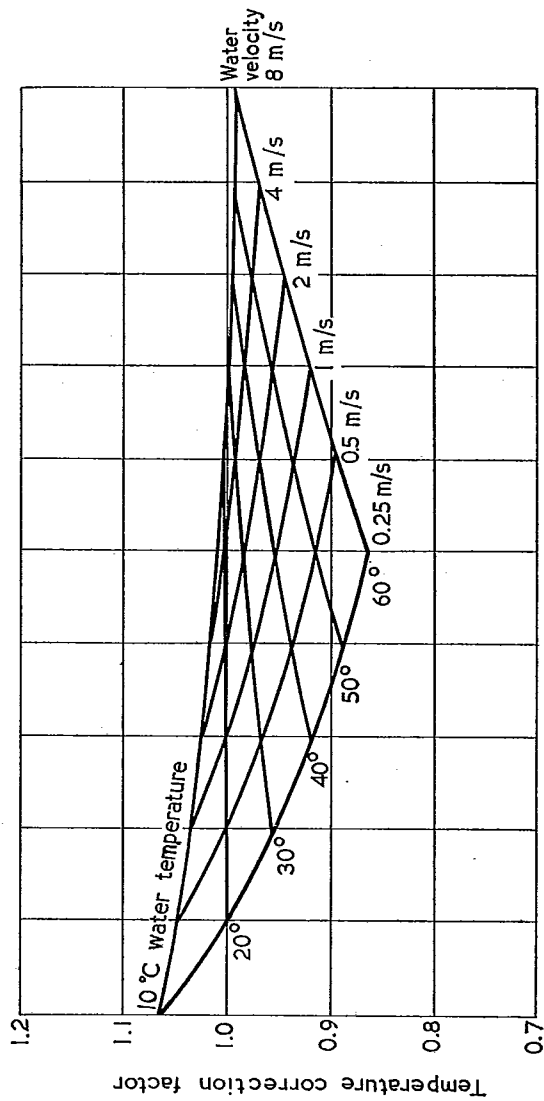
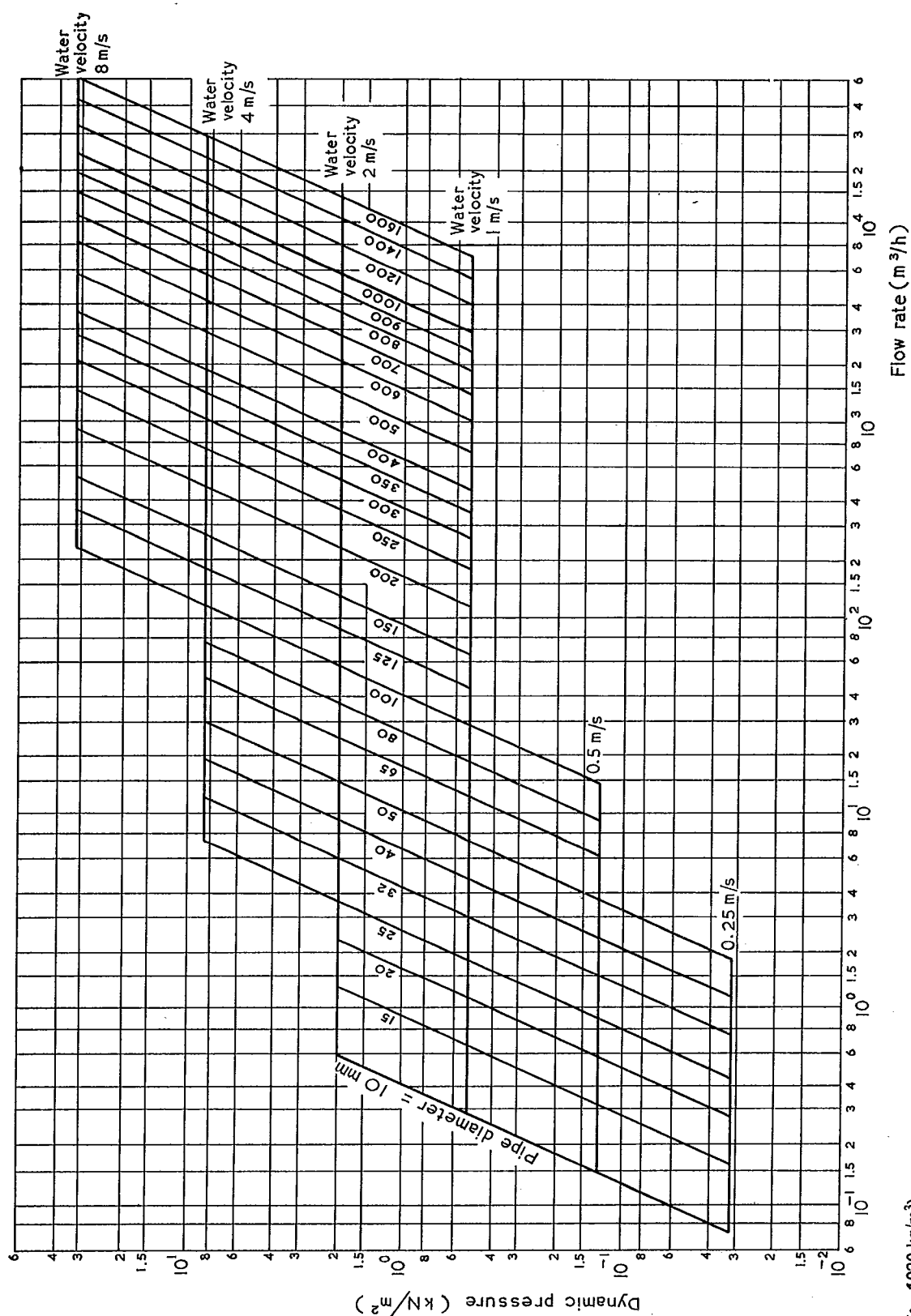


Fig. 20. Temperature correction factor for loss in new steel pipes

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($\rho=1030 \text{ kg/m}^3$)

Fig. 21. Dynamic pressure of salt water

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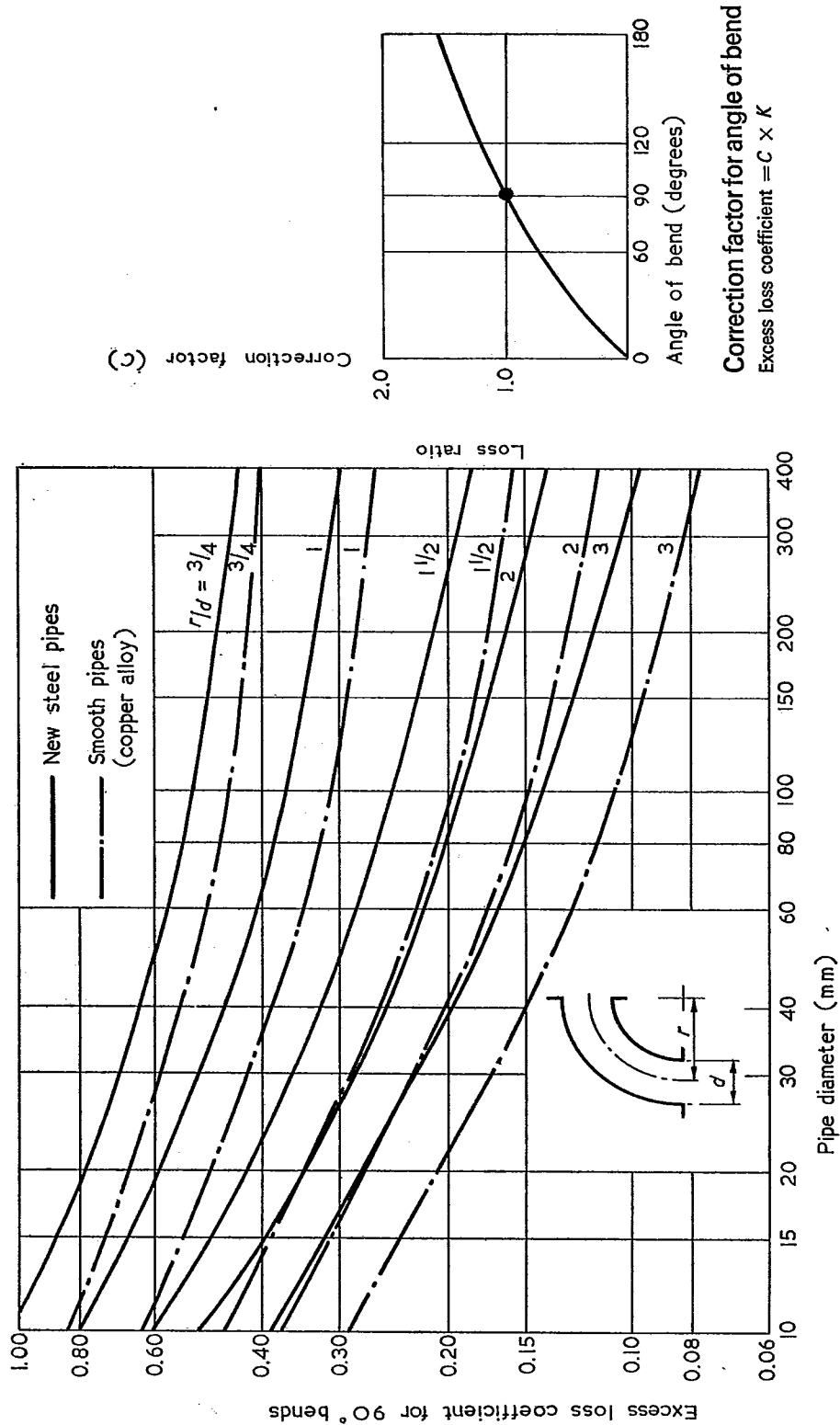


Fig. 22. Excess loss coefficients for bends

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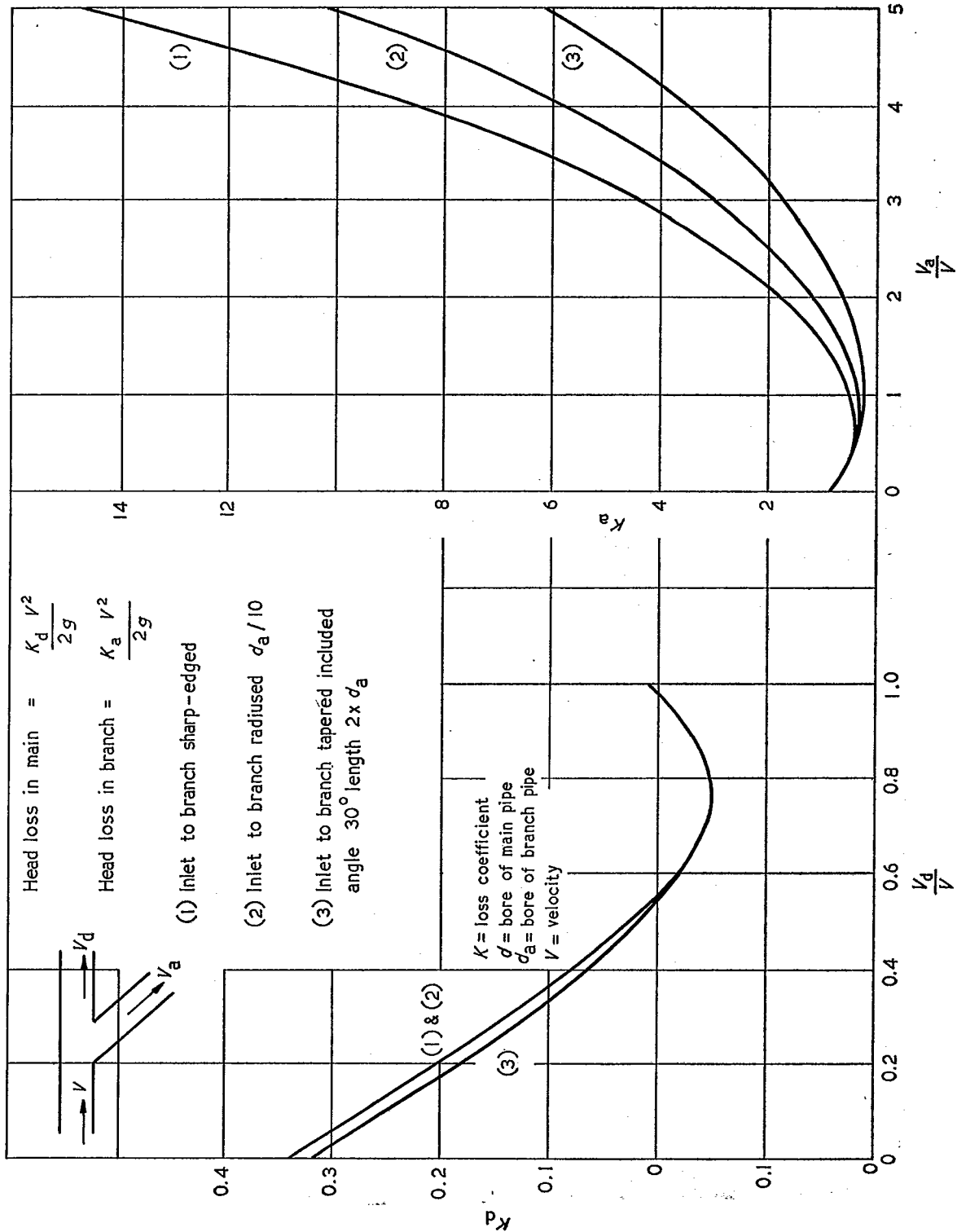
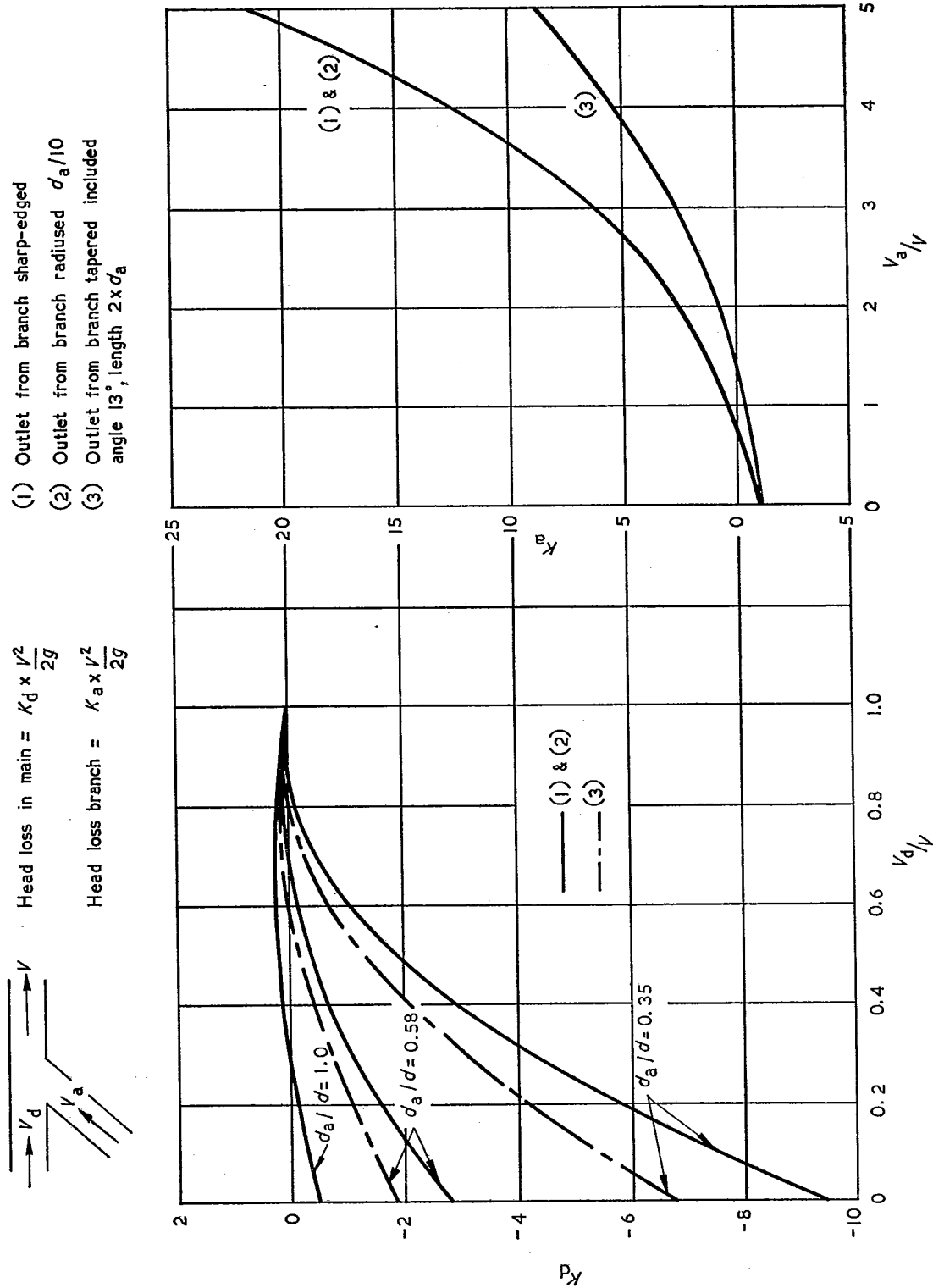


Fig. 23. Loss coefficient for flow in a 45° branch (dividing flow $0.352 < d_a/d < 1.00$)

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Fig. 24. Loss coefficient for flow in a 45° branch (uniting flow $0.352 \leq d_a/d \leq 1.00$)

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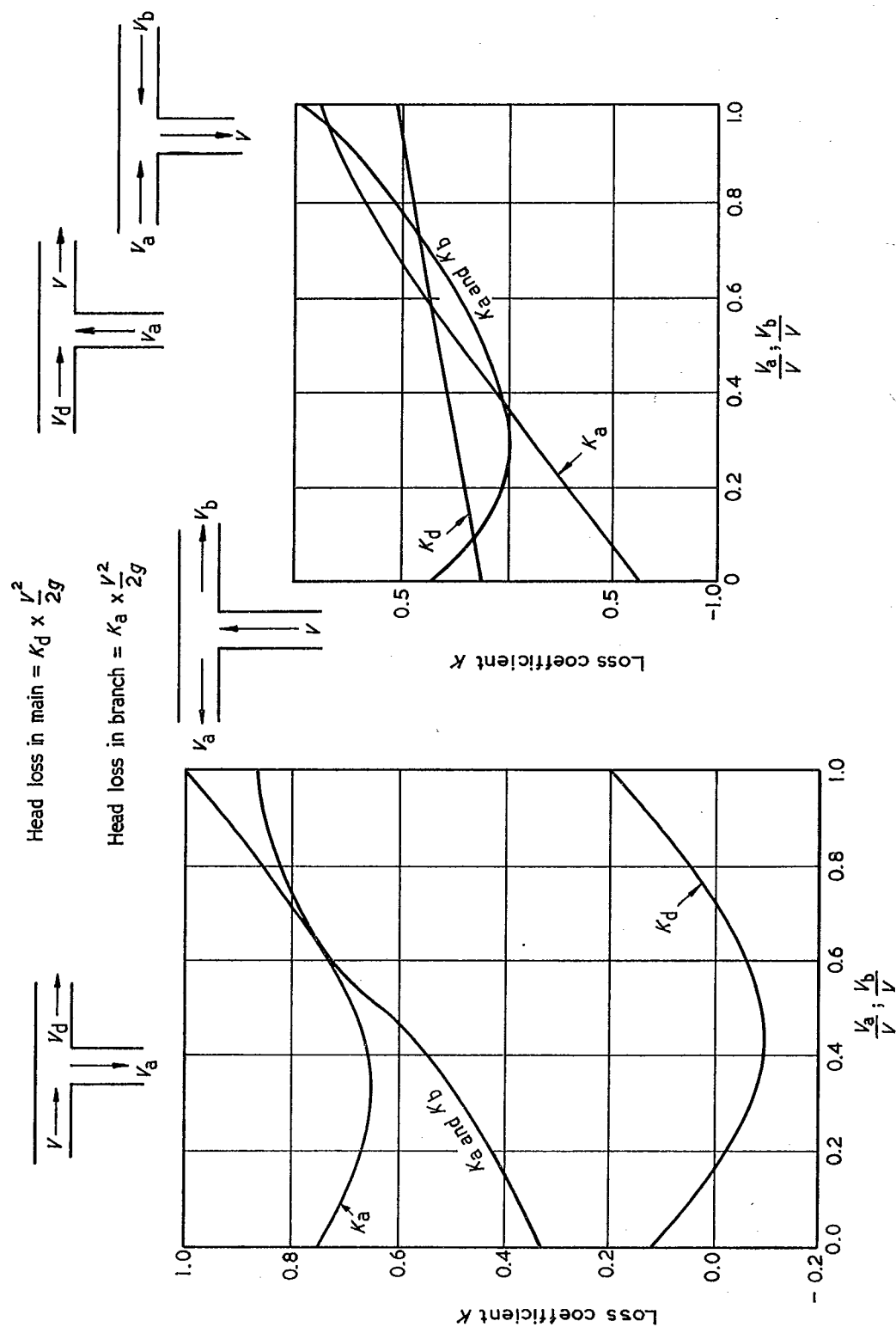


Fig. 25. Loss coefficient for flow in equi-diameter right-angle branches

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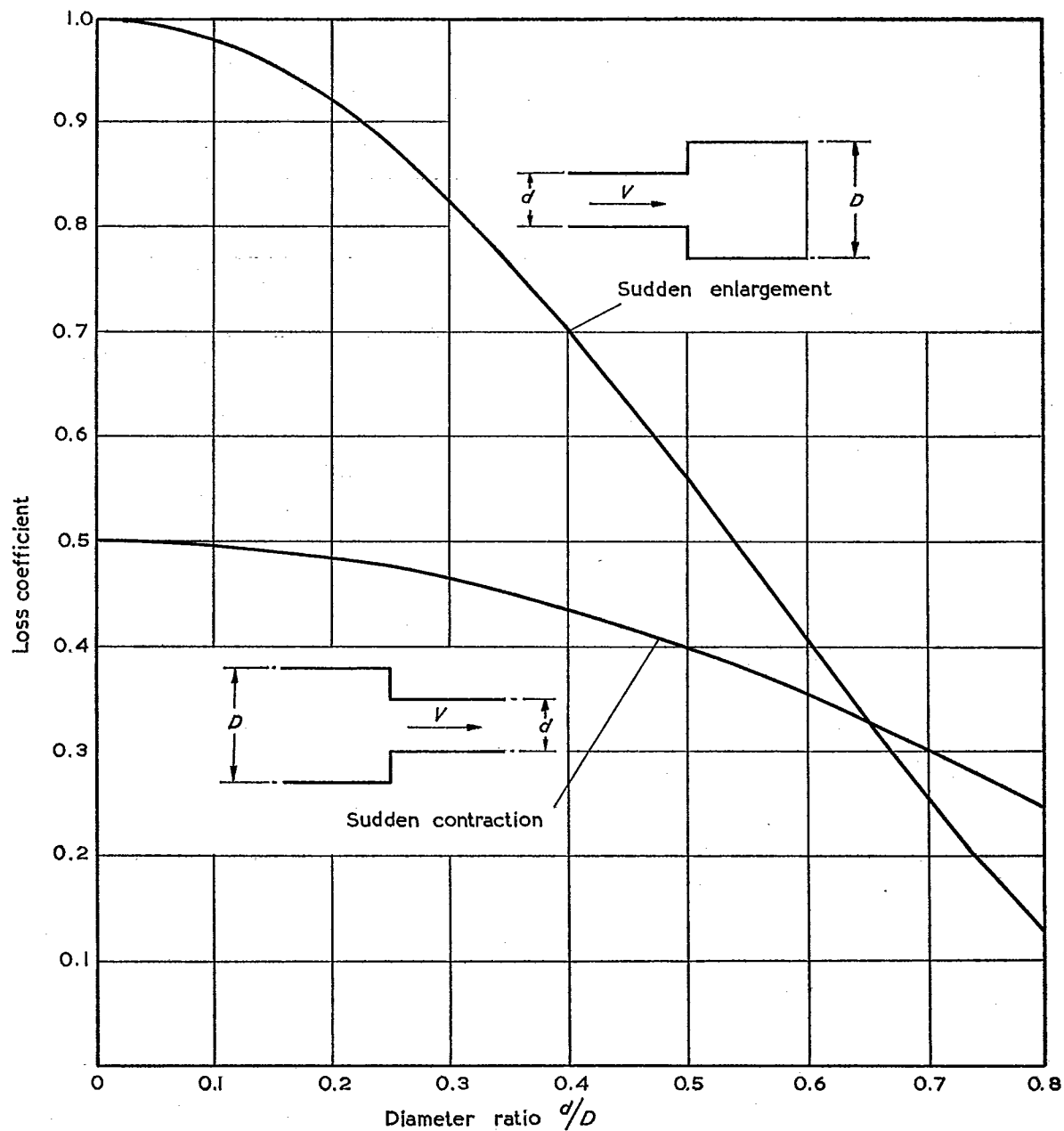
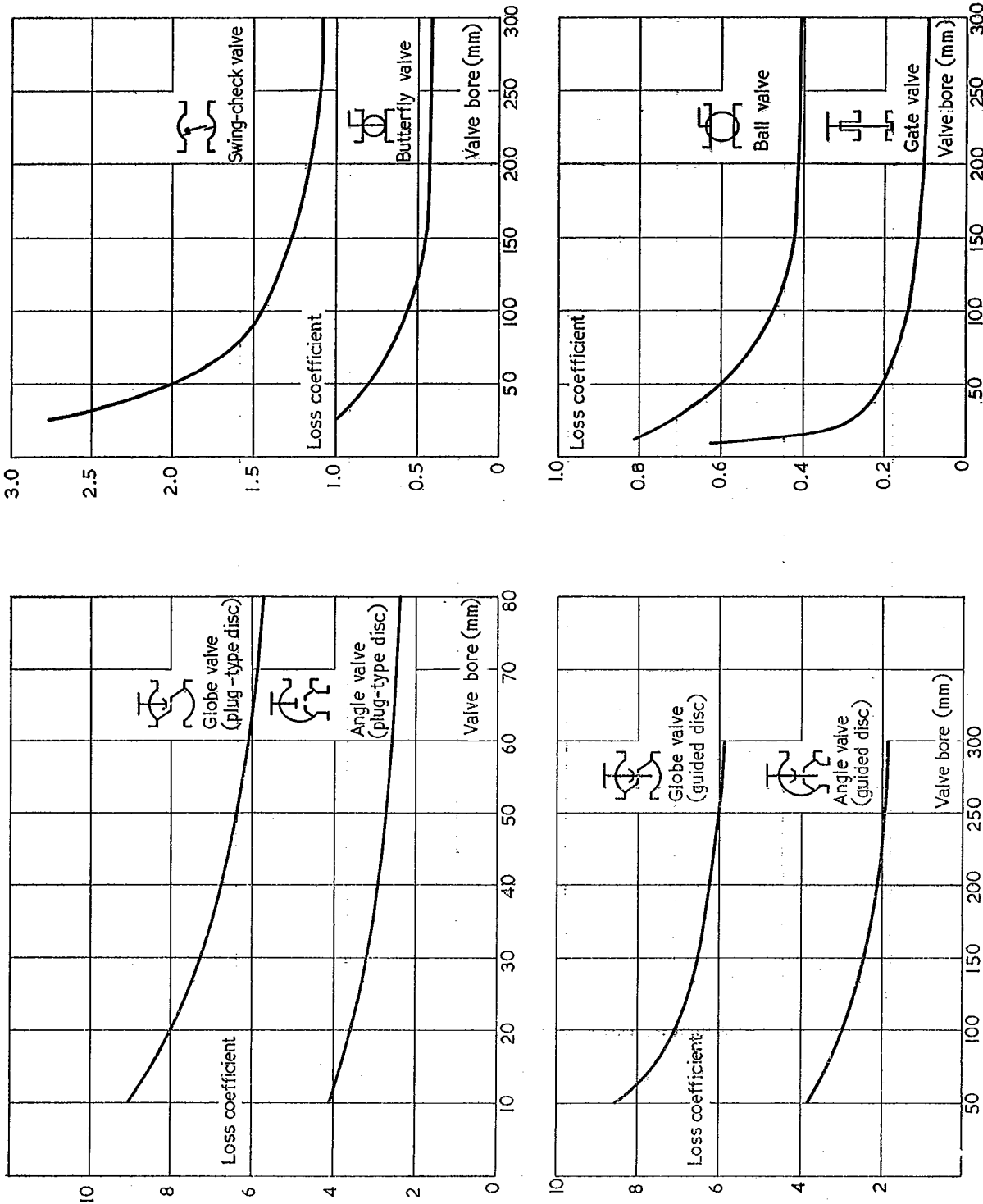


Fig. 26. Loss coefficient for sudden enlargement and contraction

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NOTE. Drawings of valves are diagrammatic and not intended for use as symbols on diagrams.
Fig. 27. Loss coefficients for valves

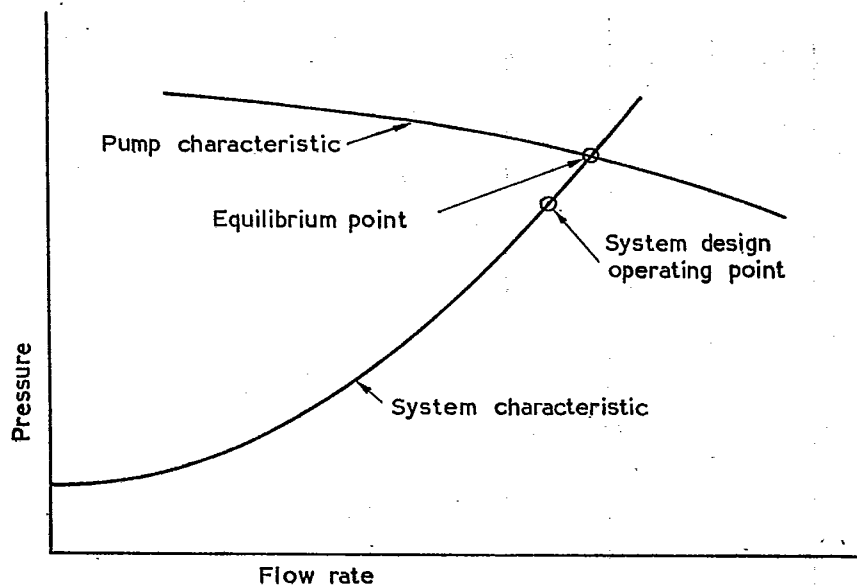


Fig. 28. Comparison of pump and system characteristics

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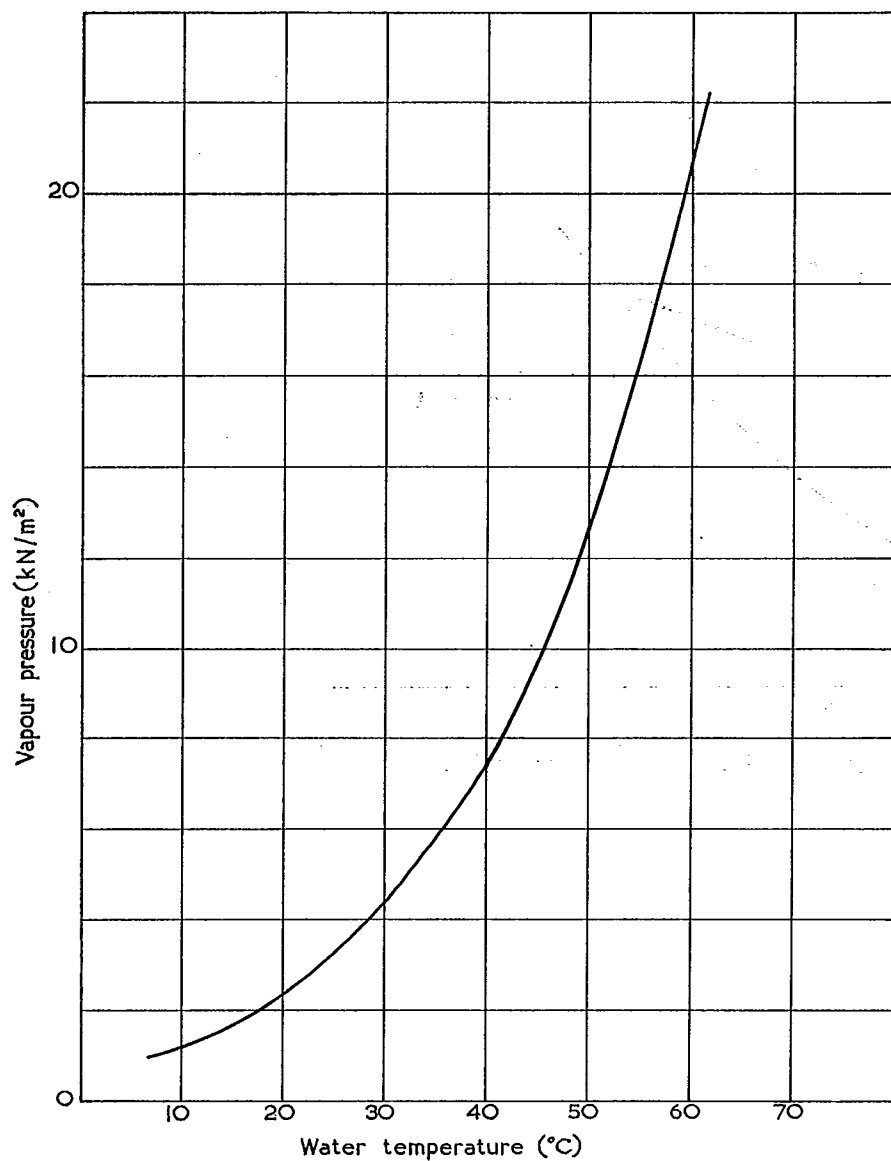


Fig. 29. Vapour pressure of water

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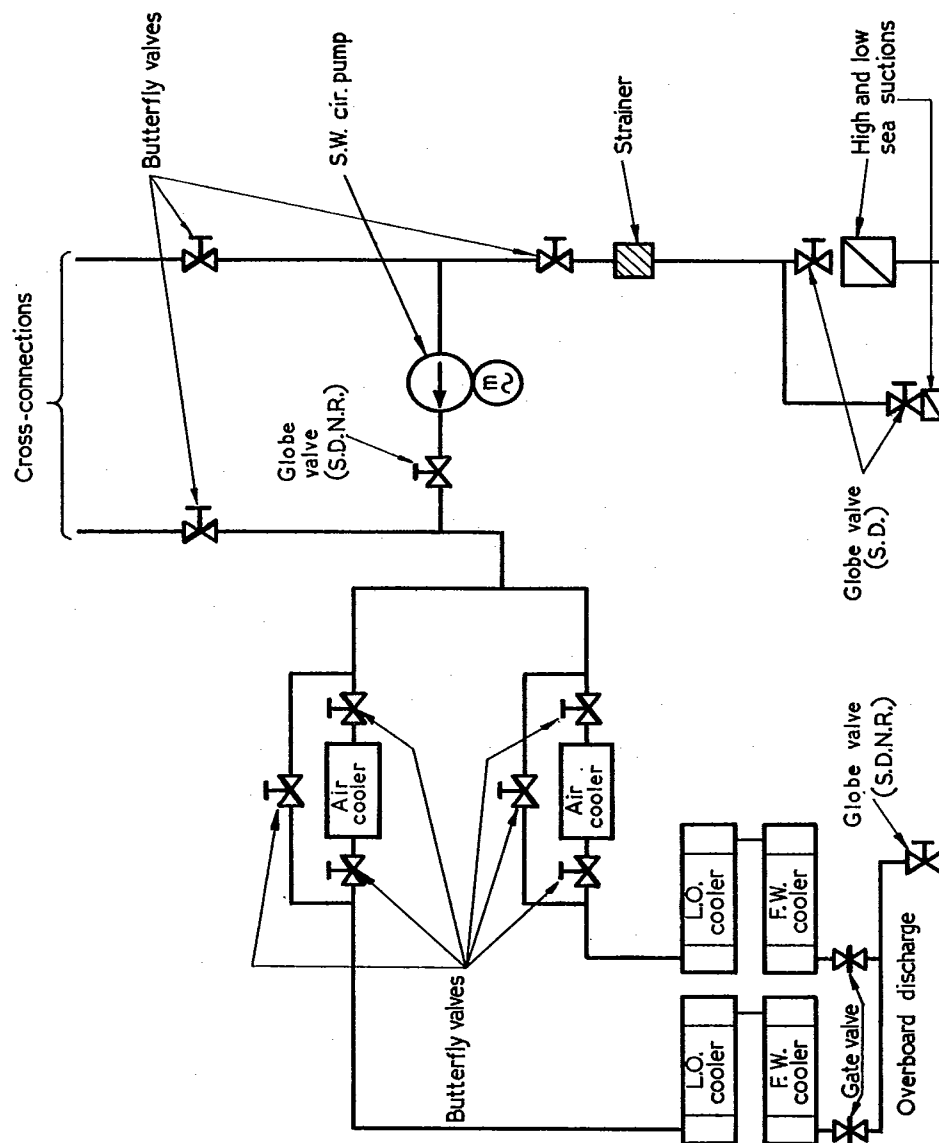


Fig. 30. Typical sea water circulating system

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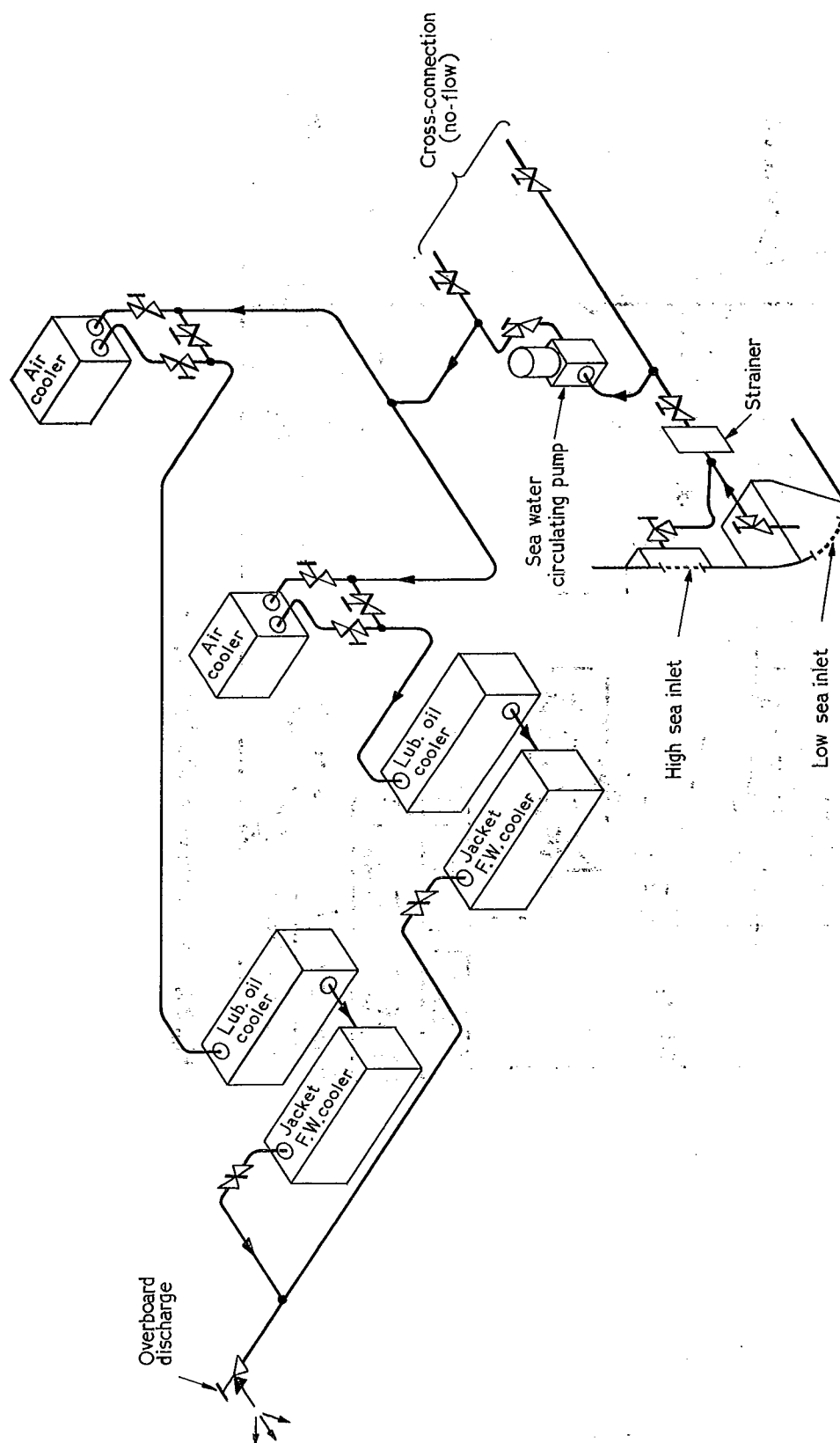


Fig. 31. Isometric view of piping layout (for Appendix A example calculation only)

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ISBN: 0 580 07833 7

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Committee reference SME/3 Draft for comment 71/30076



**Amendment Slip No.1, published 30 September 1976
to British Standard MA 18 : 1973**

(Marine Series)

Salt water piping systems in ships

Revised text

**AMD 2101
September 1976**

Foreword

In the list of reference standards delete the asterisk against BS 3600; delete the associated footnote.

Delete the entry for BS 3601 and substitute the following:

'BS 3601 Steel pipes and tubes for pressure purposes: carbon steel with specified room temperature properties'

**AMD 2101
September 1976**

Clause 4.3.1.1.1 BS 3601

Delete the existing text and substitute the following:

'Seamless (S) or electric resistance welded (ERW) steel pipes of Grades 320, 360 and 410.

Submerged arc welded (SAW) steel pipes, Grade 410, provided they are welded internally and externally.'

**AMD 2101
September 1976**

Table 1. Copper alloy components

Delete all references to materials AB1-C and CA106.

In column 2, against 'Valves', delete the existing terminology for components and substitute the following:

Body, bonnet, cover, dish, wedge and ball

Disc, wedge, ball, facing rings, body seat
rings and other trim components

Internal fasteners

Stem, spindle and shaft (9)

For line 1 of this new information, under the heading 'Rods and sections', insert 'X' in the columns headed 'CA104', 'PB102' and 'NA13'; under the heading 'Forging stock and forgings', insert 'X' in the column headed 'CA104'.

At the end of Note 5 insert '(See 4.3.5.3 and 4.3.5.4.)'

Delete the text of Note 6 and substitute the following:

'See 4.3.5.2 for alternative materials.'

Insert the following new Note 9:

'NOTE 9. Stainless steel stems, spindles or shafts may be fitted. For grades of stainless steel see 4.3.5.3.'

AMD 2101
September 1976

Clause 4.3.4.2 Internal fittings and trim
After 'All internal fittings' insert 'other than those given in 4.3.4.3'.

AMD 2101
September 1976

New clause
Insert the following new clause:
'4.3.4.3 *Stems, spindles, shafts and internal fasteners.* Any of the material given in Table 1 or specified in 4.3.5.3.'

AMD 2101
September 1976

Clause 4.5.4 Orifice plates
Delete the existing text and substitute the following:
'Where orifice plates and pressure reducing constrictions are permanently fitted, the materials shall be as agreed between the manufacturer and the purchaser.'

AMD 2101
September 1976

Clause 5.2.1
Insert the following new paragraph:
'Whilst it is important that the maximum water velocities should be restricted, attention is also drawn to the importance of ensuring that the flow should not be established at such a low figure that, when operating under polluted water conditions, sediment and slime are allowed to build up. This will inevitably lead to corrosion followed by early failure. It is recommended that polluted water should not be allowed to remain stagnant in pipework and equipment for long periods. It is recommended that during construction, fitting out and operation all items of equipment should be regularly run for short periods at least to ensure that a flushing-through can be assured, and attention is also drawn to Appendix B.'

AMD 2101
September 1976

Clause 5.3.2
Delete item (5) and substitute the following:
'(5) *Air vents.* Arrangements shall be made for relieving air from the highest point in the inlet box. Air vents are preferred in the form of pipes with steeply inclined runs leading from the highest point in the inlet box to a height above the deepest load line of the ship. A shut-off valve should be fitted between the vent line and the box. The highest parts of the system should also be provided with vents, and any positions where the water speed is low should be vented. Where boxes are not in the bottom, air release may be through holes at the highest point connecting to the sea; preferably vent pipes of adequate size may be used.'

AMD 2101
September 1976

Clause 6.2.1.1 Bends (general)
Insert the following new paragraph:
'Proprietary seamless or seam welded bends in copper alloys or bends in cast copper alloys in accordance with 4.2 may be used. For pipe sizes up to 57 mm, proprietary fittings according to 6.1.3 may be used.'

AMD 2101
September 1976

Clause 6.2.1.2 Bends (short radius)
Delete this clause entirely.

AMD 2101
September 1976

Clause 6.3.2.3.2.1

In line 3 delete 'bushes' and substitute 'bosses'.

AMD 2101
September 1976

Clause 6.3.2.3.2.3 For no-flow conditions

Delete this clause entirely.

AMD 2101
September 1976

Table 4. Filler metals for arc welding copper alloy pipelines

In the penultimate line of column 1 delete 'CN104' and substitute 'CA104'.

In the last line of column 1 delete 'CA106'.

In column 3 delete the second entry (beginning 'Weldable steel flanges . . .') and substitute the following:

'Weldable steel flanges as detailed in 4.3.2 and bulkhead pieces as in 6.4.2.2'

In the last line of column 3 delete '6.4.1.2' and substitute '6.4.2.2'.

AMD 2101
September 1976

Clause 6.4.1 General

In line 1 delete 'Where a pipe has to pass through a bulkhead' and substitute 'Where a pipe has to pass through a watertight, gastight or oiltight bulkhead'.

Delete paragraph 2.

AMD 2101
September 1976

Clause 7.4.1 Bulkhead pieces for steel pipes

Delete the number and title of this clause and substitute the following:

'7.4.2 Fabricated steel bulkhead pieces'

AMD 2101
September 1976

Clause 7.4.2 Bulkhead pieces for grey and ductile iron pipes

Delete the number and title of this clause and substitute the following:

'7.4.3 Grey and ductile iron bulkhead pieces'

AMD 2101
September 1976

New clause

Insert the following new clause:

'7.4.1 General. Where a pipe has to pass through a watertight, gastight or oiltight bulkhead, it is necessary to attach the pipe to it while maintaining the integrity of the bulkhead. Typical approved types are described in 7.4.2 and the choice of design depends upon accessibility and the space available in the bulkhead itself.'

AMD 2101
September 1976

Clause A.1.2 Losses in bends, fittings and valves

In Equation (2) delete ' V ' and substitute ' V^2 '.

AMD 2101
September 1976

Clause A.3 Total system loss and pump selection

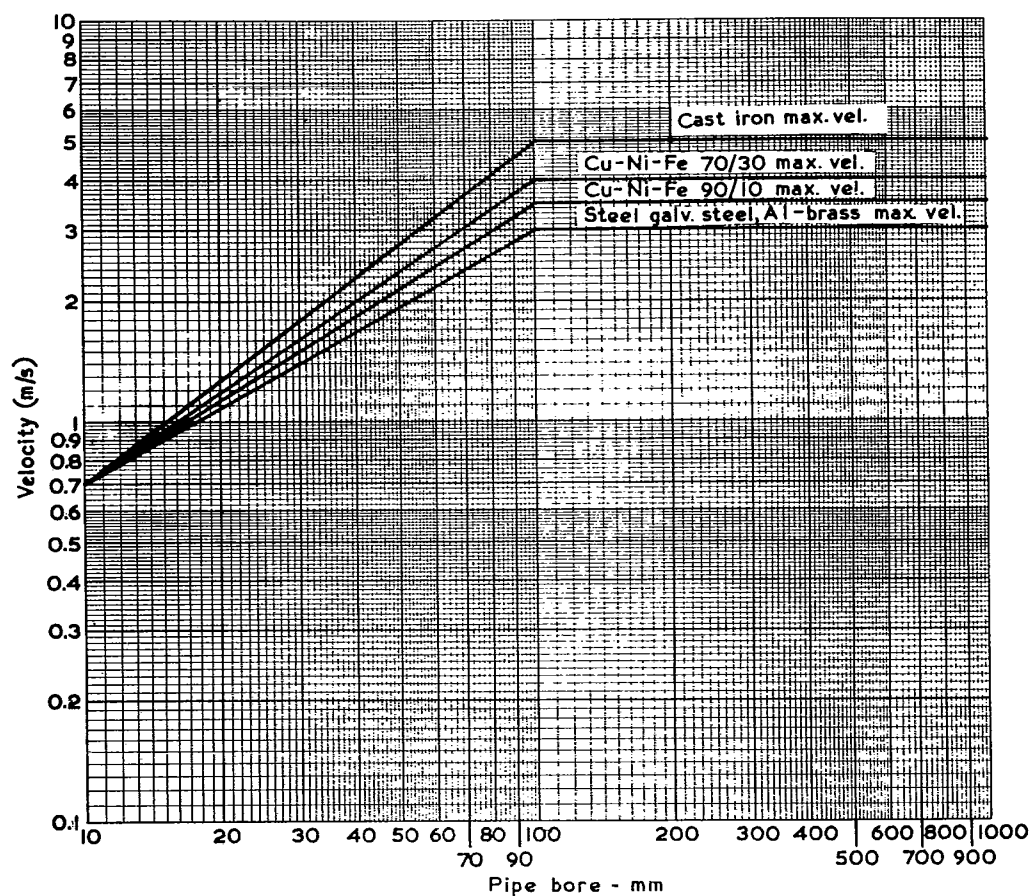
Immediately below ' g = gravitational constant (9.81 m/s^2)' insert the following:

' ρ = density (kg/m^3),'

AMD 2101
September 1976

Fig. 1. Salt water velocities in pipes; for continuous flow

Delete the existing figure and substitute the attached new Fig. 1.



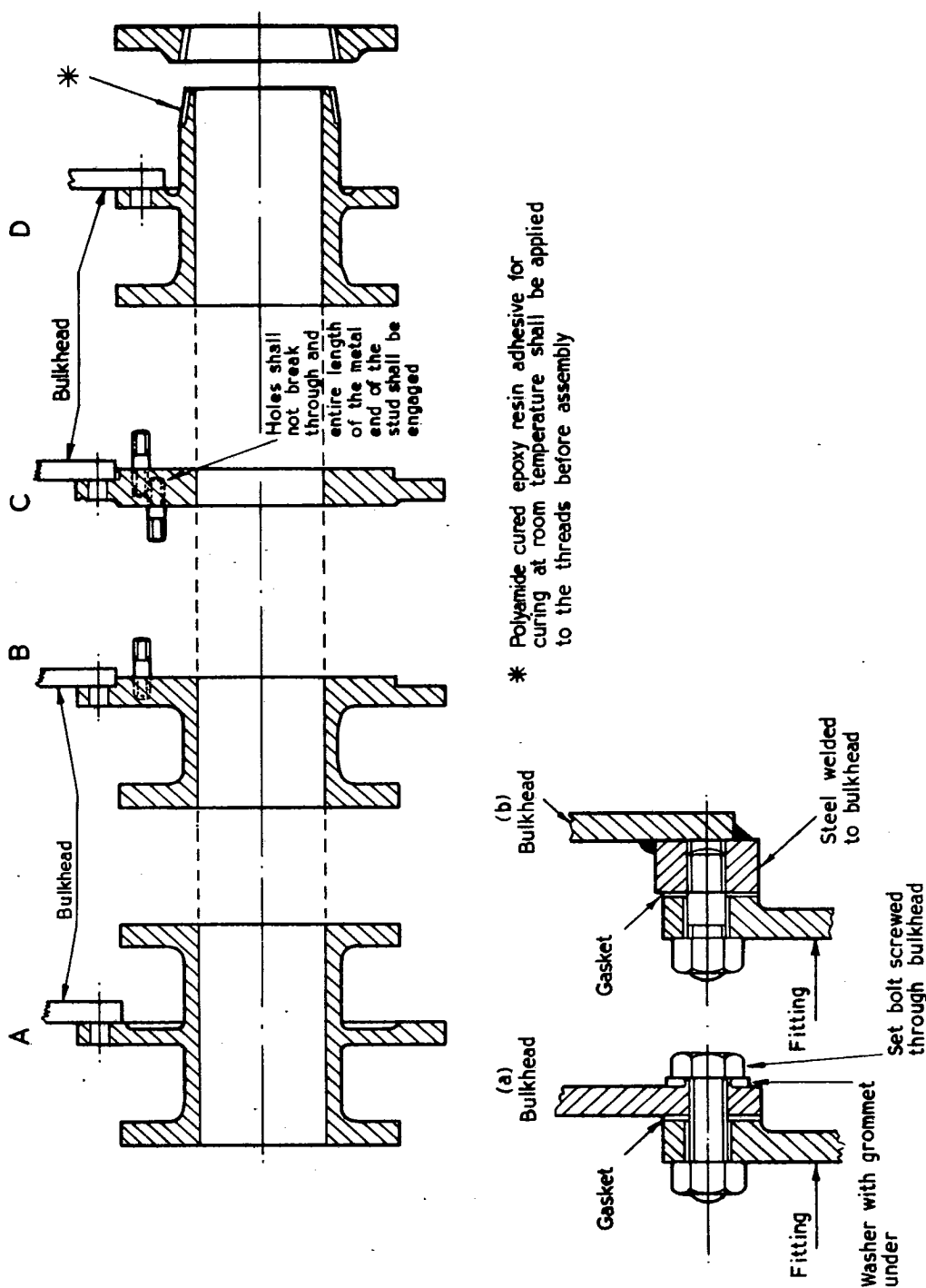
NOTE 1. Maximum velocities are based on materials; due regard should be given to design considerations i.e. pressure drops versus pump discharge head.

NOTE 2. Suction velocities would tend to be lower than those indicated, particularly for high suction lift conditions.

Fig. 1. Salt water velocities in pipes; for continuous flow

Fig. 11a. Cast bulkhead pieces

Delete the existing figure and substitute the attached new Fig. 11a.

Methods of attaching bolted on types of fittings to watertight, gastight or oiltight bulkheads.
Fig. 11a. Cast bulkhead pieces