RULES FOR
CLASSIFICATION OF

SHIPS / HIGH SPEED, LIGHT CRAFT AND NAVAL SURFACE CRAFT

NEWBUILDINGS

MACHINERY AND SYSTEMS
MAIN CLASS

PART 4 CHAPTER 7

BOILERS, PRESSURE VESSELS, THERMAL-OIL INSTALLATIONS AND INCINERATORS

JANUARY 2003

This booklet includes the relevant amendments and corrections shown in the July 2008 version of Pt.0 Ch.1 Sec.3.

CONTENTS PAGE

DET NORSKE VERITAS

Veritasveien 1, NO-1322 Høvik, Norway Tel.: +47 67 57 99 00 Fax: +47 67 57 99 11

CHANGES IN THE RULES

General

This booklet is a reprint of the previous edition and apart from clarifications of text and the inclusion of amendments and corrections, published in the July 2002 edition of Pt.0 Ch.1 Sec.3, no other changes have been made.

This chapter is valid until superseded by a revised chapter. Supplements will not be issued except for an updated list of minor amendments and corrections presented in Pt.0 Ch.1 Sec.3. Pt.0 Ch.1 is normally revised in January and July each year.

Revised chapters will be forwarded to all subscribers to the rules. Buyers of reprints are advised to check the updated list of rule chapters printed in Pt.0 Ch.1 Sec.1 to ensure that the chapter is current.

Comments to the rules may be sent by e-mail to *rules@dnv.com*
For subscription orders or information about subscription terms, please use *distribution@dnv.com*
Comprehensive information about DNV and the Society's services is found at the Web site http://www.dnv.com

Computer Typesetting (FM+SGML) by Det Norske Veritas
Printed in Norway

CONTENTS

SECTION 1 GENERAL REQUIREMENTS

A. Classification

A 100 Application

101 The rules in this chapter apply to:

- boilers, including mountings
- pressure vessels, including mountings, necessary for performing the main functions listed in Pt.1 Ch.1 Sec.1 A200 of the Rules for Classification of Ships
- other pressure vessels containing:
  - toxic fluids
  - fluids with flash point below 100°C
  - fluids with temperature above 220°C
  - fluids with pressure above 40 bar
  - compressed gases where pV ≥ 1.5

  p = design pressure in bar
  V = volume in m^3
- thermal-oil installations
- permanently installed incinerators.

102 Boilers and pressure vessels according to 101 are subject to certification by the Society.

103 The control and monitoring systems shall be certified according to Ch.9 for the following:

- boilers
- thermal-oil installations
- incinerators
- oil fired water heaters.

A 200 Cross-references

201 Pressure vessels for liquefied gases are to meet the requirements in the Rules for Classification of Ships Pt.5 Ch.5 Sec.5.

Cargo process pressure vessels, as defined in the Rules for Classification of Ships Pt.5 Ch.5 Sec.1, are to be graded as class I pressure vessels. However, the selections of materials, qualification of welding procedures and production weld tests are to be according to the Rules for Classification of Ships Pt.5 Ch.5 Sec.2 and Sec.5. Non-cargo process pressure vessels, as defined in the Rules for Classification of Ships Pt.5 Ch.5 Sec.1, are to meet the requirements of Ch.7.

Boiler installations on liquefied gas carriers with gas operated machinery are to meet the requirements in the Rules for Classification of Ships Pt.5 Ch.5 Sec.16.

202 Pressure vessels for refrigerating plants are, in addition to the requirements in this chapter, to meet the requirements of the Rules for Classification of Ships Pt.5 Ch.10.

B. Definitions

B 100 Terms

101 A *boiler* is defined as a welded container or a pipe arrangement in which steam or hot water with a temperature exceeding 120°C is generated by the application of heat, resulting from the combusting of fuel (solid, liquid or gaseous) or from hot combustion gases.

Superheaters, economisers, reheaters and other pressure parts including valves and fittings, connected directly to the boiler without intervening valves, are to be considered as parts of the boiler.

102 A *thermal-oil installation* is defined as an arrangement in which thermal-oil is heated and circulated for the purpose of heating cargo- or fuel oil or for production of steam and hot water for auxiliary purposes.

103 An *incinerator* is defined as a permanently installed arrangement for the purpose of burning products such as sludge oil with flash point above 60°C and other waste products which do not cause danger of explosion.

B 200 Symbols

201 The symbols used are as given below in addition to those specifically stated in the relevant sections.

p	=	calculating pressure, in bar
D	=	nominal diameter, in mm
T	=	design temperature, in °C
c	=	corrosion margin, see Sec.4 B700
σ_t	=	nominal design stress at design metal temperature, in N/mm^2
R_m	=	specified minimum tensile strength at room temperature, in N/mm^2
R_{mt}	=	specified minimum tensile strength at design material temperature in N/mm^2
R_{eH}	=	specified minimum upper yield stress at room temperature, in N/mm^2. If the stress-strain curve does not show a defined yield stress, the 0.2% proof stress is to be applied
R_{et}	=	specified minimum lower yield stress at design material temperature in N/mm^2. If the stress-strain curve does not show a defined yield stress, the 0.2% proof stress is to be applied
$R_{m/100000}$	=	average stress to produce rupture in 100 000 hours at design material temperature in N/mm^2
$R_{p1.0}$	=	1.0% proof stress in N/mm^2.

B 300 Units

301 Unless otherwise specified the following units are used in this chapter:

- dimensions (lengths, diameters, thicknesses etc.): mm
- areas: mm^2
- pressures: bar
- mechanical properties of materials (ultimate tensile strength, yield strength etc.): N/mm^2.

B 400 Grading

401 For rule purposes, boilers and pressure vessels are graded in classes as shown in Table B1.

It may be required that a pressure vessel is manufactured in accordance with the requirements of a superior class when considering material, temperature, type of fluid, etc.

Pressure vessels containing toxic fluids are to be graded as class I pressure vessels.

402 Requirements for manufacturers, material certificates, testing and heat treatment for the different classes are indicated in Table B2.

Table B1 Grading of pressure vessels

Class	*Boilers*	*Steam heated steam generators*	*Other pressure vessels*	*Material limitations*
I	$p > 3.5$	$p > \frac{15000}{D_i + 1000}$	$p > 50$ 1) or $t > 38$	All grades permitted
II 2)	$p \leq 3.5$	$p \leq \frac{15000}{D_i + 1000}$	$\frac{20000}{D_i + 1000} < p \leq 50$ or $16 < t \leq 38$ or material design temperature > 150°C	Carbon and carbon-manganese and austenitic stainless steels 3) are to have a specified minimum tensile strength ≤ 520 N/mm^2
III 2)			Pressure vessels not included in class I and II Condensers, vacuum and atmospheric	Carbon and carbon-manganese and austenitic stainless steels 3) are to have a specified minimum tensile strength < 460 N/mm^2

p = design pressure in bar, D_i = internal diameter in mm, t = shell thickness in mm.
Cargo process vessels for liquefied gas carriers are graded as class I pressure vessels.

1) Pressure vessels not containing compressible fluids, fluids with flashpoint below 100°C or fluids with temperature above 220°C may be graded as class II pressure vessels even if p > 50 bar.

2) Pressure vessels of class II and III which are calculated with higher joint efficiency factor for welds than the values listed for the class of vessels, and have scantlings appropriate to a superior class, may be approved for the superior class if the manufacturing and testing are carried out according to the requirements of that class.

3) For materials other than carbon and carbon-manganese and austenitic stainless steels, the limitations for use in class II and III pressure vessels will be specially considered, taking into account the weldability of the materials.

Table B2 Requirements to different classes of pressure vessels.

Class	*Approved manufacturer* Sec.8 A101	*Material certificates*	*Visual and dimensional inspection*	*Welding procedure qualification* Sec.8 A102	*Non-destructive testing* Sec.8 D100	*Heat treatment*	*Welding production tests* Sec.8 D400	*Hydraulic test* Sec.8 D500
I	Required	See Sec.2 A103	Required	Required	Required	See Sec.8 C	Required	Required
II	Required	See Sec.2 A103	Required	Required	Spot required	See Sec.8 C	Required for t ≥ 16 mm	Required
III		See Sec.2 A103	Required					Required

C. Documentation

C 100 General

101 The control and monitoring system for the following shall be submitted for approval by the Society:

— boilers
— thermal-oil installations
— incinerators
— oil fired water heaters.

For requirements to documentation, see Ch.9.

C 200 Boilers and pressure vessels

201 The following plans are to be submitted for approval:

— arrangement plan including arrangement of valves and fittings
— dimensional drawings.

202 The plans are, as far as applicable, to give particulars on:

— scantlings
— grade of material
— welding procedure specification
— welded connections
— attachments and supports
— design pressure and temperature
— calculating pressure
— heating surface of boiler and superheater
— estimated pressure drop through superheater
— estimated evaporation
— proposed setting pressure of safety valves on steam drum superheater, and economiser
— pressure vessel class
— information on heat treatment and testing of welds
— hydraulic test pressure
— overpressure protection for condensers.

203 Together with the plans strength calculations are to be forwarded for information.

204 For class III pressure vessels intended for water and lubricating oil, plans need not be submitted for approval if the temperature of the fluid is less than 95°C.

In such cases, certification is to be based on visual inspection, review of materials certificates and pressure testing.

C 300 Thermal-oil installations

301 The following plans are to be submitted for approval:

— schematic piping diagram
— arrangement for fire protection and fire extinguishing in the heater furnace and in the heater vicinity.

The following plans are to be submitted on request:

— calculations of maximum temperature of oil film in the furnace tubes (the calculations are to be in accordance with a recognised standard, for example DIN 4754)
— material for evaluation of test results.

302 The plans are to give particulars on:

- design pressure and design temperature

- materials used
- specification with all relevant data for the applicable thermal-oils
- details of flange connections with gaskets and packing arrangements for valve spindles and pump shaft seals
- details of welded connections, welding procedures and filler materials.

303 The following plans are to be submitted for information:

- cross section of the heater
- arrangement plan of the heater showing valves and fittings
- manuals for operation and maintenance of the plant, also including detail instructions for starting up, emptying, dehumidifying and recharging.

C 400 Incinerators

401 The following plans are to be submitted for approval:

- arrangement showing location of incinerator and smoke-uptake
- cross sections of incinerator
- schematic piping diagram.

D. Seamless Gas Cylinders

D 100 Certification

101 Seamless gas cylinders are to be certified by the Society. Certification can be based on a standard recognised by the Society when the cylinder is designed, manufactured and tested in accordance with the standard.

Guidance note:
Some of the standards recognised by the Society are BS 5045/Part 1, JIS B 8241, TRG 801, 84/525/EEC or ISO 4705.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

The following information or documentation is to be submitted:

- fully dimensioned drawings of cylinders and fittings
- design calculations
- name of gases
- volumetric capacity
- filling pressure at 15°C for permanent gases
- filling ratio for liquefied gases
- test pressure, corrosion allowance and heat treatment
- material specification (steel making process, chemical composition and mechanical properties)
- copies of prototype test reports as required by standard
- service application.

E. Signboards

E 100 General

101 Signboards are required by the rules in:

Sec.3 A500 — Purging of boilers before firing.
Sec.3 B700 — Thermal-oil installations.

SECTION 2
MATERIALS

A. Material Requirements

A 100 General

101 Materials for boilers and pressure vessels and thermal-oil heaters together with their valves, fittings, etc. are to meet the requirements given in the relevant chapters and sections of Pt.2.

102 Materials used in cargo process pressure vessels on liquefied gas carriers are in addition to meet the requirements in the Rules for Classification of Ships Pt.5 Ch.5 Sec.2.

103 The materials used are to have certificates according to Table A1. For definition of the different types of certificates, see Pt.1 Ch.1 Sec.4 of the Rules for Classification of Ships.

Table A1 Certificates for materials

	Pressure vessel class	
	I and II	III
Plates	NV 1)	W
Pipes and flanges	W	W
Bolts	TR	TR

1) For plate heat exchangers, the end plates can be accepted with material works certificates (W).

104 For valves and fittings, requirements for certificates and certification are specified in Ch.6 Sec.6 C300 of the Rules for Classification of Ships.

A 200 Boilers and pressure vessels

201 Rolled steels for boilers and pressure vessels designed for material temperatures not lower than 0°C are to comply with the specifications given in Pt.2 Ch.2 Sec.2 B.

Semi-killed, fully killed and fine grain, normal strength structural steels complying with the specifications given in Pt.2 Ch.2 Sec.1 will, however, be accepted for the following class III pressure vessels:

— pressure vessels intended for water or lubricating oil if the fluid temperature is less than 95°C
— other pressure vessels where

$$p < \frac{15000}{D_i + 2000}$$

202 The steel grades NV 360-0A, 410-0A and 460-0A will be accepted only for class II and III pressure vessels with material thickness maximum 25 mm.

203 Steel grades complying with recognised national or proprietary standards with chemical composition and mechanical properties differing from the specifications referred to above, and with minimum specified tensile strength not exceeding 520 N/mm^2, may be accepted subject to approval in each case. In such cases the values of the mechanical properties used for deriving the allowable stress are to be subject to agreement by the Society.

204 Materials for pressure vessels designed for material temperatures below 0°C are subject to approval in each case.

205 Grey cast iron is in general not to be used for the following:

— class I and II pressure vessels
— class III pressure vessels where:

$$p > \frac{15000}{D_i + 2000}$$

— pressure vessels containing toxic fluids and fluids with a flash point below 100°C.

However, for bolted heads, covers or closures not forming a major part of the pressure vessel, grey cast iron may be used for $p \leq 10$ bar.

The use of grey cast iron in economisers will be subject to special consideration.

206 Nodular cast iron for ordinary use, Pt.2 Ch.2 Sec.8, Table B1, is in general subject to the limitation of use as grey cast iron as specified in 205.

207 Nodular cast iron with special requirements, Pt.2 Ch.2 Sec.8, Table B1, is not to be used for temperatures exceeding 350°C.

A 300 Valves and fittings

301 Valves and fittings made of cast and forged carbon and carbon-manganese steel may be used for temperatures up to 400°C. Application for higher temperatures may be approved if metallurgical behaviour and time-dependent strength, $R_{m/100000}$, are in accordance with national or international standards and if such values are guaranteed by the steel manufacturer. Otherwise, special heat-resisting alloy steels are to be used.

302 Valves and fittings in grey cast iron may be used when the design pressure does not exceed 2 bar and the design temperature does not exceed 120°C.

303 Nodular cast iron for ordinary use, Pt.2 Ch.2 Sec.8, Table B1, is in general subject to the limitation of use as grey cast iron specified in 302.

304 Nodular cast iron with special requirements, Pt.2 Ch.2 Sec.8, Table B1, is not to be used for temperatures exceeding 350°C.

305 Valves and fittings made of bronze are in general not to be used for temperatures exceeding 220°C. However, special bronze suitable for high temperature service may be considered for use at temperatures up to 260°C.

A 400 Thermal-oil installations

401 Tubes and pipes for thermal-oil are to be seamless steel tubes and pipes or welded steel tubes and pipes which are approved as equivalent to seamless types.

402 Pump housings, valves and fittings are to be of steel or nodular cast iron, grade 1 or 2.

SECTION 3 ARRANGEMENT

A. Boilers and Pressure Vessels

A 100 Instruments

101 All oil-fired boilers are to be provided with instrumentation permitting local surveillance.

A 200 Inspection openings

201 Pressure vessels are to have openings sufficient in number and size for internal examination, cleaning and maintenance operations such as fitting and expanding of tubes.

Guidance note:
See Appendix A regarding number, type and locations of openings.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

202 Manholes are not to be less than 300 x 400 mm or 400 mm in inside diameter. Where the neck height of a manhole is excessive, the size of the manhole is to be suitably increased.

203 Detachable ends or covers and suitably located, removable pipe connections may be used as inspection openings.

204 For boilers see also Sec.5 H.

A 300 Drains

301 All pressure vessels are to be provided with drainage positioned at the lowest part.

A 400 Fuel oil supply

401 Manual rapid shut-off of fuel oil supply is to be possible locally at the boiler. This quick closing device is to be so arranged that reopening is possible only locally at the boiler.

402 For steam-atomising burners, and when steam blowing is used for cleaning of the burners, effective precautions are to be taken in order to prevent fuel oil from penetrating into the steam system.

403 If electric preheaters are applied, precautions are to be taken in order to prevent the temperature at the heating element from rising too high, if the flow stops.

A 500 Combustion air supply

501 The boiler is to be ensured a sufficient air supply during all working conditions. When the boiler is installed in the same room as other large air consumers, ventilation is to be arranged so that no disturbance in the air supply to the boiler occurs.

502 At the operating stations for the boilers there are to be placed a readily visible signboard with the following instructions:

CAUTION!
NO BURNER TO BE FIRED BEFORE
THE FURNACE HAS BEEN PROPERLY PURGED

503 Oil-fired boilers are in general not to have flaps or other arrangements which may interfere with the draught in funnels or uptakes.

A 600 Positioning

601 Boilers and pressure vessels are to be installed on foundations of substantial strength and in such a position that there is sufficient access for cleaning, examination and repair anywhere on the outside.

602 The clearance between boiler with uptake and tanks for fuel oil, lubricating oil and cargo oil and cargo hold bulkheads are to be adequate for free circulation of air to keep the temperature of the oil well below the flashpoint and to avoid unacceptable heating of the cargo.

Alternatively the tank surfaces and bulkheads are to be insulated.

Guidance note:
The following clearances are considered to be sufficient:

- Distance between fuel oil tanks or hold bulkheads to:
  - flat surfaces of boilers and uptakes: 500 mm
  - cylindrical surfaces of boilers and uptakes: 300 mm.
- Vertical distance from top of boiler to nearest deck: 1300 mm.
- For watertube boilers, distance between the tank top and the underside of the bottom of the combustion chamber space: 750 mm.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

603 If oil-fired boilers are placed in the engine casing or in the funnel, the arrangements are to be such that oil spray, in the case of leakage, will be intercepted and will not reach heated surfaces beneath. Coamings for stairs, pipe openings, etc. are to be of ample height.

The platforms are to be fitted with sufficient drains to a waste-oil tank in the double bottom. These drains are to be fitted in addition to those specified for drip trays of oil tanks and fuel-oil pump units.

B. Thermal-oil Installations

B 100 Installation

101 Oil fired thermal-oil heaters are normally to be located in separate rooms. The arrangement is to provide easy access to all parts of the plant for operation, inspection, maintenance and cleaning.

102 If oil fired thermal-oil heaters are not located in separate rooms they are to be surrounded by coamings of height not less than 150 mm and with drainage to a closed tank.

103 Oil fired thermal-oil heaters installed in separate rooms are to comply with the requirements for incinerators for waste products as given in C102.

104 Oil piping in the exhaust fired thermal-oil heater area is to be so arranged that spray or drip from detachable pipe and valve connections can neither reach the heater and exhaust ducts nor flow to the engine room below.

105 Thermal-oil piping is to be installed so as to provide sufficient flexibility to accommodate thermal expansion. The use of bellows or similar expansion elements in thermal-oil piping is not permitted within machinery spaces.

106 Thermal-oil pipes are to have welded connections, with the exception of flange connections required for the servicing of system components. The requirements for NDT of welded joints for thermal oil piping can be found in the Rules for Classification of Ships Pt.4 Ch.6 Sec.7 A500.

B 200 Circulation system

201 Arrangements are to be made to ensure a minimum circulation through the heater in case consumers are shut-off. Such arrangements are to be automatically operated.

202 Each circulation system is to have a minimum of two circulation pumps. One pump is to be in continuous operation, the other in auto stand-by. Starting of the stand-by pump is to be initiated by the dropping out of the contactor for the pump in operation.

203 For heating of liquid cargoes with flashpoint below 60°C, see the Rules for Classification of Ships Pt.5 Ch.3 Sec.4 D.

204 The oil fired heater main inlet and main outlet pipes for thermal-oil are to have stop-valves, arranged for local and remote manual operation from an easily accessible location outside the heater room.

B 300 Control and monitoring system

301 Circulation pumps and heater burners are to be arranged for local start and stop and remote stop from an easily accessible location outside the thermal-oil heater room.

302 The heater regulation and the burner management are to be capable of ensuring that, under all operating conditions, the thermal-oil temperature at no place in the heater will exceed a temperature which would cause an unacceptable rate of deterioration of the thermal-oil.

303 For extent of monitoring see Sec.7 E.

304 For requirements for oil burner control system see Sec.7 A200.

B 400 Safety arrangements

401 The thermal-oil heater and heat exchangers in the system are to have liquid relief valves.

The relief set-point is not to be higher than 10% above maximum operating pressure. The relief pipes are to lead to a sludge tank.

402 The heater is to be so designed that release of internally stored heat in case of unintended stop of thermal-oil circulation pumps (e.g. black-out) will not cause the thermal-oil temperature to exceed the permissible level.

403 The plant arrangement is to ensure that the temperature of thermal-oil coming into direct contact with air will be below 50°C in order to prevent excessive oxidation.

404 Fast gravity discharge of the oil into a separate collecting tank is to be possible.

405 The expansion tanks are to have overflow pipes leading to the collecting tank. The discharge valve is to be arranged for remote operation from the machinery central control position.

406 System tanks and vessels where water may accumulate, are to be arranged with drain cocks.

407 All vent pipes are to be led to open deck and are to be arranged with drainable water traps at the lowest points.

408 Drip trays with drains to a waste oil tank are to be arranged under all plant components where leakage may occur.

409 The boiler furnace is to be fitted with a fixed fire-extinguishing system, subject to approval. Manual release is to be arranged locally and remote.

B 500 Insulation and shielding

501 All insulation is to be covered with an outer barrier, which shall be impervious to liquid. In areas and locations where pipes may be exposed to mechanical impact, the outer barrier is to be made of galvanised steel plates or aluminium plates of sufficient impact strength to resist deformations from normal wear and strain.

502 The arrangement of pipes and components is to provide sufficient space for satisfactory insulation installations. Flanged pipe connections are to have installed effective detachable shielding, which will prevent oil leakage from reaching potential danger areas.

B 600 Exhaust-fired thermal-oil heaters

601 The heater is to be so designed and installed that all tubes may be easily and readily inspected for signs of corrosion and leakage.

602 The heater shall be fitted with temperature sensor(s) (exhaust gas side) with an alarm for fire detection.

603 The thermal-oil heater shall be arranged with the possibility for bypassing the exhaust by means of damper(s).

The dampers will not be accepted as a means for controlling the temperature of the thermal-oil heaters.

The bypass may be internal or external to the heater. In either case, the arrangements are to be such that fire extinguishing in the heater is possible without stopping the propulsion of the vessel.

Guidance note:
For heaters with smooth surface heater tubes. Temperature control by means of exhaust gas dampers may be accepted on the condition that it can be shown that a minimum gas velocity of 12 m/s through the heater is maintained, throughout the control range.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

604 A fixed fire extinguishing and cooling system shall be fitted. A drenching system providing copious amounts of water may be accepted. The exhaust ducting below the heater shall be arranged for adequate collection and drainage, to prevent water flowing into the diesel engine. The drain shall be led to a suitable location.

605 High temperature alarm(s) in the thermal oil outlet, from the heater, is to be fitted.

606 Soot cleaning arrangements are to be fitted in accordance with D200.

B 700 Test equipment and signboards

701 Cocks or valves for taking thermal-oil samples in a safe manner are to be arranged.

702 Notices are to be posted at the control stations of the circulating pumps stating that the pumps are to be in operation at least for 10 minutes after stop of burners.

703 Further notices are to state:

— plant manufacturer
— year installed
— maximum operating pressure
— maximum operating temperature
— maximum thermal output.

C. Incinerators

C 100 General

101 Incinerators and boilers for sludge oil may be installed in the engine room or in a separate room. Incinerators for rubbish installed in the engine room are to be screened with due attention to size and location of the incinerator. If incinerators are installed in a separate room outside the engine room, bulkheads and decks of this room are to be approved «A» class divisions having an insulating value of 60 minutes (as defined in SOLAS 1974) if adjacent to accommodation, oil tanks, cargo, etc.

102 If incinerators are installed in a separate room, the room is to have mechanical ventilation, automatic fire detecting and an approved fixed fire-extinguishing system, operated from an easily accessible place outside the room. Stop of ventilation, oil-burner and oil-booster pumps is also to be arranged outside the room. Ventilating ducts are to be possible to close by means of flaps.

103 Incinerators are to be fitted with a pilot-burner with sufficient energy to secure a safe ignition and combustion is to take place under a pressure which is below atmospheric pressure.

104 The fire door for rubbish is to be arranged so that back-firing from the combustion chamber is prevented.

105 The rubbish-shoot is to be provided with approved fire-extinguishing equipment.

106 The surface temperature of the incinerator is not to exceed 60°C.

107 Drip tray with drain to the sludge-oil tank is to be fitted.

108 Smoke-uptakes and surfaces of incinerators are not to be less than 500 mm from cargo, oil tank, or accommodation bulkheads. Smoke-uptake and exhaust-pipe are to be insulated and are to be carried well away from electrical and inflammable installations. Exhaust pipes in the casing are to be led to the top of the funnel. Uptakes from incinerators, which are installed in separate rooms outside the engine room, are to be approved in each case.

D. Exhaust Gas Boiler or Economisers

D 100 Circulation systems

101 One stand-by pump is required when forced circulation is necessary for operation of the boiler or economiser.

D 200 Soot-cleaning arrangement

201 Water tube exhaust gas boilers or economisers of a design where soot deposit may create a problem regarding fire hazard, e.g. exhaust gas boilers with extended surface tubes are to have a soot-cleaning arrangement for use in the operation mode. In such cases, the soot cleaners are to be equipped with automatic start and arranged for sequential operation and possibility for manual over-ride.

Guidance note:

For extended surface tubes, soot deposits may create a problem when exhaust gas velocity is less than 12 m/s at normal operating condition.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

202 Exhaust gas collecting pipes are to be provided with drain. The drainage system is to be capable of draining all water when the water washing or water fire extinguishing system in the exhaust gas boiler or economizers are in operation.

Necessary protection is to be made, so that water can not enter into any of the engines.

The drainage is to be led to a tank of suitable size.

SECTION 4
GENERAL DESIGN REQUIREMENTS

A. General

A 100 Application

101 The requirements in this section apply to pressure vessels under internal pressure and subjected mainly to static loadings.

102 Where fatigue is considered to be a possible mode of failure, fatigue calculations may be required. The calculations may be carried out according to a recognised pressure vessel code.

103 Pressure vessels subjected to external pressure, except furnaces, fireboxes and uptakes (see Sec.5), are to be calculated according to the Rules for Classification of Ships Pt.5 Ch.5 Sec.5, items I700 and I800.

104 Parts of pressure vessels not covered by these rules, e.g. flanges, bolts and tube plates in heat exchangers, or having geometrical properties outside the limits of application of the calculating formulae, are to be designed and calculated according to a recognised code.

In general the nominal design stress is not to exceed that given in B500.

The allowable stresses for the bolts are to be as specified in the recognised code.

105 The rules do not take into account thermal stresses. It is a condition for approval that the thermal stresses are accounted for by a sufficiently flexible construction and a sufficiently slow heating up and cooling down period.

In special cases an analysis of thermal stresses may be required.

106 For terms used in stress analysis, equivalent stress and stress limits, see the Rules for Classification of Ships Pt.5 Ch.5 Sec.5 G.

107 Where parts of pressure vessels cannot be calculated with satisfactory accuracy and if empirical data are insufficient, strain gauge measurements and/or hydraulic proof test may be required.

Information on test pressure, testing method and results obtained is to be submitted for approval.

B. Design Criteria

B 100 Design pressure

101 The design pressure, p_d, is defined as the pressure at the top of the pressure vessel and is not to be less than the highest nominal set pressure of the safety valve(s).

The design pressure is not to be less than the maximum allowable working pressure.

Guidance note:

It is advised that a suitable margin should be provided above the pressure at which the pressure vessel will normally be operated to avoid unnecessary lifting of the safety valve(s).

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

B 200 Calculating pressure

201 The calculating pressure, p, is the pressure used for the purpose of determining the thickness of the vessel section or component under consideration.

202 The calculating pressure is normally to be taken as the design pressure with additional pressure due to static head of the fluid exceeding 3% of the design pressure.

The calculating pressure, p, is the greater of:

$$p_d \text{ and } p_d + \left(\frac{\rho g_0 h}{100} - 0.03 p_d\right)$$

ρ = density of fluid in t/m^3
g_0 = standard acceleration of gravity = 9.81 m/s^2
h = vertical distance from load point to top of pressure vessel in m.

203 In special cases, see note, the calculations are also to be carried out with a calculating pressure taking dynamic loads due to the ship's motions from wave actions into account.

The calculating pressure is to be:

$$p = p_d + \left[\frac{\rho g_0 h}{100}\left(1 + \frac{a_v}{g_0}\right) - 0.03 p_d\right]$$

a_v = the most probable largest combined vertical acceleration in 10^8 wave encounters (probability level $Q = 10^{-8}$).

Values for a_v may be as given in the Rules for Classification of Ships Pt.3 Ch.1 Sec.4 B600.

When this calculating pressure is used a 15% increase in the nominal design stress as given in 500 will be permitted.

Guidance note:

The above calculating pressure may be determining for the scantlings of large vertical low pressure storage tanks, e.g. bulk mud and cement tanks.

Tanks for liquefied gases are to meet the requirements in the Rules for Classification of Ships Pt.5 Ch.5.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

B 300 Other loadings

301 In the design of a pressure vessel it may be necessary to take into account the effect of the following loadings in addition to the calculating pressure:

— additional loads due to pressure testing
— loadings from supports and connected piping
— loadings from different thermal expansion
— fluctuating pressure and temperatures
— shock loads due to water hammer or surging of vessel's content.

Guidance note:

The effect of loadings from supports and connected piping on the shell may be calculated according to PD 5500, Appendix A and G.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

B 400 Design material temperature

401 The design material temperature is defined as the temperature in the middle of the shell thickness. Generally the design material temperature is not to be taken less than the maximum temperature of the internal fluid.

402 For boilers the design material temperature is made up of a reference temperature and a temperature allowance in accordance with the Table B1 unless a lower temperature is justified by detailed calculations. The design material temperature is, however, not to be taken less than 250°C.

For furnaces, fireboxes and other pressure parts subjected to similar rates of heat transfer, the reference temperature is to be the saturation temperature at design pressure of the internal fluid and the temperature allowance is not to be less than 4 times the material thickness plus 15°C.

For economiser tubes the reference temperature is to be the maximum temperature of the internal fluid and the temperature allowance is not to be less than 35°C for finned tubes and 25°C for plain tubes.

403 By unheated parts for superheated steam the temperature allowance of 15°C may be reduced to 7°C provided that special measures are taken to ensure that the design material temperature is not exceeded.

404 Drums and headers of thickness exceeding 30 mm are not to be exposed to combustion gases having an anticipated temperature exceeding 650°C, unless they are efficiently cooled by closely arranged tubes accommodated therein.

B 500 Nominal design stress

501 For carbon, carbon-manganese and low-alloy steels the nominal design stress, σ_t, is defined as the lowest of the following values:

For pressure vessels operating at a temperature up to and including 50°C:

$$\frac{R_{eH}}{1.8} \text{ and } \frac{R_m}{2.7}$$

For pressure vessels operating at a temperature higher than 50°C:

$$\frac{R_{eH}}{1.8}, \frac{R_{et}}{1.6}, \frac{R_m}{2.7} \text{ and } \frac{R_{m/100000}}{1.6}$$

502 For austenitic stainless steel the nominal design stress is defined as the lowest of

$$\frac{R_{p1,0}}{1.5} \text{ and } \frac{R_m}{2.7}$$

503 For steel castings the nominal design stress is limited to 80% of the value determined according to 501 or 502.

Where steel castings are subjected to non-destructive tests, consideration will be given to increase the nominal design stress up to 90% of the value determined according to 501 or 502.

504 For ferritic nodular cast iron with special requirements, Pt.2 Ch.2 Sec.8, Table B1, the nominal design stress is not to exceed 60% of the value determined according to 501.

505 For grey cast iron the nominal design stress is not to exceed $R_m/10$.

506 For copper alloys the nominal design stress is not to exceed $R_{mt} / 4$.

507 For aluminium alloys the nominal design stress is not to exceed the lowest value of:

$$\frac{R_{mt}}{4} \text{ and } \frac{R_{et}}{1.5}$$

508 Values for R_m, R_{eH}, R_{et}, $R_{p1,0}$ and $R_{m/100000}$ are given for different grades of rolled steel in Pt.2 Ch.2 Sec.2 and for steel tubes in Pt.2 Ch.2 Sec.4.

For steel tubes the design stresses at elevated temperatures are given in Ch.6 Sec.6 of the Rules for Classification of Ships.

Where other materials are proposed, the values of mechanical properties to be used for deriving the nominal design stresses are subject to consideration by the Society.

If higher values for R_{et} than given in Pt.2 Ch.2 Sec.2 are used for deriving the nominal design stress, the requirements given in Pt.2 Ch.2 Sec.2 B302 are to be complied with.

509 For boilers the nominal design stress is not to exceed 170 N/mm^2.

Guidance note:

The mechanical properties used for deriving the nominal design stress are specified minimum values according to the material specification. If higher values are measured in material tests, these may therefore not be used to determine the design stress.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

Table B1 Temperature allowances

Reference temperature	*Minimum temperature allowance*		
	Unheated parts	*Heated parts subjected mainly to:*	
		convection heat	*radiant heat*
Saturation temperature at design pressure	0°C	25°C	50°C
Superheated steam temperature	15°C See also 403	35°C	50°C

B 600 Shell thickness

601 The nominal thickness after forming of any shell or head is not to be less than:

For carbon and low-alloy steel:

$$3 + \frac{D_i}{1500} \quad \text{(mm)}$$

with a minimum of 7 mm for boilers.

For stainless steel and non-ferrous materials: 3 mm.

D_i = inside diameter of shell or inside diameter of cylindrical shirt for dished ends.

602 For pressure vessels where the cylindrical part is made of a pipe, a smaller minimum thickness may be approved.

B 700 Corrosion allowance

701 For carbon and low-alloy steels, the corrosion allowance, c, is in general 1.0 mm.

For austenitic steels, no corrosion allowance will in general be required.

Where adverse corrosion or erosion conditions exist a greater allowance may be required.

B 800 Tolerance and fabrication allowance

801 The calculated thicknesses according to the formulae are the minimum required.

Minus tolerance on wall thickness and a possible reduction in wall thickness due to fabrication, e.g. flanging or bending, are to be added to the calculated thicknesses.

For assessment of a design, e.g. reinforced openings or dished ends, the minus tolerance and fabrication allowance are to be deducted from the design wall thickness.

C. Scantlings of Shells and Flat and Dished Ends

C 100 Conditions

101 The formulae given in 200, 300 and 400 are based on the following conditions:

- The ratio of the outside radius to the inside radius does not exceed 1.5.
- In the case of shells consisting of sections of different thicknesses, the median lines of the sections are to be in line with each other at each longitudinal joint within the limits of tolerances specified in Sec.8 B300 (see Fig.1).

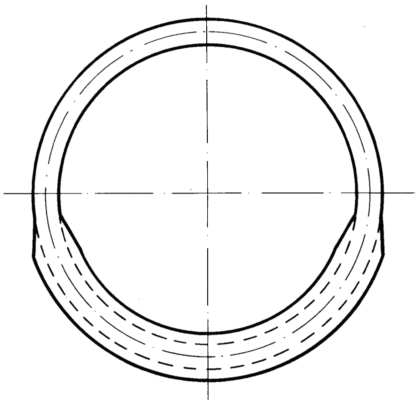


Fig. 1
Shell section

102 Joint efficiencies for l_{w1} welded joints, e, used in the formulae in 200, 300 and 400 are to be taken equal to:

- 1.00 for class I pressure vessels
- 0.80 for class II pressure vessels
- 0.60 for class III pressure vessels.

C 200 Cylindrical shells

201 The thickness of a cylindrical shell is not to be less than:

$$t = \frac{pR}{10\sigma_t e - 0.5p} + c \quad \text{(mm)}$$

R = inside radius of shell or shell section
e = joint efficiency as given in 102.

C 300 Spherical shells

301 The thickness of a spherical shell is not to be less than:

$$t = \frac{pR}{20\sigma_t e - 0.5p} + c \quad \text{(mm)}$$

R = inside radius of shell or shell section
e = joint efficiency as given in 102.

C 400 Conical shells of circular sections

401 The thickness of a conical shell is not to be less than:

$$t = \frac{pD_C}{20\sigma_t e - 0.5p}\,\frac{1}{\cos\alpha} + c \quad \text{(mm)}$$

D_C = internal diameter at the large end of the cone
α = the half apex angle of the section
e = joint efficiency as given in 102.

402 The formula in 401 applies only if the half apex angle α does not exceed 75° and the thickness t obtained is less than one sixth of the external diameter at the large end of the cone.

403 Conical shells may be constructed of several ring sections of decreasing thickness and the formula in 401 is to be applied to each section.

404 The thickness of the large end of a cone/cylinder or cone/cone junction and adjoining parts of the shells within a distance L from the junction is to be determined by the following formula:

$$t = \frac{pD_0 k}{20\sigma_t e} + c + c_1 \quad \text{(mm)}$$

D_o = outside diameter of the conical section, see Fig.2
e = joint efficiency (as given in 102) of junction or of circumferential welds located within a distance L from the knuckle, see Fig.2
L = length equal to:

$$0,5\sqrt{\frac{D_0(t-c)}{\cos\psi}} \quad \text{(mm)}$$

c_1 = 0 for $t - c/D_o \geq 0.005$
= 1 mm for $t - c/D_o < 0.005$
K = a factor taking into account the stress in the junction.

Values of K are given in Table C1 as a function of ψ and r_i/D_o, where:

ψ = difference between angle of slope of the adjoining parts
r_i = inside radius of transition knuckle in mm, which is to be taken as 0.01 D_C in the case of butt welded junctions.

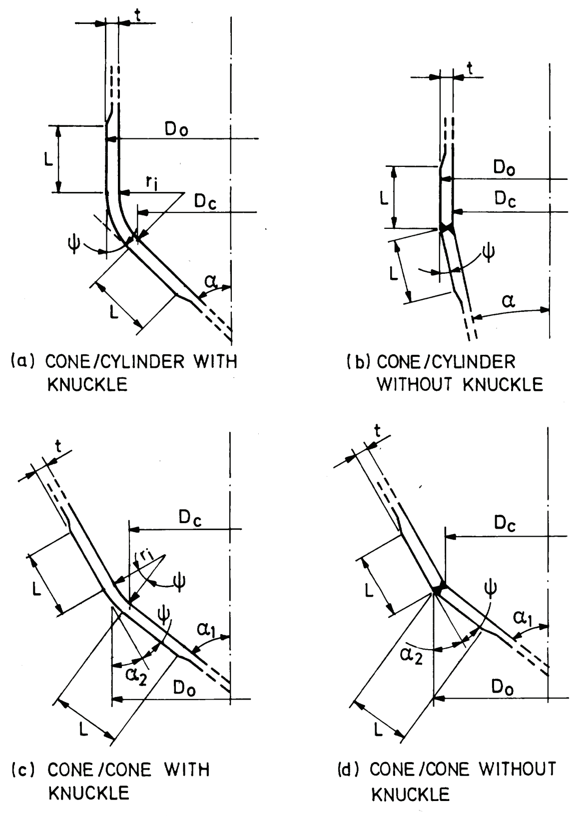


Fig. 2
Junction arrangements

The thickness of the junction or knuckle and the adjacent parts shall not be less than that for the cone determined by the formula in 401.

If the difference in angle of slope exceeds 30°, welded junctions are not permitted. In these cases, knuckle connections with a minimum inside radius r_i of 0.06 D_o are to be applied.

Table C1 Values of K as a function of ψ and r_i/D_o

ψ	*Values of K for r_i/D_o for ratios of*								
	0.01	*0.06*	*0.08*	*0.10*	*0.15*	*0.20*	*0.30*	*0.40*	*0.50*
10°	0.70	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
20°	1.00	0.70	0.65	0.60	0.55	0.55	0.55	0.55	0.55
30°	1.35	0.90	0.85	0.80	0.70	0.65	0.55	0.55	0.55
45°	2.05	1.30	1.20	1.10	0.95	0.90	0.70	0.55	0.55
60°	3.20	2.00	1.75	1.60	1.40	1.25	1.00	0.70	0.55
75°	6.80	3.85	3.50	3.15	2.70	2.40	1.55	1.00	0.55

405 The thickness of conical sections having a half apex angle of more than 75° is to be determined as for a flat plate.

406 Cone and cylinder forming a junction at the small end of a cone shall have the thickness of the adjoining parts determined by

$$t_r = M\,t \quad \text{(mm)}$$

M = a factor given in Fig.3 as a function of the ratio $p/\sigma_t\,e$
t = the thickness of the cylinder determined by the formula in 201.

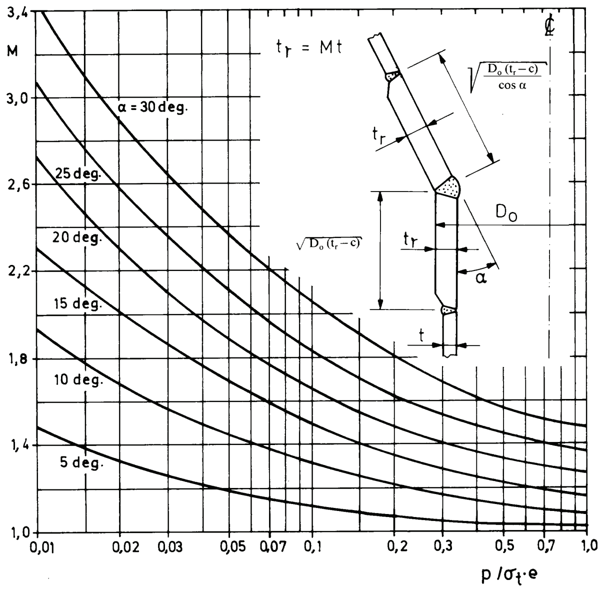


Fig. 3
Values of M for small end cone-cylinder junction

The above formula applies only for junctions with half apex angles of the cone less than 30°.

In no case is t_r to be less than the thickness for the cone determined by the formula in 401. The increased cylinder thickness t_r is to extend a minimum distance $\sqrt{D_0(t_r - c)}$ from the junction and the increased cone thickness t_r is to extend a minimum distance:

$$\sqrt{\frac{D_0(t_r - c)}{\cos\alpha}} \quad \text{(mm)}$$

from the junction.

407 Cone or cylinder connections at the small end of cones with half apex angles exceeding 30° are to be manufactured by means of knuckle transitions. The thickness of the knuckle will be considered in each case.

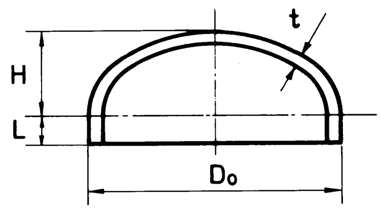


Fig. 4
Elliptical end

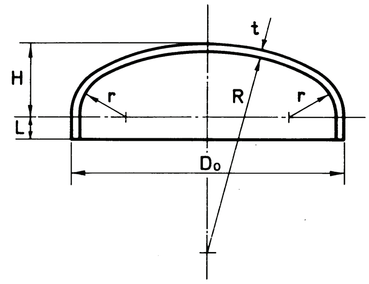


Fig. 5
Torispherical end

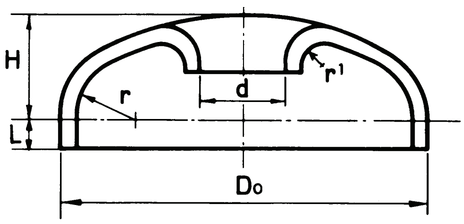


Fig. 6
End with opening

C 500 Dished ends

501 The thickness of dished ends without stays, concave to the pressure side, is not to be less than:

$$t = \frac{pD_0}{20\sigma_t e}K + c \quad \text{(mm)}$$

t = required end plate thickness after dishing
D_o = outside diameter of end plate, in mm
e = joint efficiency for welded joints, see 505
K = shape factor defined in 503.

The thickness t is not to be less than the thickness required for a seamless, unpierced, cylindrical shell of the same diameter and material, except where the end plate is a complete hemisphere.

The required thickness is to be obtained through an iteration process.

502 The formula in 501 applies to:

— hemispherical ends
— elliptical ends with $H \geq 0.2\ D_o$
— torispherical ends satisfying the following conditions:
$H \geq 0.18\ D_o$; $R \leq D_o$; $r \geq 0.1\ D_o$; $r \geq 3\ t$; $L \geq 2\ t$

H = outside height of the end, in mm, measured from the junction of the dished part with the cylindrical

shell
r = inside knuckle radius of torispherical ends, in mm
R = inside radius of spherical part of torispherical ends, in mm
L = length of the cylindrical part of the end, in mm.

See also Fig.4 and 5.

The formula in 501 is not valid for ends with openings exceeding $d/D_o = 0.5$ where:

d = diameter of opening, in mm.

See also Fig.6.

Guidance note:

The outside height of torispherical ends may be determined from the following formula:

$$H = R + t - \sqrt{(R-r)^2 - (D_0/2 - t - r)^2}$$

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

503 The shape factor K to be used in the formula in 501 is to be determined from the curves in Fig.7 depending on the ratio H/D_o as follows:

— Plain ends without openings or with openings reinforced in accordance with D300 or with small openings not requiring reinforcement according to D200, the shape factor K depends on the ratio $(t - c)/D_o$ as well as on the H/D_o ratio. The unbroken line curves are to be used and trial calculations may be necessary.
— For ends with unreinforced openings and for flanged openings, the shape factor is to be as given in Fig.7, depending on the ratio H/D_o and with:

$$\frac{d}{\sqrt{D_0(t-c)}}$$

as a parameter, where d is the diameter of the largest opening in the end plate (in the case of an elliptical opening, the larger axis of the ellipse).

In addition, the following conditions are to be satisfied:

$$\frac{t-c}{D_0} \le 0,1$$

K is not to be less than given for a plain end with the same $t - c/D_o$-ratio.

The radius r^1 of the flanging is not to be less than 25 mm. The thickness of the flanged portion may be less than the calculated thickness t. See Fig.6.

Guidance note:

In the case of ends containing only compensated openings, read K from full curves of $(t - c)/D = 0.002$ to $(t - c)/D = 0.04$ interpolating as necessary.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

Guidance note:

In the case of ends containing uncompensated openings, read K from the broken line curves $d/(\sqrt{Dt-c}) = 5.0$ to $d/(\sqrt{Dt-c}) = 0.5$ interpolating as necessary. In no case, K is to be taken as smaller than the value for a similar unpierced end.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

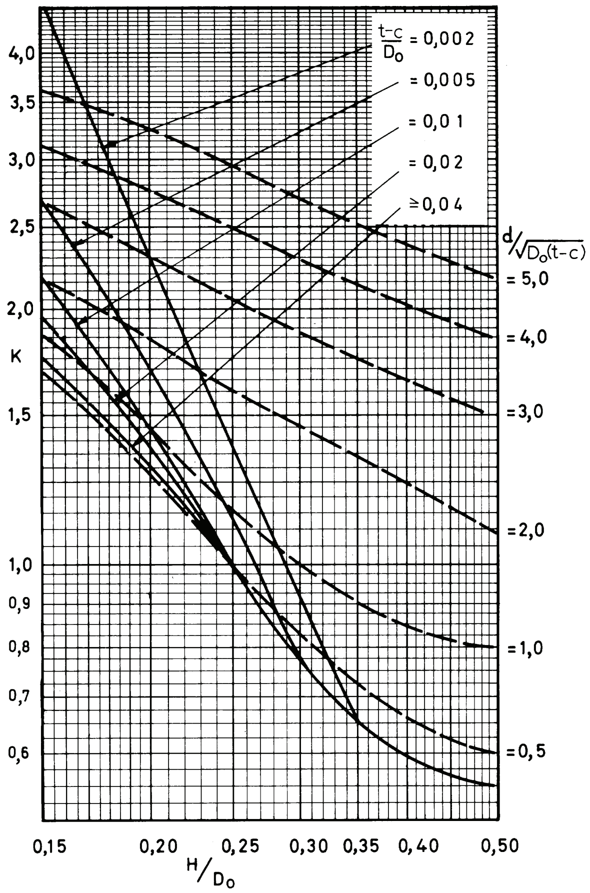


Fig. 7
Graph of shape factor K for dished ends

504 The thickness of dished ends without stays, convex to the pressure side is not to be less than:

$$t = \frac{p D_0}{16 \sigma_t e} K + c$$

t, D_o, e and K is defined in 501.

In addition the spherical section of the end is to be checked against elastic instability. The pressure, p_c, corresponding to elastic instability is to be determined from the following formula:

$$p_c = 2.4 \; E \left(\frac{t-c}{R}\right)^2$$

E = modulus of elasticity in N/mm^2 at design material temperature, see table in Sec.5 E107.

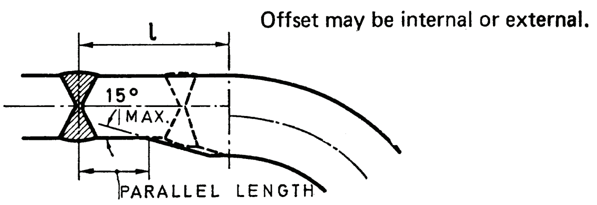
The design pressure is not to exceed:

$$p = \frac{p_c}{S_F}$$

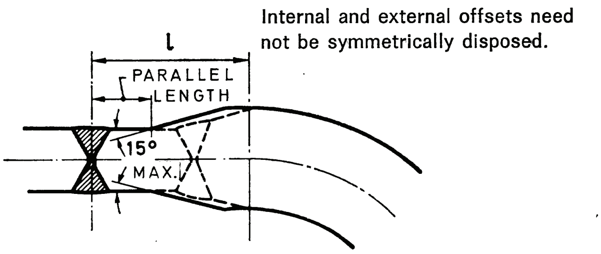
$S_F = 3.7$ for $\frac{t-c}{r} \le 0.001$

$S_F = 3$ for $\frac{t-c}{r} \ge 0.003$

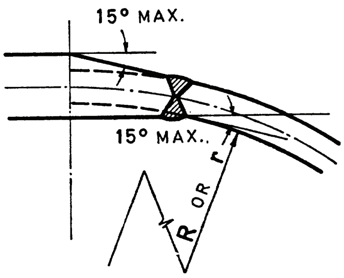
Intermediate values may be interpolated.



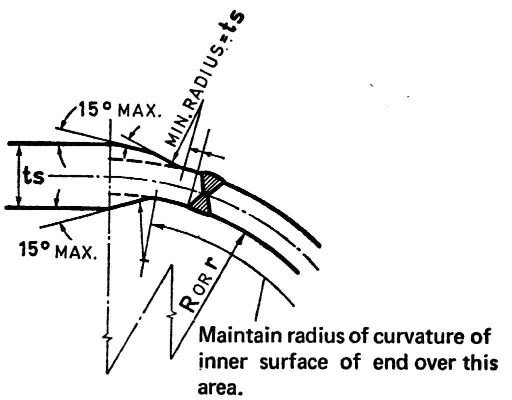
End thicker than shell, median planes offset



End thicker than shell, median planes approx. coinciding



End thinner than shell



End thinner than shell

Fig. 8
Dished ends — cylindrical shell connections

505 For torispherical and elliptical ends dished from one plate, e = 1.

For hemispherical ends, e is to be taken as given in 102.

For torispherical and elliptical ends made of welded plates, e is to be taken as given in 102, except that e = 1 may be used also for class II and III pressure vessels for welded seams situated within the area 0.6 D_o of the spherical part.

506 Examples of connections between dished ends and cylindrical shells are shown in Fig.8.

C 600 Unstayed flat end plates

601 The thickness of an unstayed flat end plate is to be determined by the following formula:

$$k \le \frac{14\sigma_t}{p}$$

k is a calculation factor depending upon $t_1 - c/t - c$ and $100\ (t_1 - c)/D_i$ where:

t = thickness of end plate, in mm
t_1 = thickness of cylindrical shell, in mm
D_i = inside diameter of cylindrical shell, in mm.

For determining k, see Fig.9.

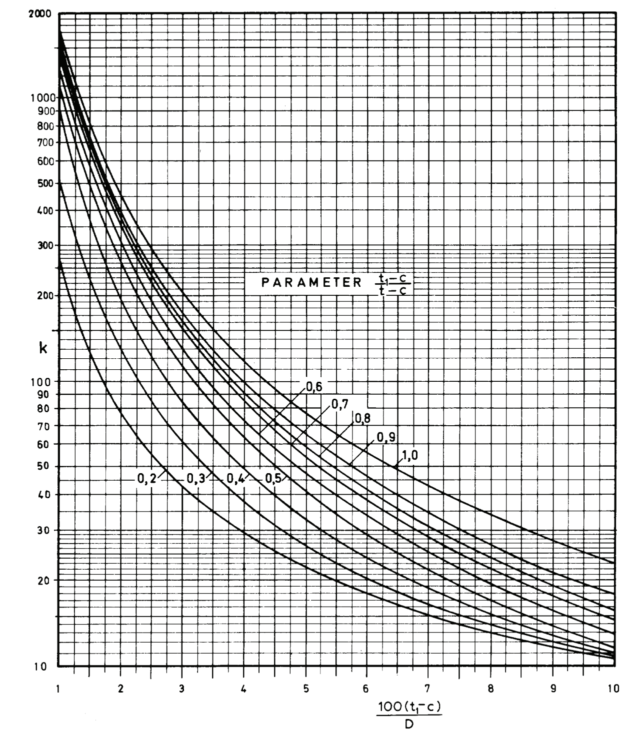


Fig. 9
Calculation factor K

602 The formula in 601 is based on the following conditions:

$$p \le 30 \text{ bar}$$

$$t_1 \le t \le 5\ t_1$$

Cases where p, t and t_1 are outside these limits, will be specially considered.

603 If t_1 is locally increased to obtain a reduction of t, the increased shell thickness is to extend at least a length $\sqrt{D_0(t_1 - c)}$ from the end plate, where D_o = outside diameter of cylindrical shell, in mm.

604 Examples of acceptable connections between flat end plates and cylindrical shells are shown in Fig.10.

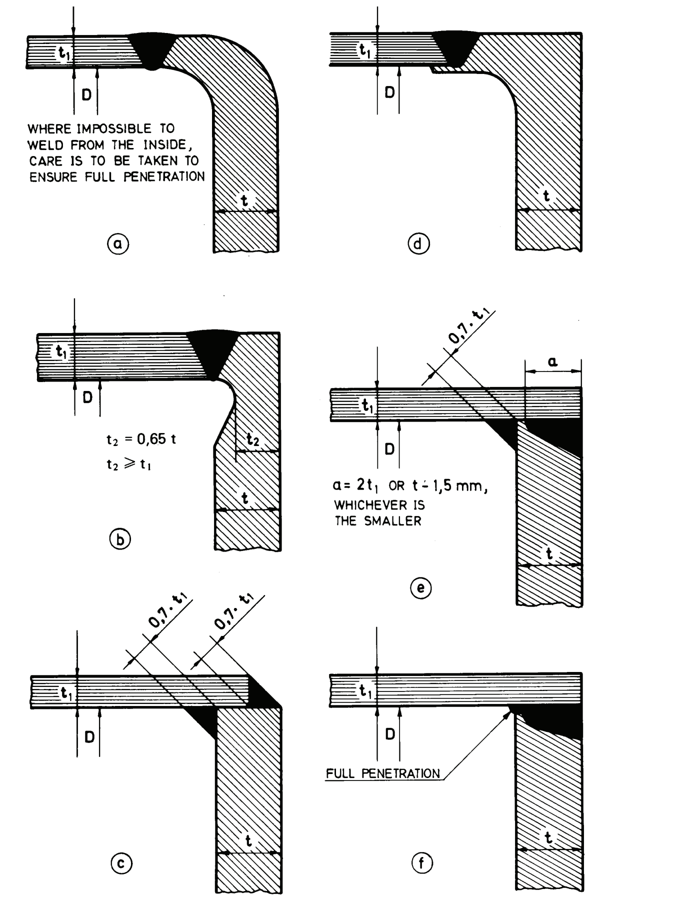


Fig. 10
Acceptable methods of attaching flat end plates to cylindrical shells

D. Openings and Compensations

D 100 General

101 The rules apply only when the following conditions are simultaneously satisfied:

- Openings are circular, elliptical or around with a ratio of major to minor inside diameters not exceeding 2.
- The axis of the branch is not having an angle with the normal to the shell greater than 15°.
- For cylindrical, conical and spherical shells:
  - the major inside diameter of the opening is not exceeding one third of the shell inner diameter.
- For dished ends:
  - the major inner diameter of the opening is not exceeding one half of the outside diameter of the end
  - the opening is so situated that in projection its outer extremity or that of its reinforcement is at least one tenth of the end external diameter from the outer surface of the cylindrical shell, see Fig.11
  - in case of multiple openings, the distance between the openings are to comply with the requirement in Fig.11.

102 The rules do not apply to multiple openings in cylindrical shells where the distance between the axes is less than 1.5 times the average diameter of the openings.

103 Openings not complying with the requirements in 101 and 102 will be subjected to special consideration.

Calculations according to a recognised code may be approved.

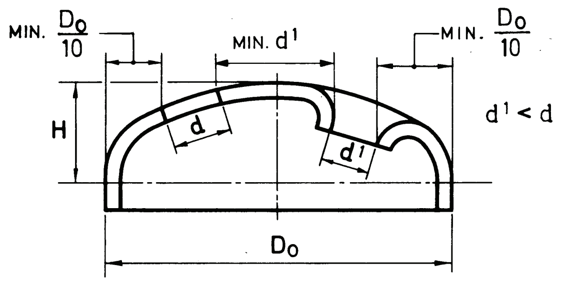


Fig. 11
Opening arrangement

D 200 Openings not requiring reinforcement

201 Reinforcements are not required for isolated openings provided:

$$d_i \leq 0.3\sqrt{(D_i + t_a)t_a}$$

with a maximum of 150 mm.

An opening is considered isolated if its centre is at a distance greater than:

$$d_a + 3\sqrt{(D_i + t_a)t_a}$$

from the centre of another opening.

D_i = the inner diameter of a cylindrical or spherical shell
= twice the inner radius of the spherical part of a tori-spherical end
= for semi-ellipsoidal ends, twice the inner radius of curvature at centre of head
= for a conical shell, twice the distance along the shell normal, from the point where the axis of the opening intersects the inner surface, to the shell axis
d_i = the inner diameter of the opening or branch for a circular opening and the chord length in the plane being considered for elliptical and obround openings
d_a = mean inner diameter of the two openings
t = thickness as calculated from the formula in C200, C300 or C400 using e = 1 and c = 0
t_a = actual thickness of the shell before corrosion allowance is added.

D 300 Openings requiring reinforcement

301 Openings not conforming with 200 are to be reinforced in accordance with 302 and 303.

302 On each side of the centre line of the opening the required area of reinforcement is:

$$K\left(\frac{d_i}{2} + t_b\right)t \qquad (mm^2)$$

t_b = thickness in mm of the branch calculated from the formula in Sec.5 G101 with c = 0. For elliptical or obround reinforcement rings the chord length in the plane being considered is to be used in determining t_b.

For d_i and t, see 201.

For openings fitted with an internal cover such that the bore is not subjected to pressure, the required area of reinforcement on each side of the opening is:

$$\frac{K\,d_i\,t}{2} \qquad (mm^2)$$

k = 1 for spherical shells and for planes passing through the generatrix for cylindrical and conical shells
= 0.7 for planes normal to the generatrix for cylindrical and conical shells.

Guidance note:

Generatrix is a line parallel to the centre line of the cylindrical or conical shells.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

For oval openings in cylindrical and conical shells the reinforcement is to be determined in a plane passing through the generatrix (Fig.12 a, K = 1) and in a plane normal to the generatrix (Fig.12 b, K = 0.7). For spherical shells the reinforcement is to be determined in a plane passing through the major diameter of the opening. All planes are to pass through the centre of the opening and are to be normal to the wall.

303 Only material located within the following limits will be accepted as reinforcement:

— For the shell, measured from the outer surface of the branch along the outer surface of the shell:

$$L_s = \sqrt{(D_i + t_a)t_a} \quad \text{(mm)}$$

— For the branch, and internal protrusion, if fitted, measured from the relevant surface of the shell:

$$L = 0.8\sqrt{(d_i + t_{ba})t_{ba}} \quad \text{(mm)}$$

The area A, available as reinforcement on each side of the centre line of the opening, is shown shaded in Fig.12.

When $t_a/D_i \leq 0.02$, two-thirds of the area of compensation required is to be at a distance less than:

$$d_i/2 + 0.35\sqrt{(D_i + t_a)t_a}$$

measured from the axis of the opening on the external surface of the shell.

The reinforcement is adequate if:

$$A \geq K\left(\frac{d_i}{2} + t_b\right)t \quad (\text{mm}^2)$$

t_{ba} = actual thickness in mm of the branch before corrosion allowance is added.

For D_i, d_i, t, t_a and t_b, see 201 and 302.

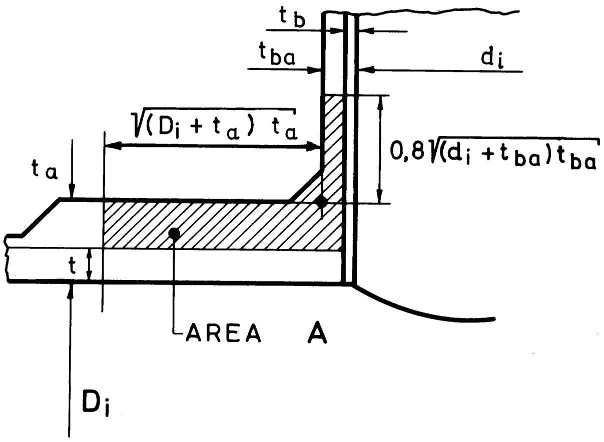
304 Where two openings or branches are sufficiently closed spaced for the limits of compensation in the shell to overlap, the limits of compensation is to be reduced so that no overlap is present.

305 Material in the reinforcement, or in a branch, is normally to have the same mechanical properties as that in the shell. In no case is the reinforcement, or the branch, to be made from a material having a nominal design stress less than 0.75 times the nominal design stress for the shell. Where material with a lower nominal design stress than that of the shell is used for reinforcement, its effective area is to be assumed reduced in the ratio of the nominal design stresses at design temperature.

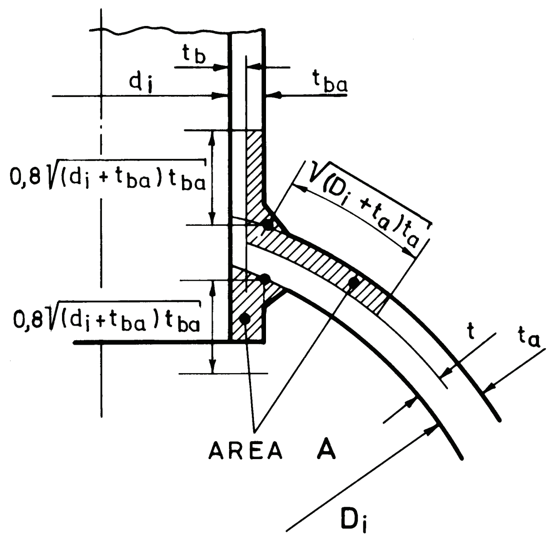
No reduction will be accepted for material with a nominal design stress greater than that of the shell.

306 Reinforcements, not in compliance with the requirements above may be approved if justified by a detailed calculation.

Additional reinforcement may be required where closing appliances can cause deformation of the shell.



a) Reinforcement area, K=1



b) Reinforcement area, K=0,7

Fig. 12
Reinforcement area

D 400 Minimum thickness of standpipes and branches

401 The wall thickness of standpipes and branches is not to be less than determined by Sec.5 G. Additional thickness may be necessary on account of loads from connected piping and vibrations.

For class I and II pressure vessels the nominal wall thickness of standpipes and branches is, however, not to be less than:

$$t = 0.04\, d_o + 2.5 \quad \text{(mm)}$$

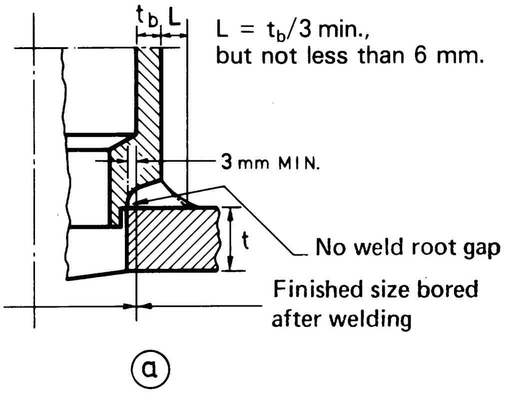
but need not be greater than the shell thickness.

d_o = outer diameter of the branch.

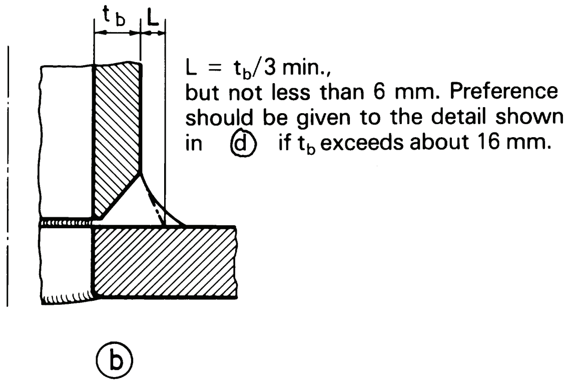
D 500 Welded branch connections

501 Acceptable welded branch connections are shown in Fig.13.

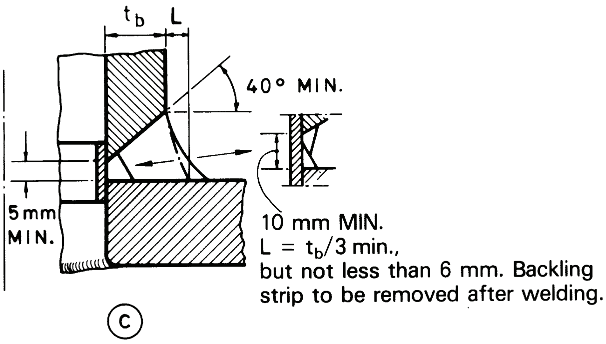
Alternative methods of attachment may be accepted provided details are submitted for consideration.



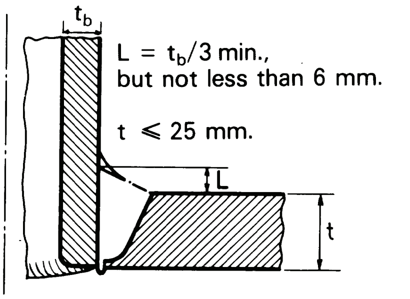
Generally used for small branch to shell diameter ratios



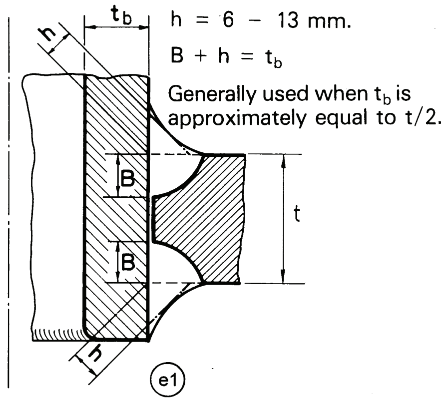
The welding procedure employed is to ensure sound root condition

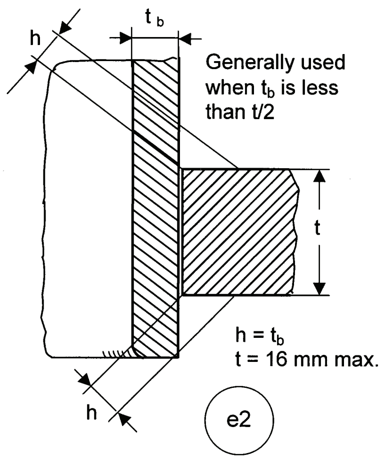


Single root run technique and double root run technique



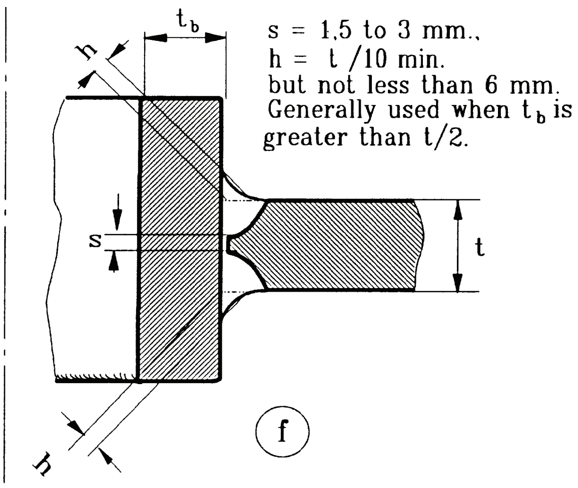
(d) The welding procedure employed is to ensure sound root conditions

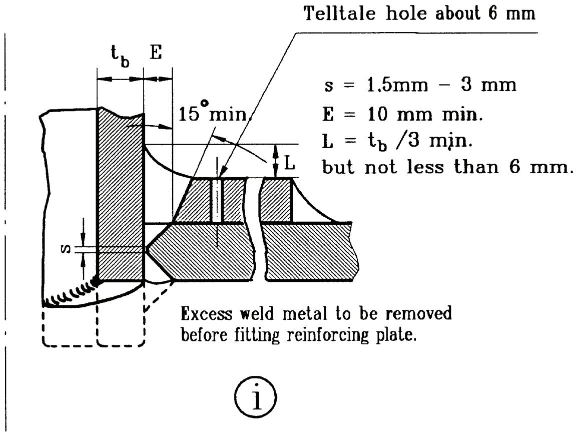


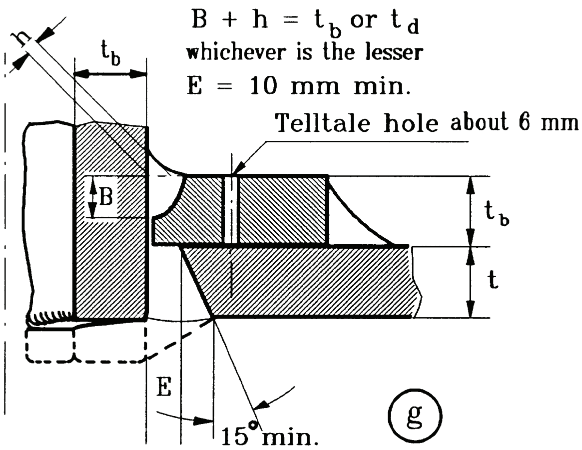


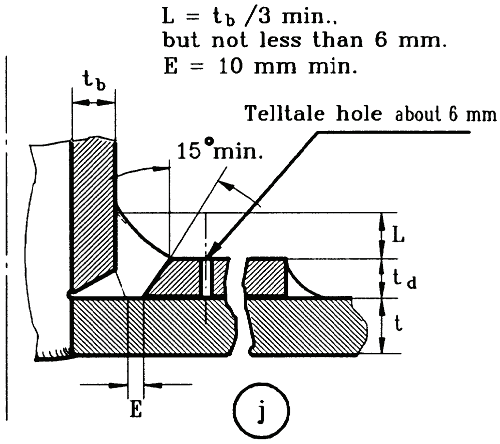
Notes to Fig.(e2):

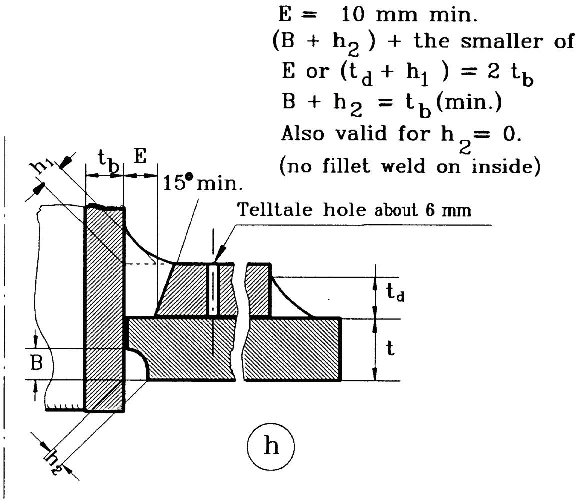
1) Fillet welds are not suitable in cases where there are fluctuating loads.
2) Weld detail (e2) is not to be used for openings that require reinforcement i.e. the required reinforcement for the openings is to be integrated in the shell plate.

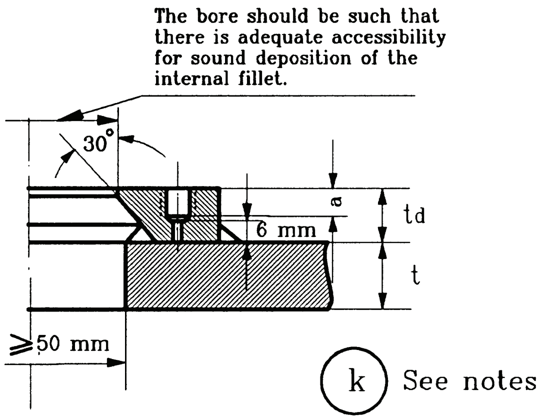

s = 1,5 to 3 mm.,
h = t /10 min.
but not less than 6 mm.
Generally used when t_b is
greater than t/2.
t_b
h
s
t
f

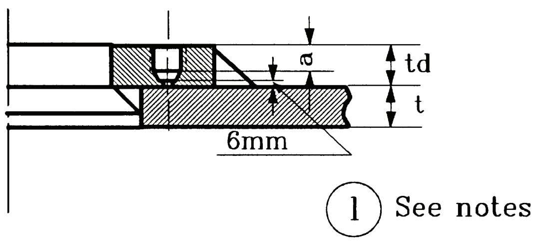

Telltale hole about 6 mm
t_b E
15°min
s = 1,5mm – 3 mm
E = 10 mm min.
L = t_b /3 min.
but not less than 6 mm.
L
s
Excess weld metal to be removed
before fitting reinforcing plate.
i


B + h = t_b or t_d
whichever is the lesser
E = 10 mm min.
Telltale hole about 6 mm
h
t_b
B
t
E
15°min.
g


L = t_b /3 min.,
but not less than 6 mm.
E = 10 mm min.
t_b
Telltale hole about 6 mm
15°min.
L
t_d
t
E
j


E = 10 mm min.
(B + h_2) + the smaller of
E or (t_d + h_1) = 2 t_b
B + h_2 = t_b(min.)
Also valid for h_2= 0.
(no fillet weld on inside)
h_1
t_b E
15°min.
Telltale hole about 6 mm
t_d
t
B
h_2
h


The bore should be such that
there is adequate accessibility
for sound deposition of the
internal fillet.
30°
a
6 mm
td
t
≥50 mm
k See notes


a
td
t
6mm
l See notes

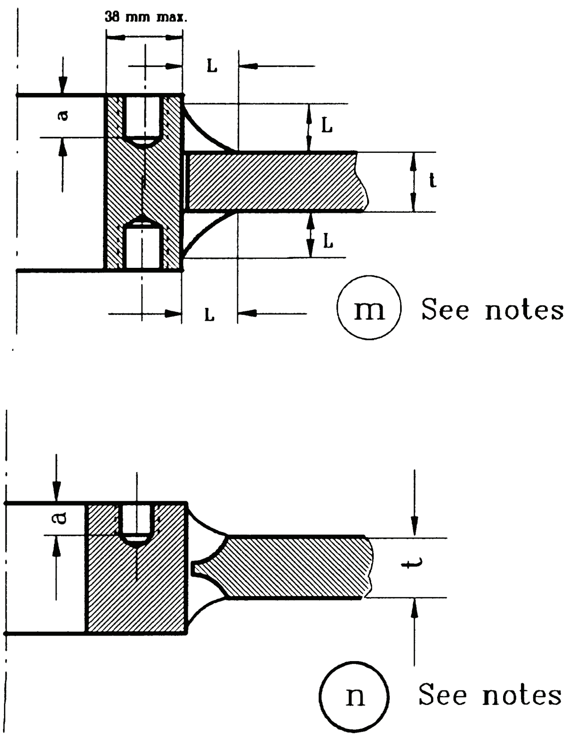


Fig. 13
Details of branch connections

Studded connections, weld details k, l, m and n are acceptable for use only on class II and III vessel with limitations as listed below.

1) Weld details k and l are only accepted for shell thickness up to 16 mm in carbon manganese steels with specified minimum tensile strength not exceeding 430 N/mm^2 and when design temperature of the vessel is maximum 120°C. Weld detail m is accepted on the same conditions, but only for shell thickness up to 10 mm.
2) Weld details k, l, and m are not to be used for openings which require reinforcement, i.e. the required reinforcement for the openings is to be integrated in the shell plate.
3) The size of fillet welds L as indicated, is to be equal to the smaller of t or t_d but not be less than 6 mm.
4) The threaded depth a is to not be less than diameter of screw or stud.

E. Covers for Inspection Openings and Manholes

E 100 General

101 The rules apply to flat circular and oval covers formed from steel plate and of the internal type, as shown in Fig.14.

102 The thickness is not to be less than:

$$t = b\sqrt{\frac{Cp}{10\sigma_t}} + c \qquad \text{(mm)}$$

minimum 15 mm for manhole covers

e = breadth of jointing surface, see Fig.14
a, b = longer and shorter half-axes in mm, as indicated in Fig.14
C = a coefficient given in Table E1.

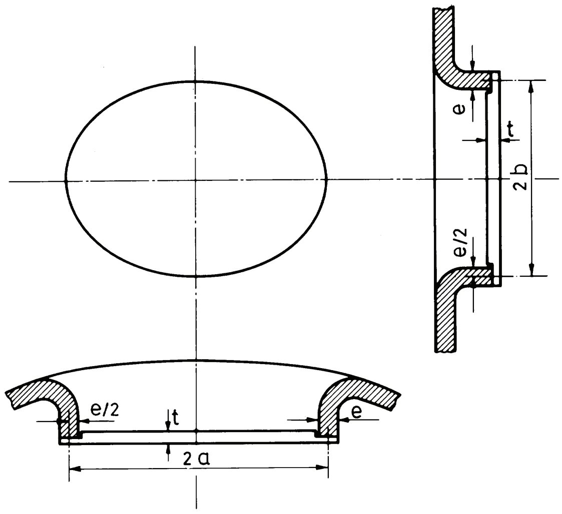


Fig. 14
Covers

Table E1 Coefficient C									
$\frac{a}{b}$	*1*	*1.1*	*1.2*	*1.3*	*1.4*	*1.5*	*2*	*3*	*4*
C	1.24	1.41	1.57	1.69	1.82	1.93	2.27	2.60	2.79

F. Heat Exchanger Tubes

F 100 General

101 The wall thickness of straight tubes is not to be less than:

$$t = \frac{pd}{20\sigma_t + p} + c$$

d = outside diameter
c = corrosion allowance.

102 The corrosion allowance is to be as follows, unless the conditions of service make a different allowance more suitable:

- Carbon and low-alloy steels: c = 1 mm
- Copper and copper alloys: c = 0.3 mm
- Stainless austenitic steels: c = 0 mm

103 If the tubes are ordered with a minus tolerance, the minimum thickness according to the formula is to be increased by the necessary amount.

Where tubes are bent, the thickness of the thinnest part of the tubes is not to be less than the calculated thickness, unless it can be demonstrated that the method of bending results in no decrease in strength at the bend as compared with the straight tube.

In connection with any new method of bending, the manufacturer is to prove that this condition is satisfied.

104 The nominal wall thickness of heat exchanger tubes (unfinned) is in general not to be less than given in Table F1.

Table F1 Nominal wall thickness			
Outside diameter mm	*Minimum nominal wall thickness, mm*		
	Copper and copper alloys	*Carbon steel*	*Austenitic steel*
10	0.7		0.7
12	0.9		0.9
16	0.9	1.2	0.9
19	1.2	1.5	0.9
25	1.5	2.0	1.2
32	1.5	2.0	1.5
38	2.0	2.0	1.5
51	2.0	2.0	2.0

SECTION 5
PARTICULAR DESIGN REQUIREMENTS FOR BOILERS

A. Shells and Headers of Cylindrical Sections

A 100 Scantlings

101 The thickness of cylindrical shells is to be determined in accordance with the requirements in Sec.4.

For drums and headers in watertube boilers, the joint efficiency factor e is to be taken as the efficiency of the ligaments between tube holes, in accordance with 200.

For shell boilers where set-in end plates are used, see Fig.8, the thickness of the shell plates within a distance 250 mm from the end plate is, however, not to be less than determined from the following formula:

$$t_1 = \frac{pR}{10\sigma_t X - 0.5p} + c$$

R = inside radius of shell or shell section
X = 0.8 for $t_2/(t_1 - c) \geq 1.4$
= 1.0 for $t_2/(t_1 - c) \leq 1.0$
t_2 = calculated thickness of end plate at the junction with the shell without corrosion allowance.

For intermediate values of $t_2/(t_1 - c)$ the values of X is to be found by linear interpolation.

The required shell thickness is to be obtained through an iteration process.

102 The nominal thickness of a boiler shell is not to be less than 7 mm.

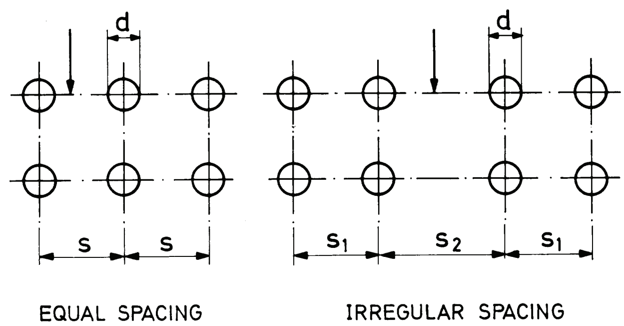


Fig. 1
Parallel drilling

A 200 Efficiency of ligaments between tube holes

201 When drilling holes parallel to the axis, the efficiency e of ligament is given by:

$$e = \frac{s - d}{s} \text{ for eqal spacing for holes, and}$$

$$e = \frac{s_1 + s_2 - 2d}{s_1 + s_2} \text{ for irregular spacing of holes}$$

d = mean effective diameter of the tube holes, after allowing for any counterboring or recessing, in mm. For compensating effect of tube stubs, see 301
s = pitch of tube holes in mm
s_1 = the shorter of any two adjacent pitches, in mm
s_2 = the longer of any two adjacent pitches, in mm.

For irregular spacing, the value of the double pitch ($s_1 + s_2$), giving the lowest efficiency, is to be applied. The value of one pitch is in no case to be taken as being greater than twice the other pitch.

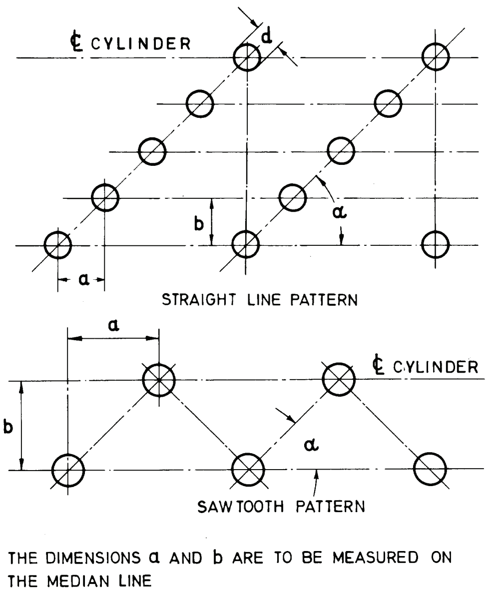


Fig. 2
Diagonal drilling

202 Provided that the spacing between holes, in the case of a circumferential drilling, gives an efficiency of ligaments, calculated according to the formulae in 201, less than one half of the efficiency of longitudinal ligaments, twice the efficiency of circumferential ligaments is to be used. The pitch of tubes for circumferential drilling is to be measured along the median line.

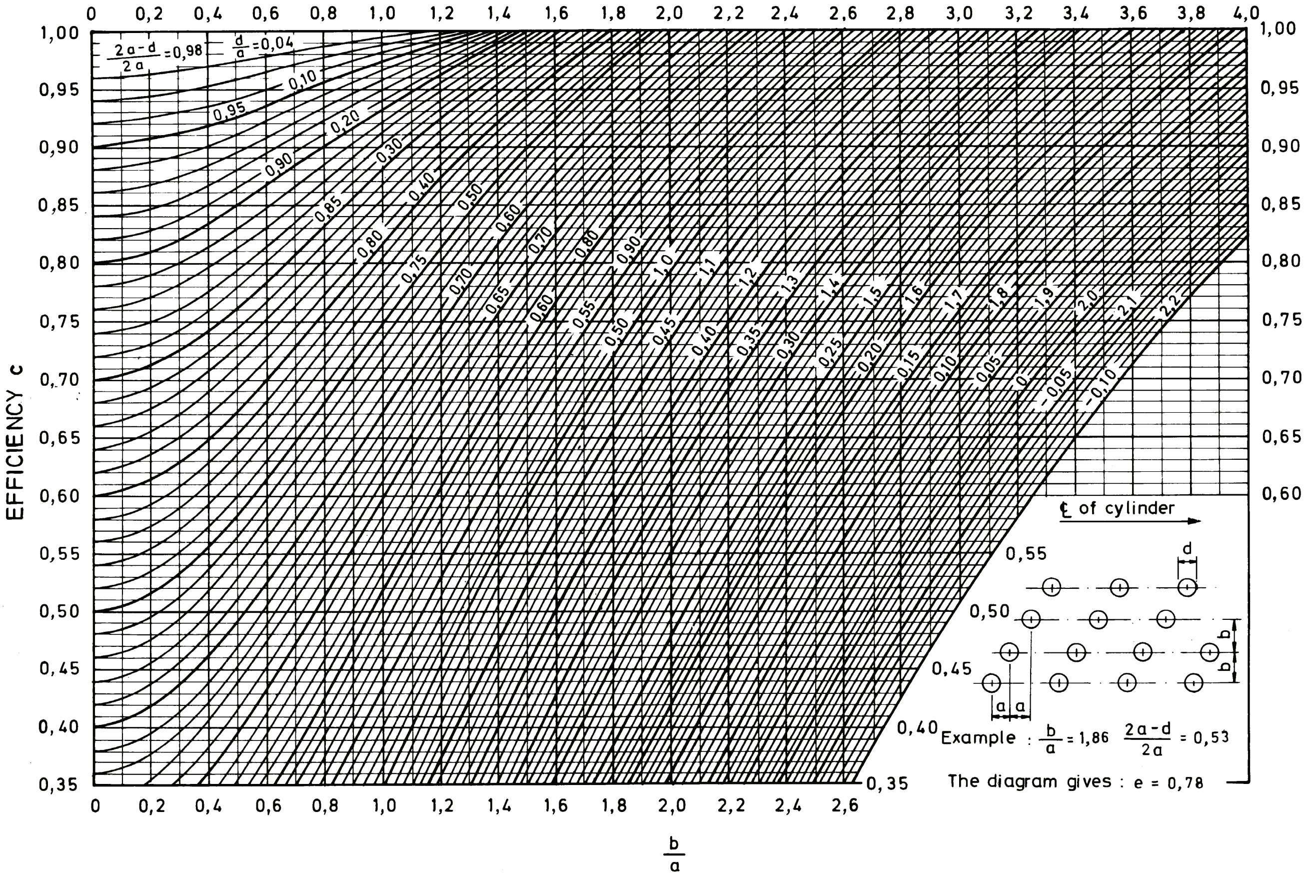


Fig. 3
Ligament Efficiencies — diagonal drilling

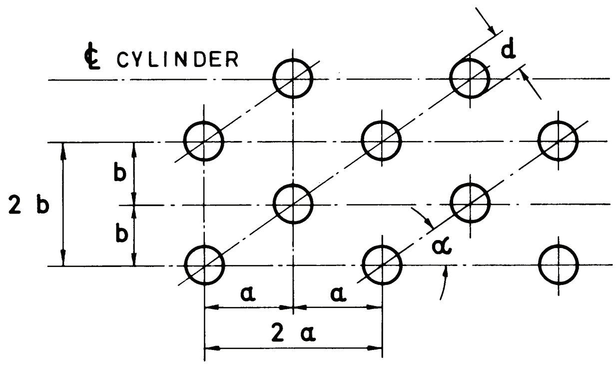


Fig. 4
Regularly staggered spacing

203 When drilling holes along a diagonal line, the efficiency of corresponding ligaments is given in Fig.3 with the ratio

$$\frac{b}{a} \text{ as abcissa and } \frac{2a-d}{2a} \text{ as parameter}$$

The figure applies to regular spacing of tube holes arranged along a straight line or in a saw-tooth pattern as shown in Fig.2.

The data given in Fig.3 are based on the following formula:

$$e = \frac{2}{A + B + \sqrt{(A-B)^2 + 4C^2}}$$

$$A = \frac{\cos^2\alpha + 1}{2\left(1 - \frac{d\cos\alpha}{a}\right)}$$

$$B = \frac{1}{2}\left(1 - \frac{d\cos\alpha}{a}\right)(\sin^2\alpha + 1)$$

$$C = \frac{\sin\alpha\cos\alpha}{2\left(1 - \frac{d\cos\alpha}{a}\right)}$$

a = diagonal pitch of holes projected on longitudinal axis, in mm
b = diagonal pitch of holes projected circumferentially, in mm
α = angle of centre line of cylinder to centre line of diagonal holes.

For d, see 201.

In case of a regularly staggered spacing of tube holes, i.e. the centres are arranged on diagonal and circumferential lines as well as on lines parallel to the longitudinal axis, as shown in Fig.4, the smallest value e of all ligament efficiencies (longitudinally, circumferentially and diagonally) is given in Fig.5 by the ratio:

$$\frac{b}{a} \text{ on the abcissa, and the ratio}$$

$$\frac{2a-d}{2a} \text{ or d/a used as a parameter}$$

A 300 Compensating effect of tube stubs

301 Where a drum or header is drilled for tube stubs fitted by strength welding, the effective diameter d of holes is to be taken as:

$$d_a - \frac{A}{t}$$

The compensating area A is to be measured in a plane through the axis of the tube stub parallel to the longitudinal axis of the drum or header (see Fig.6), and is to be calculated as follows:

For a set-through stub:

$$A = 2\,(t_a - t_m)\,(t + h) + A_1 + A_2 \quad (\mathrm{mm}^2)$$

For a set-on stub:

$$A = 2\,(t_a - t_m)\,h + A_2 \quad (\mathrm{mm}^2)$$

A_1 = sectional area of the stub projecting inside the shell within the distance h from the inner surface of the shell (maximum 2 t_a h), in mm^2
A_2 = sectional area of fillet welds attaching the stub to inside and outside of shell, in mm^2
t = plate thickness, in mm
t_a = actual wall thickness of tube stub minus corrosion allowance, in mm
t_m = calculated minimum wall thickness of tube stub according to G, with c = 0, in mm
h = $0.8\sqrt{(d_i + t_a)t_a}$
d_i = inner diameter of tube stub, in mm.

Where the material of the tube stub has a nominal design stress lower than that of the shell, the compensating sectional area of the stub is to be multiplied by the ratio:

$$\frac{\sigma_t \text{ of stub}}{\sigma_t \text{ of shell}}$$

No credit will be given for the additional strength of a material having a nominal design stress greater than that of the shell.

302 The minimum pitch for roller-expanded boiler tubes, measured along the median line, is not to be less than

$$1.25\,d + 10 \quad (\mathrm{mm})$$

d is as given in 201.

303 If more than three stay bolts pierce a cylindrical shell in the same horizontal line, the efficiency in this line is not to be lower than that of the longitudinal weld, otherwise the stays are to be arranged in zig-zag.

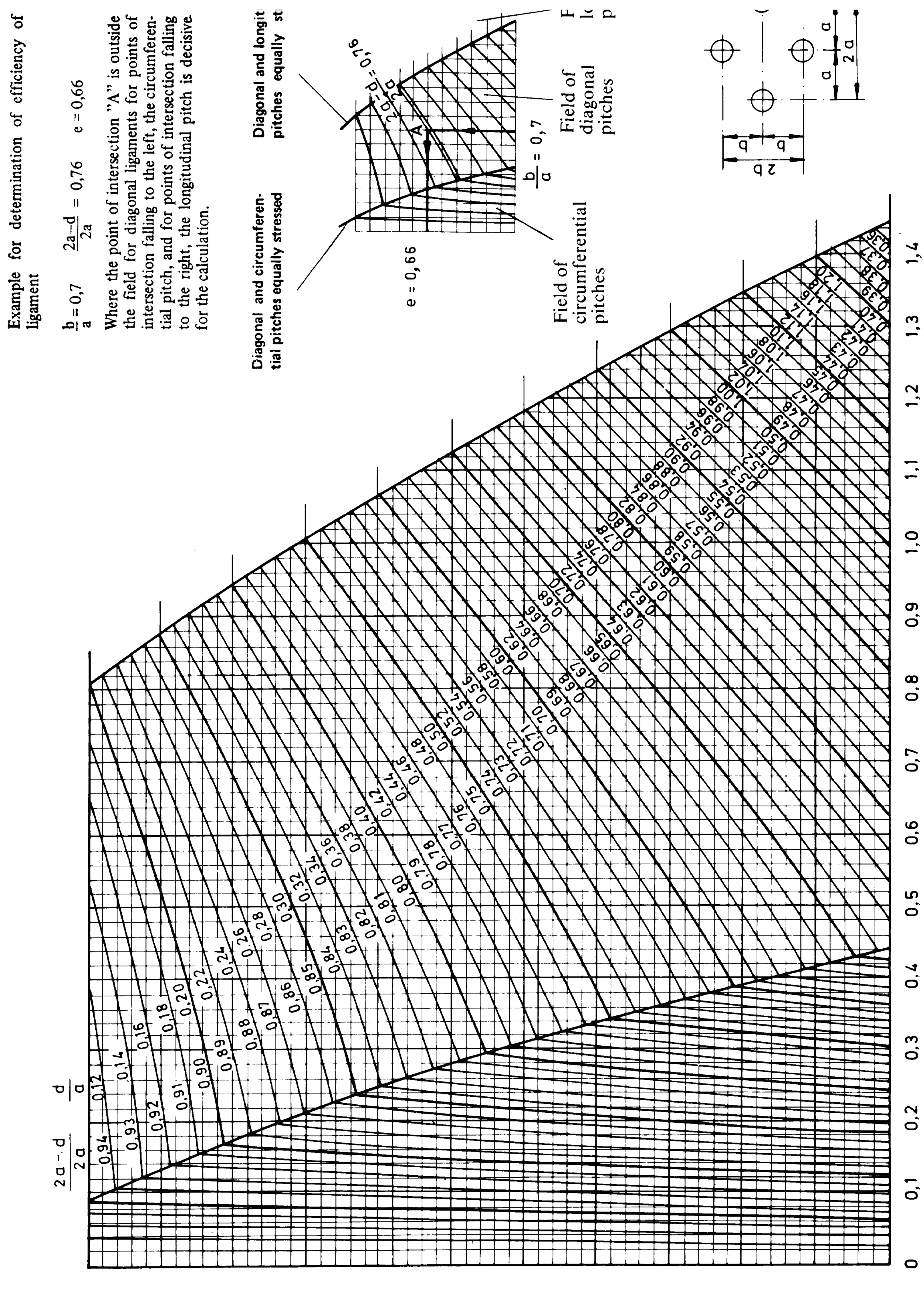
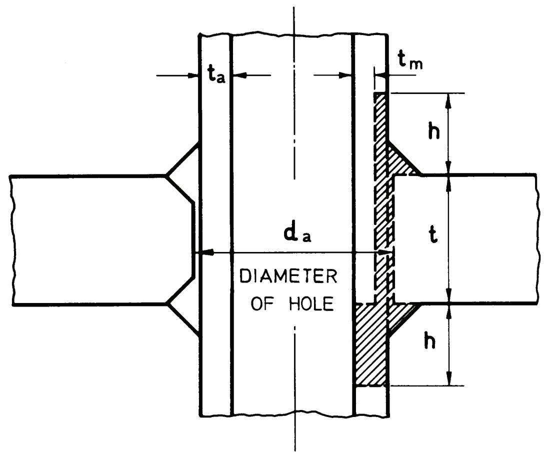


Fig. 5
Ligament efficiencies — staggered drilling



Area A equals twice the area shown cross-hatched.

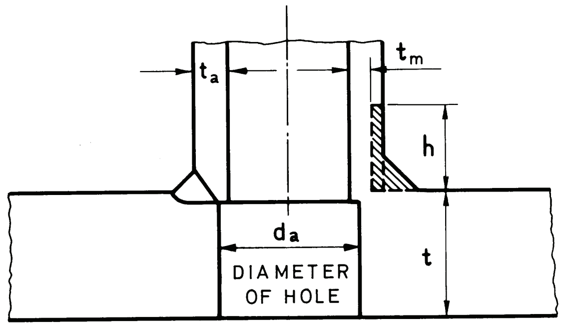


Fig. 6
Stub connections

B. Headers of Rectangular or Irregular Sections

B 100 Headers of rectangular section

101 To determine the thickness, it is necessary to consider the thickness required in the centre line of the sides, at all lines of holes and at the corners. The required thickness is the greater of these values.

102 The thickness t of the header is not to be less than:

$$t = \frac{pn}{20\sigma_t e} + \sqrt{\frac{0.45pY}{\sigma_t e_1}} + c \quad \text{(mm)}$$

e = efficiency of ligaments referring to the membrane stresses as given in 103

e_1 = efficiency of ligaments referring to the bending stresses as given in 103.

Y is a coefficient used in determining the required wall thickness of the side with internal width 2 m and is (the numerical value is to be used):

— at the centre line:

$$Y = \frac{1}{3} \cdot \frac{m^3 + n^3}{m + n} - \frac{m^2}{2}$$

— at a line of holes parallel to the longitudinal axis of the header:

$$Y = \frac{1}{3} \cdot \frac{m^3 + n^3}{m + n} - \frac{m^2 - b^2}{2}$$

— for checking the section A-A, where holes are arranged diagonally and situated equidistantly from the centre line of the wall, as indicated in Fig.7d:

$$Y = \left(\frac{1}{3} \cdot \frac{m^3 + n^3}{m + n} - \frac{m^2}{2}\right) \cos\alpha$$

— at the corners:

$$Y = \frac{1}{3} \cdot \frac{m^3 + n^3}{m + n}$$

2m = internal width in mm of header parallel with the side under consideration. See Fig.7

2n = internal width in mm of header measured at right angles to the side under consideration. See Fig.7

α = angle as indicated in Fig.7.

103 When drilling holes parallel to the longitudinal axis the efficiency of ligaments is given by:

— when considering membrane stresses:

$$e = \frac{s - d}{s}$$

— for d < 0.6 m when considering bending stresses:

$$e_1 = \frac{s - d}{s}$$

— for d ≥ 0.6 m when considering bending stresses:

$$e_1 = \frac{s - 0.6m}{s}$$

In the case of considering the section A-A, where the holes are arranged diagonally, as indicated in Fig.7d, s_1 to be used instead of s.

In Fig.7 the symbols used are as follows:

b = distance from the row of holes under consideration to the centre line of the side, in mm

s = pitch of holes, in mm

s_1 = diagonal pitch of holes, in mm

α = angle as indicated in the figure

d = diameter of holes, in mm

r = radius of curvature at corners, in mm.

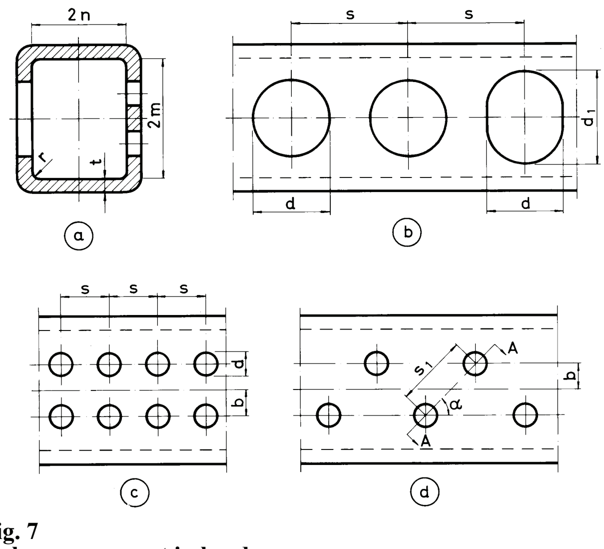


Fig. 7
Hole arrangement in header

104 In the case of oval holes, the value of d used in the formulae for e and e_1 is to be the inside dimension of the hole, measured parallel to the longitudinal axis of the header. For evaluation of the limiting value of d in 103 the inside dimension of the hole measured perpendicularly to the longitudinal axis of the header is to be used (d_1 in Fig.7b).

105 For corners and inspection openings the following is to be satisfied:

$$r \geq \frac{1}{3} t$$

t is the mean of the nominal thicknesses of the two sides.

r is in no case to be less than 8 mm.

106 At locally machined openings, the thickness may be 2 mm less than given by the above rules, but is generally not to be less than 8 mm.

B 200 Headers of irregular form

201 Where the thickness of headers of irregular form, for instance corrugated headers, has not been calculated with sufficient accuracy, and the empirical data available are insufficient, hydraulic deformation tests are to be carried out.

Information on testing method and results obtained is to be submitted for approval.

C. Dished Ends

C 100 Dished ends subject to pressure on the concave side

101 The thickness of dished ends without stays concave to the pressure side is to be determined in accordance with the requirements in Sec.4 C500.

102 The minimum thickness of dished ends forming the upper part of vertical boilers, subject to pressure on the concave side and supported by a central uptake, is to be determined from the following formula:

$$t = \frac{pR_i}{13\sigma_t} + c$$

R_i = inside radius of curvature.

R_i is not to be greater than the external diameter of the cylinder to which it is attached.

The inside knuckle radius of the arc joining the cylindrical flange to the spherical surface of the end is not to be less than four times the thickness of the end plate, and in no case less than 65 mm.

The inside radius of curvature of flange to uptake is not to be less than twice the thickness of the end plate, and in no case less than 25 mm.

C 200 Dished ends subject to pressure on the convex side

201 The thickness of dished ends subject to pressure on the convex side is to be determined in accordance with the requirements in Sec.4 C504, except for dished ends for vertical boiler fireboxes.

The thickness of dished ends for vertical boiler fireboxes is to be determined in accordance with the requirements in E600.

D. Flat Plates Supported by Stays

D 100 General

101 Where a flat plate is flanged for connection to other parts, the inside radius of flanging is not to be less than:

— for connection with the boiler shell: twice the thickness of the plate with a minimum of 38 mm
— for connection with a furnace or with the shell of fireboxes: the thickness of the plate with a minimum of 25 mm.

102 Where the flange curvature is a point of support, this is to be taken at the commencement of curvature, or at a line 3.5 times the thickness of the plate measured from outside of the plate, whichever is nearer to the flange.

Where a flat plate is welded directly to a shell, the point of support is to be taken at the inside of the shell.

103 The length of the cylindrical part of the flanged end plate is not to be less than 2.5 times the thickness of the end plate.

104 Where unflanged flat plates are connected to a cylindrical shell by welding, the weld is to be a full penetration weld, normally welded from both sides. The inside fillet weld is to have concave profile and is to merge into the plate without undercutting or abrupt irregularity. The minimum throat thickness is to be as given in Fig.8.

The inside fillet weld may only be omitted for small boilers not accessible for welding from the inside.

105 For unflanged flat end plates the ratio of end plate thickness to shell thickness is not to exceed 2.0. Where inside fillet weld is omitted the ratio is not to exceed 1.4.

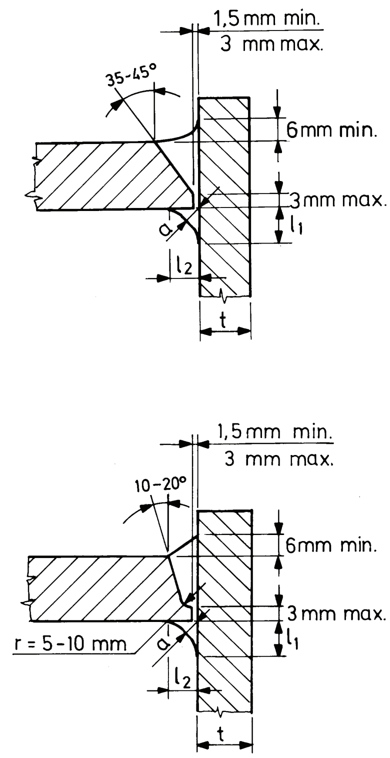


Fig. 8
Attachment of unflanged flat end plates or tube plates to shell

106 The spacing of tube holes are to be such that the minimum width of any ligament between tube holes is not less than:

for expanded tubes:

0.125 d + 12.5

for welded tubes:

0.125 d + 9 for gas entry temperatures > 800°C

0.125 d + 7 for gas entry temperatures ≤ 800°C

d = diameter of tube hole.

Guidance note:
The shape of internal fillet weld is to be concave. The ratio of leg lengths l_1 / l_2 should be approximately 4 : 3. The minimum

throat thickness, a, is to be related to the shell thickness as follows:

Shell thickness (mm)	*Minimum throat thickness (mm)*
t < 12	4.5
12 ≤ t ≤ 16	5
16 < t	6

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

Guidance note:
For non-destructive testing, see Sec.8 D101

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

Guidance note:
The use of minimum angle should be associated with a maximum radius r of 10 mm. Conversely, the maximum angle should be associated with minimum radius r of 5 mm.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

D 200 Scantlings

201 The thickness of stayed flat plates is not to be less than the greater of the values determined by the following formulae:

$$t = K\,C\,d_e\sqrt{\frac{p}{10\sigma_t}} + c \quad (1)$$

or

$$t = y\,C\,b\sqrt{\frac{p}{10\sigma_t}} + c \quad (2)$$

K = a factor depending on number of supports, see 202
C = a factor depending on the method of support, see 203
d_e = the diameter of the largest circle passing through points of support, see 205
a = the major dimension of elliptical or rectangular unsupported areas
b = the minor dimension of elliptical or rectangular unsupported areas
y = a factor depending on the ratio b/a, see 206.

202 The value of the factor K is:

— for four or more evenly distributed points of support: 1.0
— for three points of support: 1.1
— for annular areas, i.e. areas supported only by cylindrical shell and uptake, or cylindrical shell and lower part of fire boxes (2 points of support): 1.56

203 The value of the factor C is to be as given in Table D1.

Where different methods of support are used, the factor C is to be taken as the mean of the values for the respective methods adopted.

204 For parts supported by bar stays or stay tubes, d_e is the diameter of the largest circle passing through not less than three points of support. The three points of support considered are not to be situated on the same side of any diameter of this circle.

205 For parts situated near the edge of the plate or around a furnace, d_e is the diameter of the circle tangent to the support at the cylindrical shell or furnace (see 102) and passing through the centres of at least two other supports.

The three points of support considered are not to be situated on the same side of any diameter of this circle.

When, in addition to the above main circle, a sub-circle of diameter equal to 0.75 times that of the main circle can be drawn passing through two points of support and such that its centre lies outside the main circle, the thickness is to be determined from formula (2) using b as indicated in Fig.9 and y determined from the table in 206.

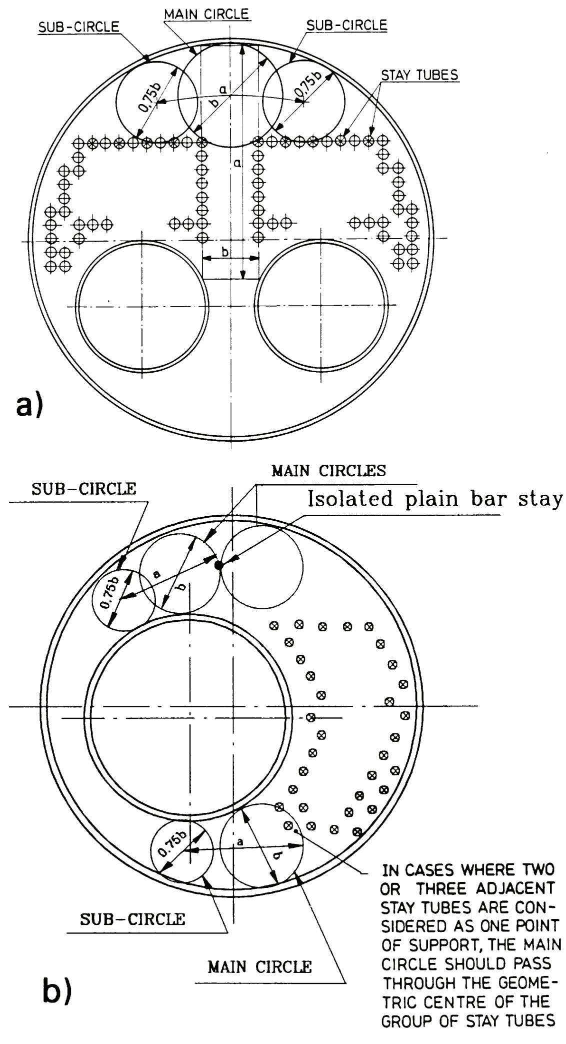


Fig. 9
Use of sub-circles and rectangular areas

206 The ratio y takes into account the increase in stress for rectangular or elliptical areas, compared with circular areas as a function of the ratio b/a according to Table D2 or Fig.10.

D 300 Stay tubes and tube plates within tube nests

301 Stay tubes are tubes welded into the tube plates in accordance with Fig.12, having a weld depth equal to the tube thickness + 3 mm.

These stay tubes are not required within tube nests except when the tube nests comprise tubes which are expanded only. Stay tubes are however to be used in the boundary rows in sufficient numbers to carry the flat plate loadings outside the tube area.

For loadings on stay tubes and required area, see F.

Table D1 Value of factor C

Type of support	*C*
Isolated plain bar stays or stay tubes, Fig.11 (a) and Fig.12	
Note: An example of an isolated plain bar stay is given in Fig.9 b	0.45
Non-isolated plain bar stays or stay tubes	0.39
Bar stays welded to reinforced plate or plate fitted with washer, Fig.11 (b) and (c)	0.35
Unstayed tube bank with plain tubes welded at both ends, Fig.13	0.30
Flat end plate or tubeplate attachment to cylindrical shell	
Flanged end plate	0.32
Set-in end plate with internal fillet weld. End plate thickness divided by shell plate thickness (Fig.8):	
≤ 1.4	0.33
> 1.4 ≤ 1.6	0.36
> 1.6 ≤ 1.8	0.39
> 1.8	0.42
Set in end plate with no internal fillet weld	0.45
Flat end plate attachment to furnace and uptake	
With internal fillet weld:	
Plain furnace	0.30
Corrugated furnace with corrugations less than 50 mm deep	0.32
Corrugated furnace with corrugations 50 mm deep or greater:	
length > 4 m	0.37
length ≤ 4 m	0.34
Bowling hoop furnace	0.32
With no internal fillet weld	0.45
Top plates of fireboxes supported by continuous welded girders	0.51

Table D2 Value of factor y

Ratio b/a	*y*	
	Rectangular plates	*Elliptical plates*
1.0	1.10	1.0
0.75	1.26	1.15
0.5	1.40	1.30
0.25	1.52	1.43
≤ 0.1	1.56	

Intermediate values are to be interpolated.

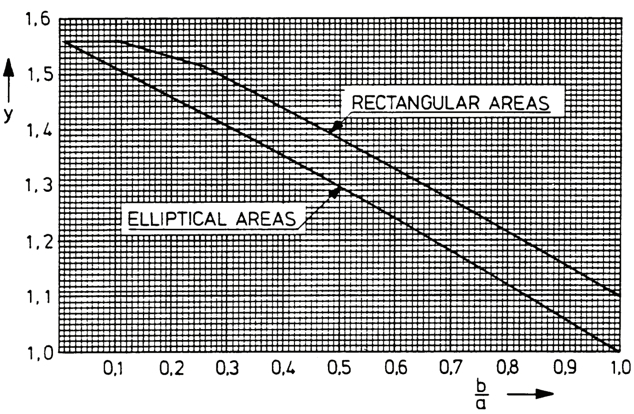


Fig. 10
Determination of factor y

302 The thickness of tube plates within tube nests with welded plain tubes, Fig.13, is not to be less than calculated according to formula (2) in 201 using b as the pitch of the plain tubes and y = 1.56. The thickness is not to be less than 10 mm.

303 For tube plates with expanded tubes and stay tubes the thickness is to be calculated according to 201 and is not to be less than:

12.5 mm when d ≤ 50 mm

14.0 mm when d > 50 mm

d = diameter of tube hole.

D 400 Vertical tube plates in vertical boilers

401 Where vertical boilers have a nest or nests of horizontal tubes, so that the tube plates are in direct tension, due to the vertical load on the boiler ends or to their acting as horizontal ties across the shell, the thickness of tube plates and the spacing of the tubes are to be such that the section of metal, taking the load, is sufficient to keep the stress within that allowed for shell plates. The thickness is not to be less than:

$$t = \frac{4pRg}{10(g-d)R_m} + c$$

R = radial distance, from centre of the outer row of tube holes to axis of the shell, in mm
g = vertical pitch, of tubes in outer rows, in mm
d = diameter of tube holes, in mm.

Every second tube in the outer vertical rows of tubes is to be a stay tube.

402 The arrangement of stay tubes in the nests is to be such that the thickness of the tube plates meets the requirements in 200.

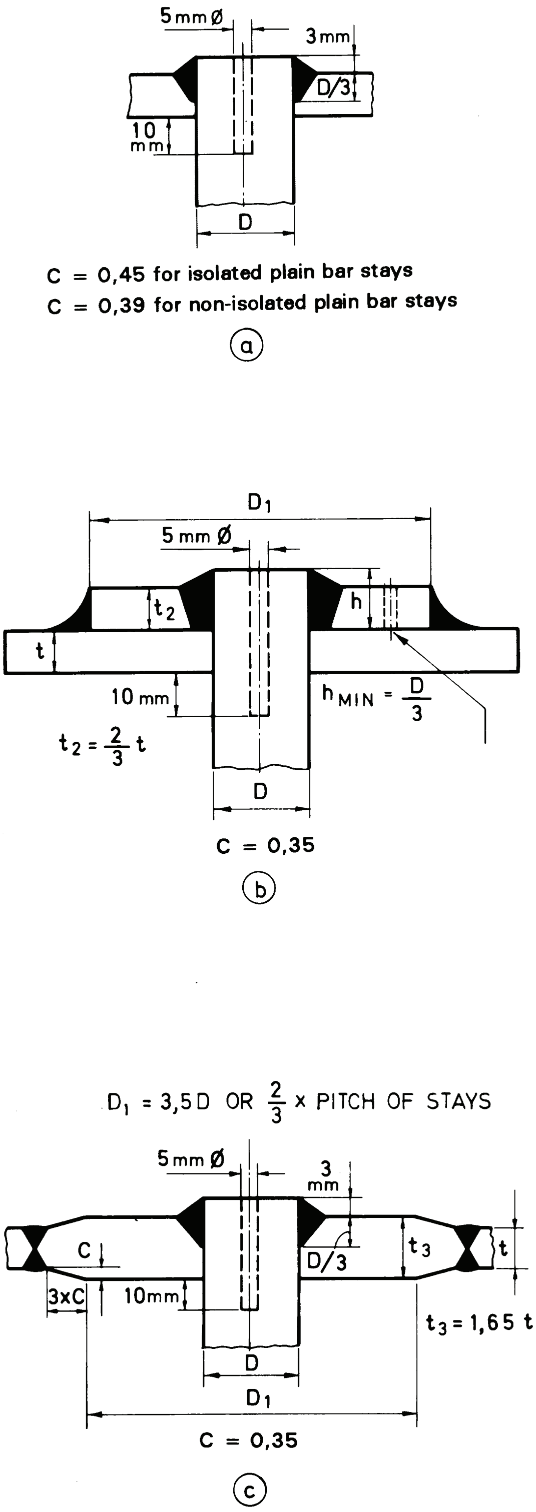


Fig. 11
Stay connections

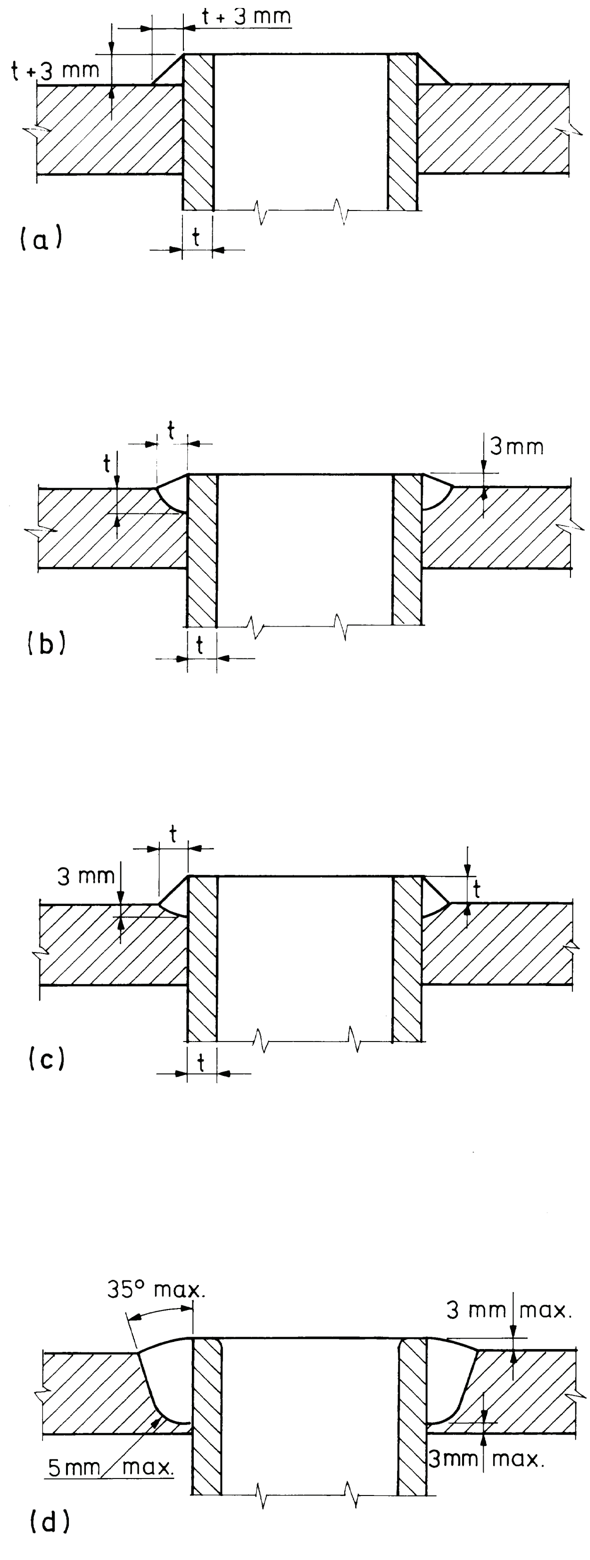


Fig. 12
Typical attachment of stay tubes

Guidance note:

The ends of the tube shall be «dressed» flush with the welds when exposed to flame or temperature exceeding 600°C.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

Guidance note:

Tubes are to be lightly expanded before and after welding.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

Guidance note:

Tubes are to be lightly expanded before and after welding.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

Guidance note:

For tubes exposed to flame or gas temperatures exceeding 600°C the ends are to be dressed flush with the welds.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

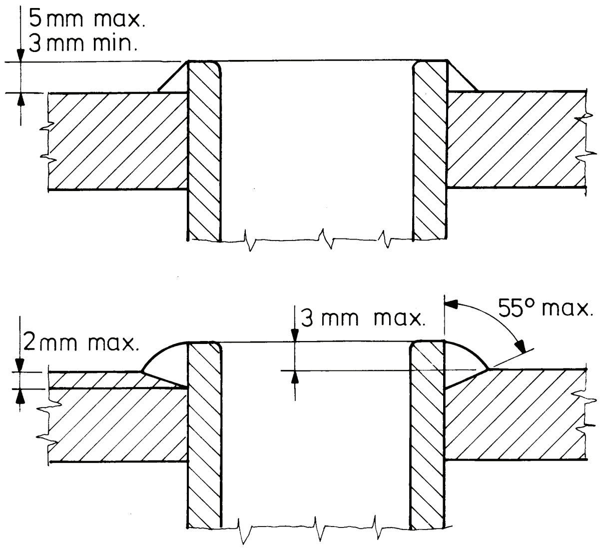


Fig. 13
Typical attachment of welded plain tubes

D 500 Firebox plates under compression

501 The thickness of firebox tube plates under compression due to pressure on the crown plate is not to be less than:

$$t = \frac{p\, l\, s}{1950(s - d)}$$

l = length of firebox measured on the inside between tube plate and back plate
s = distance between centres of tube holes
d = internal diameter of plain tubes.

The thickness is, however, not to be less than determined by the formulae in 200.

D 600 Openings in flat plates

601 The maximum diameter of an unreinforced opening in a flat plate is to be determined from the following formula:

$$d = 8 t_a \left(1.5 \frac{t_a^2}{t^2} - 1.0\right)$$

t_a = actual thickness of flat plate minus corrosion allowance
t = thickness of flat plate calculated from the formula in 201 for the part of the plate under consideration with c = 0.

602 Openings larger than those permitted according to 601 are to be reinforced.

Compensation is adequate when the area y is equal to or greater than the area x requiring compensation. See Fig.14.

603 The material in the branch, or in the pad reinforcement, is normally to have the same mechanical properties as that in the flat plate. In no case is the material to have a nominal design stress less than 0.75 times the nominal design stress of the flat plate.

Where material with a lower nominal design stress than that of the flat plate is used for reinforcement, its effective area is to be reduced in the ratio of the nominal design stresses at design temperature.

No reduction will be accepted for material with a nominal design stress greater than that of the shell.

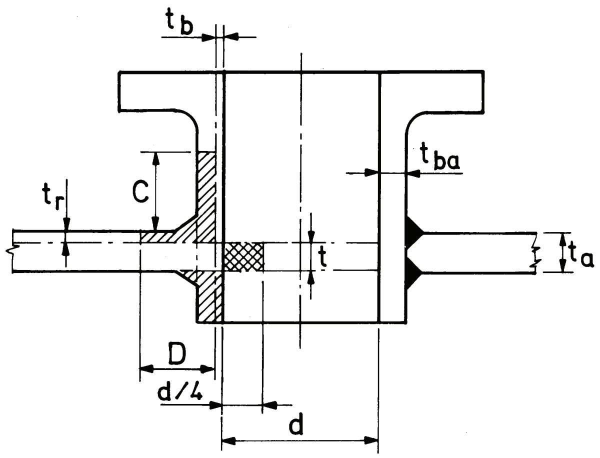


Fig. 14
Compensation of openings in flat plates

x = the area requiring compensation, marked by xxxxx
y = the compensating area, marked by ///////
t_a , t = as defined in 600
t_{ba} = the actual thickness of the branch minus corrosion allowance
t_b = the thickness of the branch calculated from the formula, in G101
D = the greater of the two values d/2 or (t_a + 75) mm
C = the smaller of the two values 2.5 t_a or (2.5 t_{ba} + t_r).

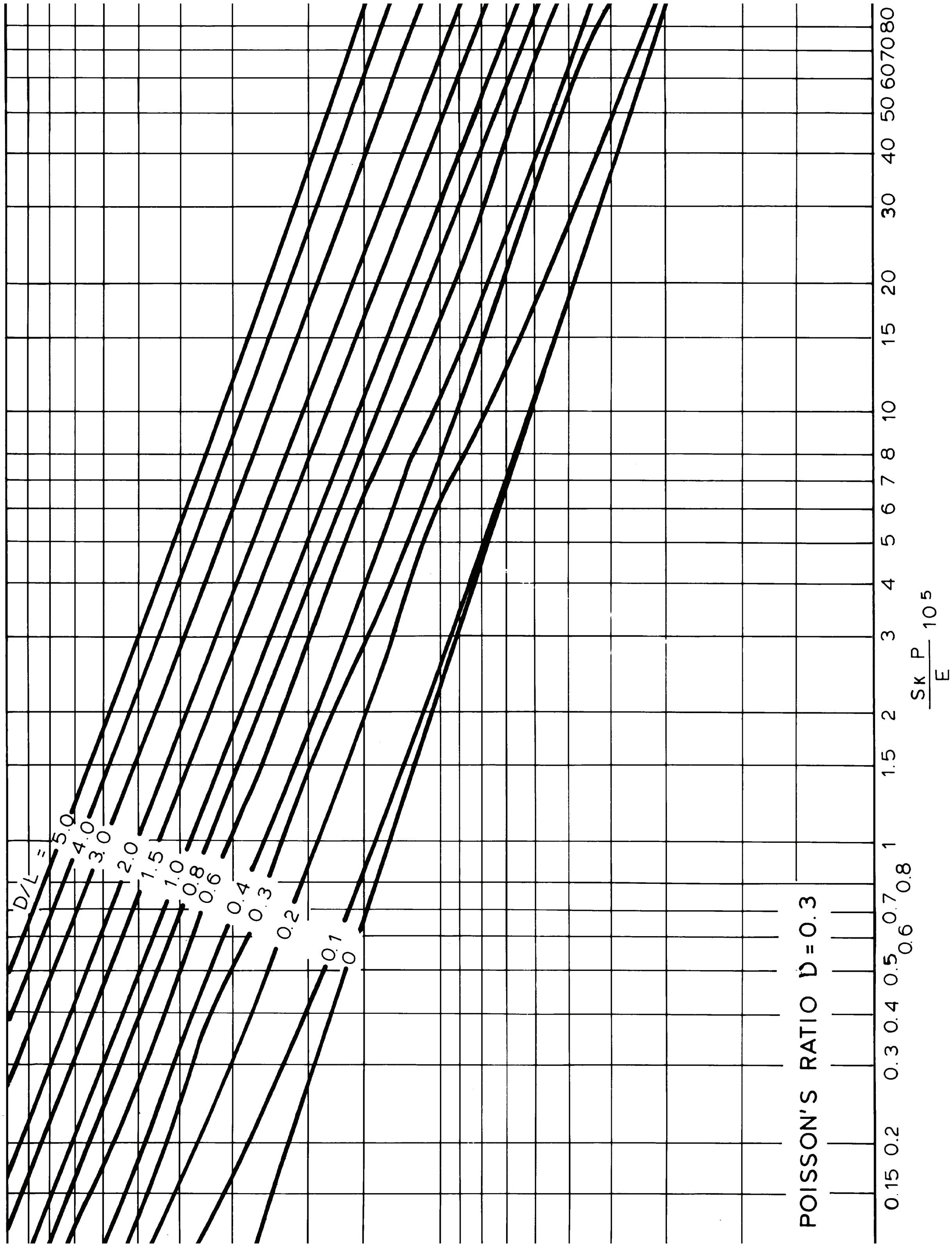


Fig. 15
Required thickness by calculation against elastic instability

E. Furnaces and Fireboxes of Cylindrical Form, Uptakes, Cross-tubes and Ogee Rings

E 100 Plain furnaces

101 The design of a plain furnace is to be checked to ensure that neither membrane yield nor elastic instability occur.

102 For calculation against membrane yield, the design pressure is not to exceed that determined by the following formula:

$$p = 10 \frac{R_{et}}{S_1} \frac{2(t-c)}{D} \frac{1 + 0.1\ D/L}{1 + 0.03 \frac{D}{t-c} \frac{u}{1 + 5\ D/L}}$$

L = the length of the furnace or distance between two effective points of support, see 301 and 401
D = mean diameter of furnace
u = percentage of out-of-roundness of the furnace. The value of u to be used in the formula is to be taken as 1.5
S_1 = factor of safety.

103 For calculation against elastic instability, the design pressure is not to exceed that determined by the following formula:

$$p = 20 \frac{E}{S_K} \left[\frac{\frac{t-c}{D_o}}{(n^2-1)[1+(n/z)^2]^2} + \frac{\left(\frac{t-c}{D_o}\right)^3}{3(1-\nu^2)} \left(n^2 - 1 + \frac{2n^2 - 1 - \nu}{(n/z)^2 + 1} \right) \right]$$

E = modulus of elasticity in N/mm² at design material temperatures, see table in 107
n = integral number of waves. $n \geq 2$ and $n > z$
z = coefficient $= \frac{0.5\pi\ D_o}{L}$
ν = Poisson's ratio
S_K = safety factor
D_o = outside diameter.

L is defined in 102.

n is to be chosen to minimise p.

n may be estimated by the following formula:

$$n = 1.63 \left[\left(\frac{D_o}{L}\right)^2 \frac{D_o}{t-c} \right]^{\frac{1}{4}}$$

For usual dimension of furnaces, p or t – c may be determined from Fig.15.

104 The nominal thickness of plain furnaces is not to be less than 10 mm for horizontal furnaces and 8 mm for vertical furnaces.

The nominal thickness is not to exceed 22 mm.

105 For ovality the percentage of out-of-roundness is:

$$u = \frac{200(D_{max} - D_{min})}{D_{max} + D_{min}}$$

D_{max} = the maximum mean diameter of the furnace
D_{min} = the minimum mean diameter of the furnace.

For local flat parts the percentage of out-of-roundness is:

$$u = \frac{4a}{D_o} 100$$

See Fig.16

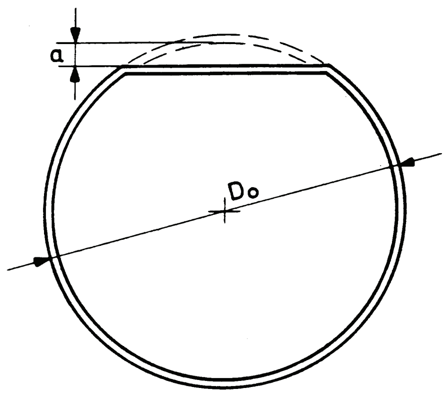


Fig. 16
Local flat parts

106 The following values are to be used for the factor of safety:

— against membrane yield:

— horizontal furnaces: $S_1 = 2.75$
— vertical furnaces: $S_1 = 2.5$

— against elastic instability: $S_K = 4.5$.

107 Values of E for carbon and carbon-manganese steels may be obtained from the following table:

Design material temperature (°C)	*250*	*300*	*350*	*400*
E N/mm² ·10⁵	1.95	1.91	1.86	1.81

For intermediate temperatures linear interpolation is to be used.

108 Plain furnaces shall not exceed 3 m in length. If corrugations are used to provide flexibility, at least one-third of the furnace length shall be corrugated.

E 200 Corrugated furnaces

201 The design of corrugated furnaces is to be checked to ensure that membrane yield do not occur.

Check against elastic instability is in general not required for usual form of corrugations.

202 The minimum thickness of corrugated furnaces after corrugation may be determined from the following formula:

$$t = \frac{p\ D_o}{K} + c$$

D_o = outside diameter at bottom of corrugations
K = 1060 for Fox, Morrison and Deighton corrugations.

203 Consideration will be given to a more accurate calculation taking depth, pitch, cross sectional area and second moment of area of the corrugations into account.

The calculation may be carried out according to a recognised code. The factors of safety are in general not to be less than that given in 106.

204 The nominal thickness is not to exceed 22 mm and is not to be less than 8 mm.

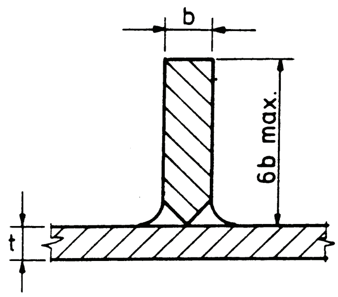
E 300 Stiffeners

301 Stiffening rings considered to give effective points of support, are to have a second moment of area not less than given by the following formula:

$$I_x = \frac{p\, D^3\, L}{1.33 \cdot 10^7}$$

L and D are defined in 102.

302 The thickness of stiffening rings are to be kept to the minimum required. For limiting dimensions see Fig.17. Stiffening rings are to extend completely around the circumference of the furnace, and are to be welded to the furnace with full penetration weld.



Note:
b is to be equal to or greater than t, but not greater than 2 t with a maximum of 22 mm.

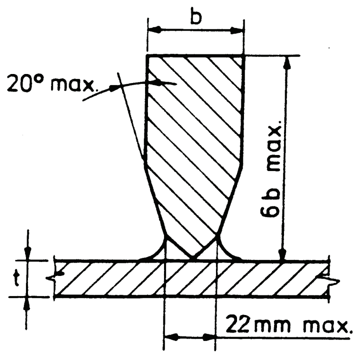


Fig. 17
Furnace stiffeners

E 400 Fireboxes for vertical boilers

401 The required thickness of plain fireboxes in vertical boilers is given in 100.

Where the firebox is tapered, the outside diameter to be used in the calculation is mean of that at the top and that at the bottom where it is substantially supported from flange, ring or row of stays.

The length of the firebox is to be taken as the length between points of substantial support, as indicated in Fig.18.

A circumferential row of stays connecting the firebox to the shell is considered as a substantial support, if the diameter of the stays is not less than 22 mm or twice the thickness of the firebox, whichever is the greater, and the pitch of the stays at the firebox does not exceed 14 times the wall thickness of the firebox.

E 500 Openings in furnaces

501 Reinforcement of openings in cylindrical furnaces is to satisfy the requirements in Sec.4 D except that:

— pad type reinforcement is not permitted
— the required reinforcement may be based on the calculated thickness of the furnace assuming an internal pressure equal to the design pressure of the boiler.

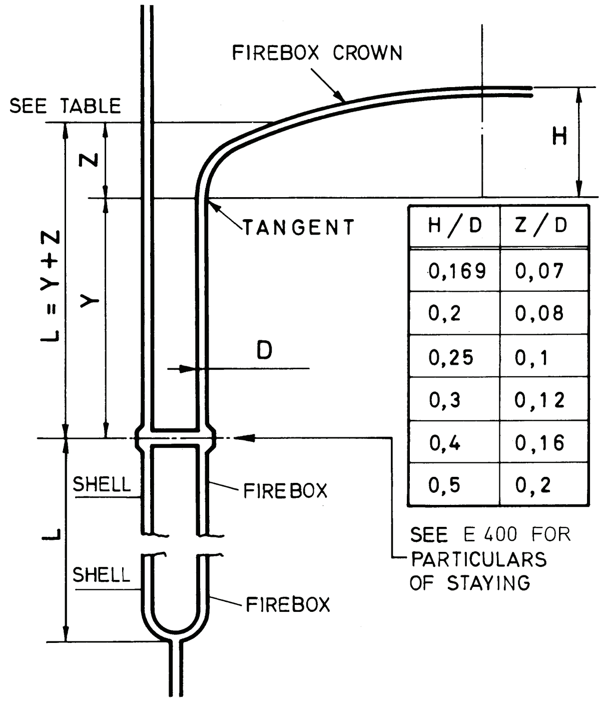


Fig. 18
Support details

E 600 Dished ends for vertical boiler fireboxes

601 The internal radius, R_i, of the spherical part of the dished end is not to be greater than the external diameter of the cylindrical firebox.

The inside radius of the flange to the cylindrical firebox is not to be less than four times the thickness of the dished end with a minimum of 65 mm.

602 The minimum thickness of dished ends for vertical boiler fireboxes subjected to pressure on the convex side and without support from stays of any kind, is to be determined from the following formula:

$$t = \frac{p\, R_i}{6 \sigma_t} + c$$

R_i is defined in 601.

The thickness is not to be less than the thickness of the firebox.

603 The minimum thickness of dished ends for vertical boiler fireboxes subjected to pressure on the convex side and supported by a central uptake is to be determined from the following formula:

$$t = \frac{p\, R_i}{10 \sigma_t} + c$$

R_i is defined in 601.

E 700 Internal uptakes in vertical boilers

701 The thickness of internal uptakes in vertical boilers is not to be less than determined by the formulae in 100.

The corrosion allowance, c, is to be 4 mm.

The safety factors may be taken as follows:

— against membrane yield: S = 2.0
— against elastic instability: S_K = 3.5.

E 800 Cross-tubes in vertical boilers

801 For vertical boilers with cross-tubes passing through the firebox shell, the minimum thickness of these tubes is not to be less than:

$$t = \frac{p\,d}{450} + 6.5$$

d = internal diameter of cross-tube.

The thickness is, however, not to be less than 9.5 mm.

802 The internal diameter of cross-tubes is not to exceed 300 mm.

E 900 Connection of firebox to shell in vertical boilers

901 Where the bottom of the firebox is connected to the shell by means of an ogee ring, and the ring sustains the whole vertical load on the firebox, the thickness of the ring is not to be less than:

$$t = \sqrt{\frac{p\,D_i(D_i - F)}{10000}} + c$$

D_i = internal diameter of boiler shell
F = outside diameter of the firebox where it joins the ogee ring.

Where the bottom of the furnace is connected to the shell by an «U-shaped ring», see Fig.19, the thickness is to be at least 20% greater than determined by the above formula.

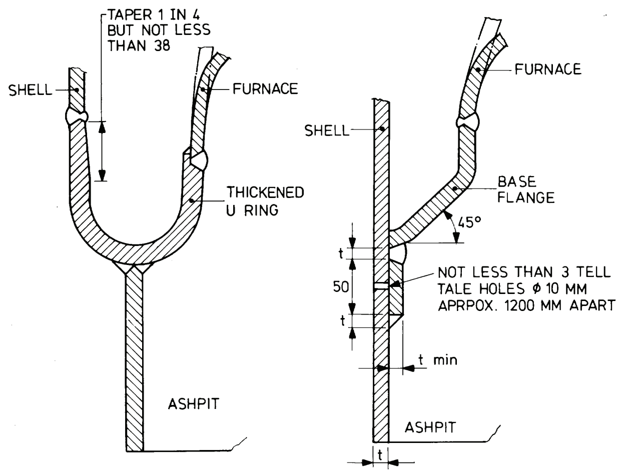


Fig. 19
Attachment of furnaces to shells for vertical boilers

F. Stays

F 100 Stay tubes and bar stays

101 The minimum required sectional area is to be determined from the following formula:

$$f = \frac{F p}{10\sigma_t}$$

σ_t = 70 N/mm² for stay tubes

$= \frac{R_m}{5.9}$ N/mm² for stay bolts

$= \frac{R_m}{5.7}$ N/mm² for longitudinal stays

F = area supported by the stay with reduction of area of holes embraced.

For a stay tube or bar stay, the area to be supported is to be the area enclosed by the lines bisecting at right angles the lines joining the stay and the adjacent points of support, less the area of any tubes or stays embraced, see Fig.20.

The calculation may be carried out in the uncorroded condition and not taking minus tolerances into account.

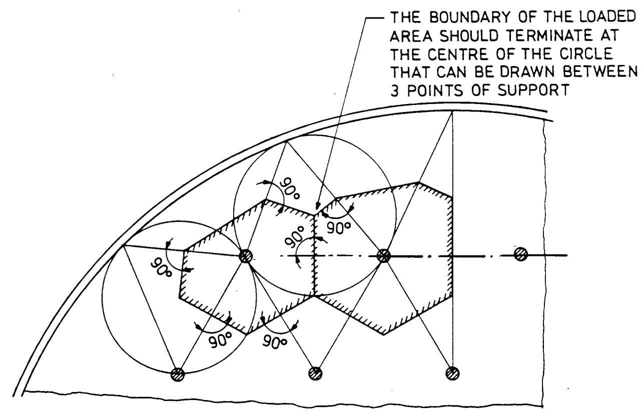


Fig. 20
Loaded area on stays

102 For top and sides of combustion chambers, the distance between stays and the commencement of curvature of tube plates and back plates at their flanges is not to be less than the distance between rows of stays.

103 For stays on furnaces for vertical boilers, see E400.

F 200 Girders for flat firebox and reversal chambers' top plates

201 The thickness of girders of rectangular section supporting flat top plates of combustion chambers is not to be less than:

$$t = \frac{p\,l^2\,b}{15\sigma_t h^2}$$

l = length of the girder between supports, i.e. measured on the inside between tube plate and back chamber plate or between sideplates, according to the method of support
b = distance between girders measured from centre to centre
h = depth of girder.

The above formula is applicable to girders welded continuously to the top plate by full penetration weld. For the depth h, a value not exceeding 8 t is to be inserted in the formula.

G. Tubes

G 100 Boiler tubes subjected to internal pressure

101 The wall thickness of straight tubes is not to be less than:

$$t = \frac{p\,d}{20\sigma_t + p} + c \quad \text{(mm)}$$

d = outside diameter in mm
c = corrosion allowance.

102 The corrosion allowance is to be 1 mm, except for tubes used in boilers with open feed water systems where the corrosion allowance is to be 2.5 mm.

103 The thickness for boiler, superheater, reheater and economiser tubes, however, is in no case to be less than the values given in Table G1.

Table G1 Minimum thickness of tubes

Outside diameter of tube (mm)	*Minimum thickness (mm)*
d ≤ 38	1.75
38 < d ≤ 51	2.16
51 < d ≤ 70	2.40
70 < d ≤ 76	2.60
76 < d ≤ 95	3.05
95 < d ≤ 102	3.28
102 < d ≤ 127	3.50

104 If the tubes are ordered with a minus tolerance, the minimum thickness according to the formula and the table in 103 is to be increased by the necessary amount.

Where tubes are bent, the thickness of the thinnest part of the tubes is not to be less than the calculated thickness, unless it can be demonstrated that the method of bending results in no decrease in strength at the bend as compared with the straight tube. In connection with any new method of bending, the manufacturer is to prove that this condition is satisfied.

105 Tubes strength welded to tube plates will be specially considered with respect to sufficient thickness for sound welding.

106 The minimum thickness of downcomer tubes and pipes, which form an integral part of the boiler and which are not exposed to combustion gases, is to comply with Ch.6 Sec.6 of the Rules for Classification of Ships.

G 200 Boiler tubes subjected to external pressure

201 The wall thickness of tubes with outside diameter 100 mm and less is not to be less than:

$$t = \frac{p\,d}{16\sigma_t} + c \quad \text{(mm)}$$

d = outside diameter of tube in mm.

202 For corrosion allowance is to be as given in 102. For additional thickness due to minus tolerances and bending, see 104.

203 The nominal thickness of the tubes is, however, in no case to be less than given in Table G2.

Table G2 Nominal thickness of tubes

Outside diameter of tube (mm)	*Nominal thickness of tube (mm)*				
	2.9	*3.2*	*3.6*	*4.0*	*4.5*
	Design pressure (bar)				
51	11.0	15.0	21.0		
57	10.0	13.5	18.0	22.0	
63.5	9.0	12.5	16.0	21.0	
70	8.0	11.0	15.0	19.5	
76.1		10.0	13.5	17.5	21.0
82.5		9.0	12.5	16.0	19.5
88.9		8.5	11.5	15.0	18.0

For stay tubes, see F.

H. Access and Inspection Openings

H 100 General

101 All drums, headers and other large components for boilers shall be provided with openings, adequate in number and size, to allow access for fabrication, cleaning and internal inspection. See also Sec.3 A200.

102 Shell boilers with a shell diameter of 1400 mm or greater are to be designed to permit entry of a person and are to be provided with a manhole for this purpose.

Also boilers with a shell diameter less than 1400 mm which are capable of being entered by a person are to be provided with a manhole. Otherwise boilers with a shell diameter between 800 mm and 1400 mm are to be provided with a headhole as a minimum requirement.

103 Special consideration is to be taken to the accessibility for inspection of welded connections subjected to high bending stresses, e.g. corner welds between flat plates and cylindrical shells or furnaces and attachment welds of stays.

In case of circumferential corner welds not more than one single length equal to half the shell diameter or a number of lengths totalling one shell diameter are, in general, to be hidden by tube nests.

104 In all cases it shall be possible to inspect the bottom of the shell and the longitudinal welds.

105 Vertical boilers with large cross tubes are to have a sight hole in the shell opposite to one end of each tube to permit the tubes to be examined and cleaned.

106 Fired boilers including exhaust gas heated boilers/economisers are to be fitted with adequate number and size of openings and facilitates for internal inspection and cleaning of the gas side.

SECTION 6
MOUNTINGS AND FITTINGS

A. General

A 100 Construction

101 Construction and arrangement of valves and cocks are to be such that it can be seen without difficulty whether they are open or shut.

All valves are to be closed with a right-hand motion (clockwise rotation).

102 Valves exceeding 50 mm in diameter are to be fitted with outside screws, and the covers are to be secured by bolts or studs.

103 Where mountings are secured by studs, the studs are to have full thread holding in the plate for a length of a least one diameter. Holes for studs are not to penetrate the whole thickness of the plate. For welded standpipes, see Sec.4 D.

B. Safety Valves

B 100 Valves on boilers and steam-heated steam generators

101 Boilers and steam-heated steam generators with a heating surface of 10 m^2 and greater are to have not less than two safety valves.

Boilers and steam-heated steam generators with a heating surface less than 10 m^2 are to have at least one safety valve.

Exhaust gas water tube boilers/economisers are to have one or more safety valves with a total discharge capacity equal to or greater than the total design evaporation in normal and shut-off condition.

102 Superheaters are to have at least one safety valve on the outlet side. Where a boiler is fitted with an integral superheater without an intervening stop valve, the safety valve(s) on the superheater may be considered as boiler safety valve(s). The safety valves are to be so proportioned and positioned that when relieving, sufficient steam is forced through the superheater to prevent damage to the heater. At least 75% of the required safety-valve capacity is to be placed on the boiler. Where a superheater, reheater or economiser is fitted with a valve between one of these and the boiler, the unit is to have appropriate safety valves. Such safety valves are not to be regarded as safety valves for the boiler.

103 All the safety valves on each boiler or steam-heated steam generator may be fitted in one chest, which is to be separate from any other valve chest. The chest is to be connected directly to the shell by a strong and stiff neck. Safety valve chests are to have drain pipes leading the drain to the bilge or to a tank, clear of the boiler. No valves or cocks are to be fitted in these drain pipes.

104 The design of the safety valves is to be such that they cannot unintentionally be loaded beyond the set pressure, and in the event of fracture cannot lift out of their seats.

For safety valves operating at pressures below 17.5 bar, it should be possible for the valves to be turned round on their seats.

105 Easing gear is to be provided for lifting the safety valves on a boiler or steam-heated steam generator at the same time and is to be operable from the boiler or engine room platforms.

The superheater safety valve(s) are also to be provided with easing gear, but this may be operable only from an accessible place in the boiler room, free from steam danger.

106 The aggregate area of the orifices through the seatings of the safety valves (for full lift valves, the net area through seats after deducting the guides and other obstructions, when the valves are fully lifted) on each boiler is not to be less than:

For saturated steam:

$$A_1 = \frac{KE}{p+1} \quad (mm^2)$$

For superheated steam:

$$A_2 = A_1\,(1 + 0.0018\ T_D) \quad (mm^2)$$

p = design pressure of the boiler, in bar
E = designed evaporation, in kg/hour
T_D = difference between the temperature of superheated and saturated steam, in degrees Centigrade
K = 21 for valves of the ordinary type having a lift of at least 1/24 of the internal diameter of the seating
= 14 for valves of high-lift type having a lift of at least 1/16 of the internal diameter of the seating
= 10.5 for valves of improved high-lift type having a lift of at least 1/12 of the internal diameter of the seating
= 5.25 after special approval for valves of full-lift type having a lift of at least 1/4 of the internal diameter of the seating.

If a discharge capacity test, carried out in presence of the surveyor, proves that the capacity exceeds that indicated by the constant K, consideration will be given to the use of a lower value of K based on up to 90% of the measured capacity.

107 Notwithstanding the requirements in 106, the safety valves fitted to any boiler (and integral superheater) are to be capable of discharging all the steam which can be generated without causing a pressure rise of more than 10% in excess of the design pressure.

108 Steam-heated steam generators are to be protected from excessive pressure resulting from failure of the high-pressure heating tubes.

For this purpose, it may be required that the area of the safety valves be somewhat greater than that calculated in the formula in 106, unless other protective devices are provided to control the supply of steam to the heating tubes.

109 Safety-valves of ordinary type with seats of less than 38 mm inside diameter are not to be used. For full lift safety valves the inside seat diameter is not to be less than 20 mm.

Where only one safety valve of ordinary type is fitted, the inside diameter of the valve seat is not to be less than 50 mm.

110 For ordinary, high-lift and improved high-lift type safety valves, the waste-steam pipe and the passages leading to it are to have a cross-sectional area at least 10% greater than the aggregate valve area calculated by the formulae in 106.

For full-lift safety valves, the cross-sectional area of the waste-steam pipe and passages is not to be less than twice the aggregate-valve area where K = 5.25, and not less than three times the aggregate-valve area where K has a lower value.

Two or more safety valves may have a common waste-steam pipe, the cross-sectional area of which is not to be less than the total cross-sectional areas of the branch waste-steam tube. The valves are to be such that the back pressure from one blowing valve will not influence the functioning of the other valve(s). Balanced valves will satisfy this requirement.

111 Where boilers are not fitted with superheater, the safety valves are to be set to open at a pressure of not more than 3% above the approved design pressure, and in no case at a pressure higher than:

- the design pressure of the steam piping, or
- the least sum of the design pressure of machinery connected to the boiler and the pressure drop in the piping between this machinery and the boiler.

112 Where boilers are fitted with superheaters, the safety valves on the superheater are to be set to a pressure not higher than:

- the design pressure of the steam piping, or
- the least sum of the design pressure of machinery connected to the boiler and the pressure drop in the piping between this machinery and the boiler.

The safety valves on the boiler drum are to be set to a pressure not less than the superheater valve setting plus 0.35 bar plus the pressure drop through the superheater, when the boiler stop valves are closed and the superheater safety valves are relieving at their rated capacity. In no case, however, are the safety valves to be set to a pressure higher than 3% above the design pressure of the boiler.

113 Tests for accumulation of pressure are to be carried out. The boiler pressure is not to rise more than 10% above the design pressure, when the boiler stop valve is closed under full firing conditions. The duration of the accumulation test is to be 15 minutes for smoke-tube boilers and 7 minutes for water-tube boilers. During this test, no more feed water is to be supplied than is necessary to maintain a safe working water level.

The accumulation tests may upon application, be omitted. If it is desired to omit the tests, this is to be stated on the boiler and safety-valve plans when these are submitted for approval. Capacity tests of the safety valves will be required, and the valve makers are to provide a certificate stating the rated capacity of the safety valves at the approved pressure and temperature of the boilers. The boiler makers are to provide a certificate for each boiler stating its maximum evaporation.

B 200 Valves on pressure vessels other than boilers and steam-heated steam generators

201 Pressure vessels or systems of pressure vessels (see 203) are to have safety valves, except as provided for in 204.

202 Pressure vessels intended to operate completely filled with liquid are to have a liquid relief valve unless otherwise protected against overpressure.

203 Pressure vessels connected together in a system by piping of adequate capacity containing no valve that can isolate any pressure vessel, may be considered as a system of pressure vessels for the application of safety valves.

204 Where the compressor for air receivers is fitted with a safety valve, so arranged and adjusted that the receivers cannot be subjected to pressures greater than the design pressure, such receivers need not be fitted with safety valves if they are fitted with fusion plugs for quick release of pressure in case of fire. The melting point of the fusion plug is to be approximately 100°C.

The same regulation may apply to other pressure vessels, when the source of pressure is external to the pressure vessel and is under such positive control that the pressure cannot exceed the design pressure at operating temperature.

205 When a pressure vessel is fitted with heating coils, and fracture in the coils may increase the normal pressure of the fluid in the pressure vessel, the relieving capacity of the safety valve is to be sufficient for the case of fracture of one tube.

206 The total capacity of the safety valves, fitted to any pressure vessel or system of pressure vessels, is to be sufficient to discharge the maximum quantity of fluid (liquid or gaseous) that can be generated or supplied without occurrence of a rise in the pressure of more than 10% above the design pressure.

207 The safety valves are to be set to open at a pressure of not more than 3% above the design pressure.

208 The use of bursting discs or a combination of bursting discs and safety valves instead of safety valves is subject to consideration in each separate case.

B 300 Protection of condensers against overpressure

301 Vacuum condensers shall be protected against overpressure by one or more of the following means:

- safety valve(s) set to open at the design pressure
- bursting disc(s) with bursting pressure equal to the design pressure
- automatic shut-off of steam exhausting into the condenser (steam dump valve, exhaust steam from turbines) if the pressure exceeds the design pressure. In addition, an independent high pressure alarm set to warn at a pressure lower than the automatic shut-off pressure is to be fitted.

302 For atmospheric condensers, the air vent shall have a size that accommodates the maximum steam flow assuming no cooling water supply to the condenser. Alternatively, one of the means given in 301 shall be provided.

C. Stop Valves and Check Valves

C 100 Valves on boilers and steam-heated steam generators

101 Feed water intakes of main boilers or auxiliary boilers for essential services and each steam-heated steam generator are to have a stop valve and a check valve.

102 The feed water stop valve is to be attached directly to the boiler or to the economiser, if this forms an integral part of the boiler, and the valve neck is to be of sufficient length to clear valve of boiler lagging and sheathing. Where the arrangements necessitate the use of standpipes between the boiler and the valve, these pipes are to be as short as possible, and are to be of substantial thickness. The check valve is to be placed as near the stop valve as practicable.

103 Feed water is to be discharged into the boiler in such a manner that it does not impinge directly on surfaces exposed to hot gases.

104 Standpipes for feed inlets on water-tube boilers with design pressure exceeding 40 bar are to be provided with a thermal sleeve to minimize thermal stresses. Similar arrangements are to be provided for desuperheater inlets and outlets, if the desuperheated steam conditions results in a residual superheat of 60°C or higher at any rating.

105 Each steam outlet, except for safety valves and superheater inlet and reheater inlet and outlet, is to be fitted with a stop valve located as near to the boiler as practicable.

106 Where two or more boilers are connected to a common header or steam manifold, see Ch.6 Sec.5 G300 of the Rules for Classification of Ships.

C 200 Valves on pressure vessels other than boilers and steam-heated steam generators

201 Each pressure pipe is to be fitted with a stop valve located on the shell or as near to the pressure vessel as practicable. In a system of pressure vessels (see B203), each system is to be fitted with stop valves.

D. Blow-down Valves and Test Valves for Boiler Water

D 100 Blow-down valves

101 Each boiler is to be fitted with a blow-down valve secured directly to the shell.

Where this is not practicable for water-tube boilers, the valve may be placed immediately outside the boiler casing with a heavy gauge steel pipe fitted between the boiler and the valve. The pipe and valve are to be adequately supported, and the pipe, if exposed to furnace heat, is to be protected by brickwork or other heat-resisting material, so arranged that the pipe may be inspected and is not to be constrained against expansion.

102 The internal diameter of the valve and its connections to the sea are not to be less than 25 mm and need not exceed 38 mm.

103 Where blow-downs from two or more boilers are connected to a common discharge, see Ch.6 Sec.5 G300 of the Rules for Classification of Ships.

104 Blow-down cocks fitted with taper plugs are to be of the bolted cover type with separately packed glands, and are not to be used with pressures over 13 bar.

D 200 Test valves

201 At least one valve for testing boiler water is to be fitted directly to each boiler in a convenient position. It is not to be fitted on the water-gauge mountings or standpipes.

E. Gauges

E 100 Water gauges

101 Every boiler and steam heated steam generator designed to contain water at specified levels is to be fitted with at least two independent means of indicating the water level, one of which is to be a glass gauge. The other means is to be either an additional glass gauge or an approved equivalent device.

Water and steam drums exceeding 4 metres in length and placed athwartships are to have a glass water gauge at or near each end of the drum.

102 The water level indicators are to be so located that the water level can be ascertained despite the movement and inclination of the ship at sea.

103 The water gauges are to be readily accessible and positioned so that the water level is clearly visible. Water gauges are to be so located that the lowest visible water level in the glass is at the lowest, safe-working water level.

In the case of water-tube boilers, the glass water gauges are to be located so that water is just showing when the water level in the steam drum is just above the top row of tubes when the boiler is cold (generally about 25 mm above). The length of the glass water gauges is to be sufficient for verifying the water levels in case of alarm and oil supply cut-off.

In boilers where all tubes are not entirely submerged in water when cold, the glass water gauges are to be placed to the satisfaction of the surveyor, and in positions which have been found by experience to indicate satisfactorily that the water content is sufficient for safe working.

The combustion chamber top of a cylindrical, horizontal boiler and the furnace crown of a vertical boiler are to be clearly marked in a position adjacent to the glass water gauge. Water gauges are to be fitted with cocks or valves at each end of the glass gauge. The cocks are to be accessible for closing from positions free from danger in the event of the glass breaking.

104 Mountings for glass water gauges are to be fitted directly to the boiler plating or to stand pillars or columns. Stand pillars and columns are to be bolted directly to the boiler shell, but they may also be connected to the boiler by means of pipes. These pipes are to be fitted with terminal valves or cocks secured directly to the boiler shell. Valves and cocks are to have fixed hand-wheels or handles, and are to be provided with means for clearly indicating whether they are open or closed.

The upper ends of pipes, connecting the water gauge column to the boiler, are to be arranged such that there is no pocket or bend where an accumulation of water can lodge. They are not to pass through the uptake if they can be otherwise arranged. If, however, this condition cannot be complied with, they may pass through it by means of a passage at least 50 mm clear of the pipe all round and open for ventilation at both ends.

For cylindrical boilers, the required internal diameter of water gauge pillars, of columns and the pipes connecting them to the boilers is found from Table E1:

Table E1 Internal diameter of column and pipes

Internal diameter of boiler	*Internal diameter*	
	Water gauge column	*Connecting pipe*
Up to 2300 mm	45 mm	25 mm
2300 mm to 3000 mm	50 mm	32 mm
Over 3000 mm	63 mm	38 mm

E 200 Pressure gauges

201 Each boiler and superheater are to be provided with a separate steam-pressure gauge. The gauges are to be placed where they can easily be seen. The highest permissible working pressure is to be marked off on the pressure gauge in red.

SECTION 7 INSTRUMENTATION AND AUTOMATION

A. General

A 100 Cross reference

101 General requirements for instrumentation and automation, see Ch.9. Additional requirements for gas-fired boiler installations on liquefied gas carriers, see the Rules for Classification of Ships Pt.5 Ch.5 Sec.16 C100.

A 200 Oil burner control system

201 Before ignition of first burner, the boiler is to be purged to such an extent that air quantity through the boiler is at least the greater of:

— three times the volume of the flue gas (from the burner to the chimney), or
— five times the furnace volume of the boiler.

This condition is considered as satisfied if the pre-purge is carried out for 15 s, the amount of air being equal to the air flow corresponding to the nominal output of the burner.

Guidance note:
Post-purge after stopping the last burner is advised. This operation does not, however, replace the pre-purge.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

202 If air supply is continuous and above 20% of the air flow at full load, a new ignition after normal stop of burner is acceptable, irrespective of the restrictions given in 201.

203 Ignition of burners is normally to take place at reduced fuel oil supply. Fuel oil is not to be supplied before ignition device produces sufficient energy for safe ignition.

204 The safety device for flame monitoring is to ensure that the safety times given in Table A1, which depend on the oil throughput of the oil burner, are complied with.

Table A1 Safety times

Oil throughput (kg/h)	*Safety times (s) (maximum) 1)*	
	At start-up	*In operation*
up to 30	10	10
above 30	5	1

1) The safety time is the maximum permissible period of time during which the fuel oil may be delivered into the combustion space without a flame burning.

205 Automatic restarting after an unsuccessful ignition is not to take place till after manual resetting. After a flame failure during the operation, manual resetting locally on the control panel is required.

206 During stop of burners, including the pre-purge time before ignition, safe shut-off of fuel oil is to be ensured. If the fuel oil will be under pressure during shut-off of burners, the shut-off device is to be duplicated. A single shut-off device will be accepted if the burners are drained off.

207 The burner(s) are to be equipped with a safety device that shut off the fuel oil supply, when the burners are retracted or swinged out of position.

B. Boilers

B 100 Automatic control

101 When a combustion control system is fitted, the feed water control system is to have a control range at least equal to that of the combustion control system.

During all normal load variations, the water level is to be kept within the dynamic and stationary limits for reliable operation.

Guidance note:
On water tube boilers, the feed-water supply should preferably be continuous, because such boilers have a high rate of evaporation in relation to their water content.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

102 When combustion control systems is fitted, the steam pressure is to be kept within limits appropriate to the steam consuming machinery over the entire control range.

During all normal operating conditions, the air/fuel ratio and the air distribution between burners are to be such that a reliable and nearly complete combustion takes place.

Guidance note:
Routine work, such as cleaning of burners and filters, soot blowing, change over to stand-by pumps, etc. should preferably be possible without switching off the automatic system.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

B 200 Monitoring

201 Monitoring is to be arranged according to Table B1.

202 Boilers which are operated under constant attending, are at least to have alarm and shut-down at low water level and stop of circulation.

203 For main boilers, monitoring is to be according to the Rules for Classification of Ships Pt.6 Ch.3 Sec.3, Table A3.

C. Exhaust Gas Boilers or Economisers

C 100 Instruments and Monitoring

101 Exhaust gas boilers or economisers with extended surface water tubes are, in addition to the monitoring given in Table B1, to be monitored as listed below:

— Stand-by circulating pump, when required according to Sec.3 D101, to be equipped with automatic start activated by low flow in the circulating system. Alarm to be given when the pump is started.
— Soot cleaners, when required in Sec.3 D201, are to be equipped with automatic start and arranged for sequential operation.
— Alarm for high gas temperature located after the exhaust gas boiler or economiser. The alarm to be given in case of soot fire.

D. Water Heaters

D 100 Monitoring

101 Monitoring is to be arranged according to Table D1.

E. Thermal-oil Heaters

E 100 Automatic control

101 Automatic control of thermal-oil outlet temperature is to to be able to keep the oil temperature within the limits for safe operation under all load conditions.

102 The temperature set point is to be at a sufficiently low level to keep all peak temperatures, dependent on regulating system transients or on heat transfer functions, below the safe temperature limit of the thermal oil.

E 200 Monitoring

201 Monitoring is to be arranged according to Table E1.

E 300 Indication

301 Thermal-oil heaters are to be equipped with instruments for continuous indication of:

— total thermal-oil flow at heater outlet
— pressure drop in thermal-oil between heater inlet and outlet
— thermal-oil temperature at heater outlet and inlet
— flue gas temperature.

F. Incinerators

F 100 Monitoring

101 Monitoring to be arranged according to Table F1.

Table B1 Monitoring of oil fired auxiliary boilers

Item		*Alarm and safety action (stated by an x)*		*Comments*
		Alarm	*Automatic shutdown of boiler with alarm*	
Water level, not double pressure boiler	Level low	x		Independent of safety system
	Level lower		x	
	Level high	x		
Water level double pressure boilers	Primary system low	x		Independent of safety system
	Primary system lower		x	
	Secondary system low	x		
	Secondary system high	x		
Circulation	Stopped		x	Forced circulation boilers
Combustion air supply	Fan stopped		x	
Heavy fuel oil	Temperature or viscosity high	x		
	Temperature or viscosity low	x		
Steam	Pressure high	x		
	Pressure higher		x	When the automatic control system does not cover the entire load range from zero load.
	Temperature high		x	For superheated steam >350°C
Flame	Failed ignition and/or flame failure		x	Each burner to have separate monitoring device and individual shut-off

Table D1 Monitoring of oil-fired water heaters

Item		*Alarm and safety action (stated by an x)*	*Comments*
		Automatic shutdown of heater with alarm	
Water level	Level low	x	
Water temperature	Temperature high	x	
Flame	Failed ignition and/or flame failure	x	Each burner to have separate monitoring device and individual shut-off

Table E1 Monitoring of oil-fired thermal-oil heaters

Item		*Alarm and safety action (stated by an x)*		*Comments*
		Alarm	*Automatic shutdown of oil burner with alarm*	
Thermal-oil	Temperature outlet high		x	
	Flow low		x	Separate for each coil 1)
	Pressure low		x	
Flue gas	Temperature high		x	
Expansion tank	Level low		x	
	Temperature high	x		
Forced draught	Fan stopped		x	
Heavy fuel oil	Temperature or viscosity high	x		
	Temperature or viscosity low	x		
Flame	Failed ignition and/or flame failure		x	Each burner to be monitored, and be fitted with separate automatic shut-off valves

1) Alternatively, the temperature detection for each coil and common low flow detection, may be accepted.

Table F1 Monitoring of oil-fired incinerators

Item		*Alarm and safety action (stated by an x)*		*Comments*
		Alarm	*Automatic shutdown of incinerator with alarm*	
Flue gas	Temperature high		x	
	Fan stopped		x	If installed
Combustion chamber	Temperature high		x	
Forced draught	Fan stopped		x	Includes also additional auxiliary fan
Heavy fuel oil	Temperature or viscosity high	x		
	Temperature or viscosity low	x		
Flame	Failed ignition and/or flame out		x	Each burner to be monitored, and be fitted with separate automatic shut-off valve

SECTION 8 MANUFACTURE, WORKMANSHIP AND TESTING

A. Manufacture

A 100 General

101 Class I and II pressure vessels are to be manufactured by works approved by the Society.

102 Welding is to be carried out by approved welders, see Pt.2 Ch.3 Sec.3, and in accordance with approved drawings and specifications.

For class I and II pressure vessels, welding procedures are to be qualified as specified in Pt.2 Ch.3 or according to a recognised code.

B. Workmanship

B 100 Cutting of plates

101 Flame-cutting of the plates is normally to be used. Shearing of plates is not to be used, unless the sheared edge is removed by machining for a distance of one quarter of the plate thickness, minimum 3 mm.

B 200 Welded joints

201 Only full penetration butt welds are acceptable for longitudinal and circumferential main joints. Circumferential main joints other than butt welds are acceptable for shell to flat end and to tube plate connections, see Sec.5.

202 The joints are to be welded from both sides of the plates unless otherwise approved.

Circumferential joints in headers, pipes and tubes may be welded from one side only with or without backing strip. The design of the joint and the method of welding are to provide full penetration, and it is to be demonstrated to the satisfaction of the surveyor that the welding method gives a weld free from significant defects. If a backing strip is used, it is to be removed after welding and prior to any required non-destructive tests.

However, permanent backing strips can be accepted for circumferential welds when the second side is inaccessible for welding and the following conditions are satisfied:

— class III pressure vessels, or class II when the cylindrical part is seamless
— welding procedures are qualified with backing strip
— non-corrosive media.

203 Wherever practicable, no attachment is to be welded on in the immediate vicinity of a welded joint. If this cannot be avoided, the welds are to cross each other completely.

204 Where ends are made of welded plates, the welds are to be so arranged that they are exposed to the least possible stress. Welded joints passing through flanged curvatures are to be at right angles to these.

205 Unless the pressure vessel is stress-relieved after welding (see C100), not more than two weld seams are to meet at one point.

Guidance note:
Whenever possible, openings in or near welded joints should be avoided.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

206 Before welding is commenced, it is to be ascertained that the plate edges are in alignment within the following limits:

— 10% of the plate thickness with a maximum of 3 mm for longitudinal joints
— 10% of the plate thickness plus 1 mm with a maximum of 4 mm for circumferential joints.

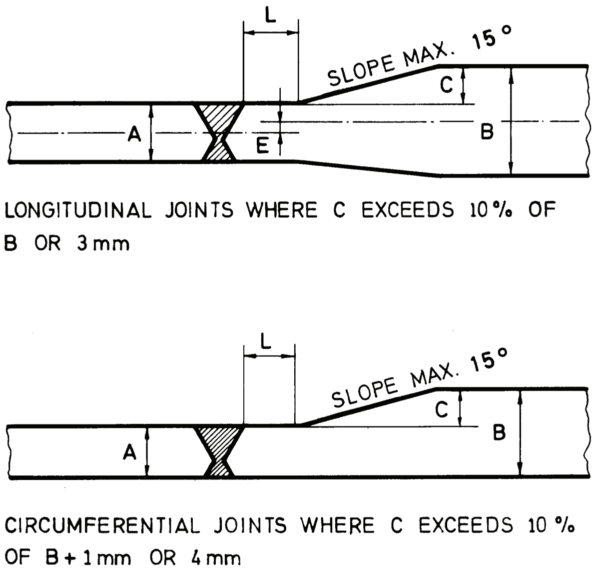


Fig. 1
Welded joints

207 If the plates are of unequal thickness, and the difference between the surfaces exceeds that given in 206 for the thicker plate, the thicker plate is to have a smooth taper with a slope not exceeding 15°, see Fig.1.

Guidance note:
In the case of pressure vessels for which full radiographic examination is required, it is advised that the thicker plate be made with a parallel section of the same thickness as the thinner plate. The width L of this parallel section should be at least 30 mm. E is not to exceed 10% of B. The greatest acceptable value of E is 3 mm.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

208 Wherever practicable, the welding is to be carried out in the downhand position. In the case of circumferential joints in cylindrical shells, means are to be adopted to ensure compliance with this requirement.

209 Welds are to have a smooth finish and are to merge into the plate without abrupt irregularity. The surface of the weld metal is at no point to fall below the surface of adjoining plates. The reinforcements of the weld are not to exceed 20% of the plate thickness, with a maximum of 4 mm on either side of the plate.

B 300 Tolerances for shells

301 Shells for class I and II welded pressure vessels are to be within the limits for out-of-roundness and local departure from circularity after heat treatment has been carried out as given in 304 and 305 respectively.

302 The measurement of out-of-roundness may be carried out either when the shell is laid flat on its side or when set up on end. When the shell is checked whilst lying on its side, each measurement for diameter is to be repeated after turning the shell through 90° about its longitudinal axis. The two measurements for each diameter are to be averaged, and the amount of out-of roundness calculated from the average values so determined.

303 Measurements may be made on the inside or outside of the shell. If the shell is made of plates of unequal thicknesses, the measurements are to be corrected for the plate thickness to determine the diameters at the middle line of the plates.

304 The difference between the maximum and minimum diameter at any cross section of a shell welded longitudinally, is not to exceed 1% of the nominal internal diameter, D, with a maximum of:

$$\frac{D + 1250}{200} \quad \text{(mm)}$$

305 There is to be no flat or peak at joints, and any local departure from circularity is to be gradual.

Irregularities in profile, checked by a 20 degree gauge, are not to exceed 5% of the plate thickness plus 3 mm. This maximum value may be increased by 25%, if the length of the irregularities does not exceed the lesser of 1 metre and one quarter of the length of the shell between two circumferential joints.

B 400 Fitting of tubes

401 The tube holes in water tube boilers are to be made in such a way that an effective tightening of the tubes is attained. Where the tube ends are not normal to the tube plates, there is either to be a neck or the tube hole ends are to be made parallel for a depth of at least 13 mm, measured in a plane through the axis of the tube at the hole. Where the tubes are practically normal to the tube plates, the depth of this parallel seating is not to be less than 10 mm.

The tubes are to be carefully fitted in the holes by means of expanding and belling, expanding and welding, strength welding or by other approved methods. The tubes are to project through the neck or bearing part of the holes by at least 6 mm. They are to be secured to prevent drawing out at each end, and if this is done by bell-mounting only, the included angle of belling is not to be less than 30°.

402 The tubes in smoke tube boilers are to have their ends firmly expanded and flared, expanded and beaded, expanded and welded or strength-welded.

403 If tubes are welded to the tube plate in accordance with Fig.12 and 13 in Sec.5, the unwelded portion of the tube within the tube hole is to be in full contact with the tube plate.

B 500 Doors and plugs

501 Doors and crossbars are to be of steel, and jointing surfaces are to be machined. Doors in boilers are to be of the internal type. The clearance between the manhole frame and the spigot or recess is not to exceed 1.5 mm all round.

502 For smaller circular openings in headers and similar fittings, a suitable type of plug may be used.

C. Heat Treatment

C 100 Post-weld heat treatment

101 Pressure vessels including boilers are to be thermally stress relieved after welding when the material thicknesses at any welded connection exceed the limits given in Table C1 for the steel grade in question.

Vessels intended for service with fluids liable to cause stress corrosion cracking in service are to be stress relieved independent of material thickness.

102 When welded joints connect parts of different thickness, the thickness to be considered in applying the limits given in Table C1 for heat treatment after welding is to be:

— the thinner of two adjacent butt-welded plates including dished end and flanged plate to shell connections
— where flat plates are inset into the shell: the greater of the thickness of the shell and 2/3 of the thickness of the flat plate
— the thickness of shell or flat plate, as appropriate, in nozzle or pad attachment welds
— the thickness of nozzle neck at joint in nozzle neck to flange connections
— the thickness of pressure part, at point of attachment where a non-pressure part is welded to a pressure part.

103 The heat treatment is to be carried out after welding of the seams and of all attachments to the shell and ends prior to the hydraulic pressure test.

104 Wherever possible, pressure vessels are to be heat treated by heating as a whole in an enclosed furnace. The furnace is to be fitted with instruments for measuring and recording the actual temperatures of the vessel during the heat treatment process.

105 Where it is found necessary to adopt special methods of heat treatment, full particulars are to be submitted for consideration.

106 Thermal stress relieving is to be carried out by heating the vessel uniformly and slowly to a suitable temperature, followed by cooling slowly and uniformly in the furnace to a temperature not exceeding 400°C. Below this temperature the vessel may be cooled in still air. Suitable soaking temperatures and time at temperature are stated in Table C2.

The heating and cooling processes and the soaking period are to be recorded in a temperature-time diagram.

C 200 Heat treatment of plates after hot or cold forming

201 For components which have been hot formed or locally heated for forming, the following requirements apply:

Components of carbon and carbon-manganese steels, NV 0.3 Mo, NV 1 Cr 0.5 Mo and NV 2.25 Cr 1 Mo are to be normalised on the completion of the operation, except that the heat treatment may be omitted if the forming operation has been carried out at a temperature within the normalising range.

The steel grades NV 1 Cr 0.5 Mo and NV 2.25 Cr 1 Mo are in addition to be tempered.

202 Components which have been cold formed are to be heat treated on the completion of the operation in the following cases:

— Components intended for low temperature service, if the cold forming introduces a plastic deformation exceeding 3%.
— Components for other applications if the cold forming introduces a plastic deformation exceeding 5%.

Carbon and carbon-manganese steels are to be normalised. NV 1 Cr 0.5 Mo and NV 2.25 Cr 1 Mo are to be normalised and tempered. In special cases a stress relieving heat treatment may be accepted in lieu of normalising. In such cases testing of the material in cold formed and aged condition may be required.

Table C1 Post-weld heat treatment

Steel grade	*Plate thicknesses above which post-weld heat treatment is required*	
	Boilers	*Unfired pressure vessels*
NV 360-0A-0N NV 410-0A-0N NV 460-0A-0N NV 490-0A-0N	20 mm 20 mm 20 mm 20 mm	30 mm 30 mm 30 mm 30 mm
NV 360-1 FN NV 410-1 FN NV 460-1 FN NV 490-1 FN NV 510-1 FN	20 mm 20 mm 20 mm 20 mm 20 mm	38 mm 38 mm 38 mm 38 mm 38 mm
NV 0.3 Mo	20 mm	
NV 1 Cr 0.5 Mo NV 2.25 Cr 1 Mo	All thicknesses to be heat treated	

Table C2 Soaking temperatures and time at temperature

Steel grade	*Soaking temperature °C*	*Time at soaking temperature*
C and C-Mn steel grades	520 - 580	60 minutes per 25 mm thickness. Minimum 30 minutes
NV 0.3 Mo	530 - 580	
NV 1 Cr 0.5 Mo	600 - 650	
NV 2.25 Cr 1 Mo	650 - 700	

C 300 Heat treatment of tubes after bending

301 Tubes are to be heat treated after bending when required in Ch.6 Sec.7 C of the Rules for Classification of Ships.

D. Testing

D 100 Extent of non-destructive testing (NDT)

101 For class I pressure vessels, non-destructive testing is to be carried out as follows:

a) All longitudinal butt welded joints in drums, shells and headers are to be subjected to 100% radiographic testing.

b) 25% of the length of circumferential butt welded joints in drums, shells and headers are to be subjected to radiographic testing.

c) 10% of the total number of circumferential butt welded joints in pipes and tubes are to be subjected to radiographic testing.

d) For set-in flat plates the cylindrical shell is to be ultrasonically tested for lamellar tearing in way of the circumferential weld to the flat plate. For shell plate thickness 15 mm and less the extent of testing is to be at least 10% and for greater thickness at least 20% of the total length of the weld. The internal fillet weld, see Fig.8 in Sec.5, is to be 100% magnetic particle tested for surface flaws.

e) For standpipes and branches with outside diameter exceeding 100 mm, all weld connections to shell and reinforcement rings are to be subjected to magnetic particle testing. For outside diameters 100 mm and less, spot testing is to be carried out. The magnetic particle testing is also to cover weld joints between reinforcement rings and shell.

f) All welded joints are to be subjected to visual inspection.

102 For class II pressure vessels, non-destructive testing is to be carried out as follows:

a) Longitudinal butt weld joints in drums, shells and headers are to be subjected to radiographic testing at the rate of 20% of the length. All crossings between longitudinal and circumferential joints are to be included in the testing.

b) All welded joints are to be subjected to visual inspection.

103 For class III pressure vessels, all welded joints are to be subjected to visual inspection.

104 For furnaces and fireboxes non-destructive testing is to be carried out as follows:

a) 10% of the length of longitudinal butt welded joints are to be subjected to radiographic examination.

b) 10% of the length of circumferential butt welded joints are to be subjected to radiographic examination.

c) 25% of the length of T-welds and corner welds are to be subjected to ultrasonic examination.

105 For non-ferromagnetic materials or materials with changes in magnetic permeability liquid penetrant testing replaces magnetic particle testing in 101.

106 For carbon and carbon-manganese steels of grades given in Pt.2 Ch.2 Sec.2 Table B1 with thickness less than 38 mm, the radiographic and ultrasonic testing may be carried out before post-weld heat treatment. Magnetic particle or liquid penetrant testing is to be carried out when all heat treatment has been completed.

Ultrasonic testing may be used in lieu of radiographic testing for thicknesses equal to or above 10 mm, and shall be carried out as specified in written procedures established in accordance with Classification Note No. 7 or recognised standards.

107 The requirements for NDT of welded joints for thermal oil piping can be found in Pt.4 Ch.6 Sec.7 A500 of the Rules for Classification of Ships.

D 200 Performance of non-destructive testing (NDT)

201 For carbon and carbon-manganese steel with thicknesses greater than 30 mm and for alloy steels the non-destructive testing is normally to be carried out not earlier than 48 hours after completion of the welds in question. For carbon and carbon-manganese steels with thicknesses 30 mm and less the time limit may be reduced to 24 hours.

202 NDT is to be performed by qualified operators. The qualification and certification of NDT-operator is to be in accordance with a recognised certification scheme accepted by the Society.

203 Radiographic testing is to be carried out as specified in Table D1.

Table D1 Radiographic testing

Item	*Requirement*
Radiation source	For steel thickness $t < 19$ mm, x-rays are preferably to be used. For $t \geq 19$ mm, Ir 192 isotope may be used.
Film	Fine grained (BAM class G II, ASTM/ ASME class 2 or equivalent or better).
Screens	0.02 mm Pb or more if insufficient.
Geometric unsharpness	Maximum 0.3 mm.
Density	1.8 to 3.0 on weld.
Image quality indicator (IQI)	Wire type (see doc. IIW/IIS-62-60). Other types of IQI's may be accepted, provided they comply with nationally accepted standards.
Required IQI sensitivity	See Fig.2.

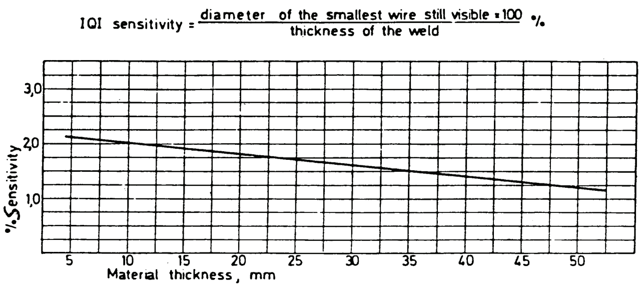


Fig. 2
Required IQI sensitivity. Source side parameter

204 For ultrasonic testing the following apply:

The welded connections in question are to be tested for laminations, transverse and longitudinal defects in accordance with the procedures and technique described in Classification Note No. 7.

205 For magnetic particle testing the following apply:

The object may be directly or indirectly magnetised.

AC yoke or prods are to be used. Care is to be taken to avoid local heating of the test surface. Prods are to be of the type «soft prods», lead tipped or aluminium alloy.

Use of permanent magnets is not permitted.

Required magnetic field strength:

$$2.4 - 4.0 \quad \frac{\text{kA}}{\text{m}}$$

The testing is on each area to be performed with the magnetic field shifted in at least two directions approximately perpendicular to each other.

206 For liquid penetrant testing the following apply:

Coloured or fluorescent water washable penetrants are to be used.

For smooth (flush grinded welds) post emulsifying or solvent removable penetrants may preferably be used.

The surface temperature during testing is to be within the temperature range 15 to 35°C, if not, a procedure qualification test is to be carried out.

The penetration time is to be at least 15 min.

D 300 Acceptance criteria for non-destructive testing and repair of defects

301 Normally the welds are at least to meet the requirements stated in Tables D2, D3 and D4.

As the test methods differ in their limitations and/or possibilities of recording and documentation, special acceptance criteria are given for each method where necessary.

Alternative evaluations ensuring an equivalent level of quality may in special cases be considered.

302 If indications of defects reach or pass the reference curve during ultrasonic test, the defects are to be repaired, unless otherwise stated in the Tables D2, D3 or D4.

Table D2 Radiographic testing

Type of defects	*Acceptance criteria*
Porosity [1) 2)] Isolated: Largest pore diameter in mm: Cluster: Largest pore diameter in mm: Maximum length along the weld of projected area in mm:	 t/4, maximum 4 3 25
Slag inclusion [1) 3)] Maximum width in mm: Maximum length in mm:	 t/4, maximum 3 t/2, maximum 25
Incomplete penetration	Not accepted
Lack of fusion	Not accepted
Cracks	Not accepted

t = the parent metal thickness. In case of dissimilar thicknesses, t applies to the thinner component.

1) If the distance between the similar defects (pore or slag) is less than the largest extent of one or more of the defects, it is regarded as one continuous defect.
If the amount of pores or slag may mask other defects, the examination is to be substituted by ultrasonic testing.

2) If the distance between pores is less than 3 times the diameter, the pores are said to form a line or cluster. Pores on a line must not be located in the weld surface.

3) Defects of lengths in the direction of the weld exceeding 3 times their width form a line. If the distance between slag lines is less than 3 times the largest extent of the cross section of the defect, the lines are considered as one defect, see Fig.3.

Table D3 Ultrasonic testing [1)]

Indication	*Acceptance criteria*
Echo height above: Maximum length [1)], mm:	100% t/2, maximum 10

1) Length is defined as a distance where indication reach or pass the stated percentage of reference level.
Cracks in transverse weld direction is not acceptable regardless of echo height above 20% of reference level.

Table D4 Visual, magnetic particle and liquid penetrant testing

Type of defect	*Acceptance criteria*
Incomplete penetration or lack of fusion	Not accepted
Cracks	Not accepted
Undercut, maximum depth, mm	0.3 [1)]

1) Provided round shape and insignificant notch effect (regardless of length).

Indications reaching a level of between 50% and 100% of the reference curve are to be evaluated in relation to the welding process, groove geometry etc. If such an evaluation indicates a possibility of two-dimensional defects (crack, lack of fusion etc.) all defects without exact identification larger than 10 mm are to be repaired.

Indications exceeding 20% of the reference curve and having an extent larger than 10 mm are to be reported for consideration if there is a possibility of two-dimensional defects.

303 NDT is to be reported, and all essential control parameters are to be given.

304 Defects which exceed the acceptance limits are to be completely removed and repaired according to an approved repair procedure. Magnetic particle testing is normally to be used to ensure complete removal of defects prior to repair welding.

305 When unaccepted defects are found in areas with less than 100% testing, the extent of testing is increased with the double. If this increased testing reveal more defects, the entire length of the weld is to be tested.

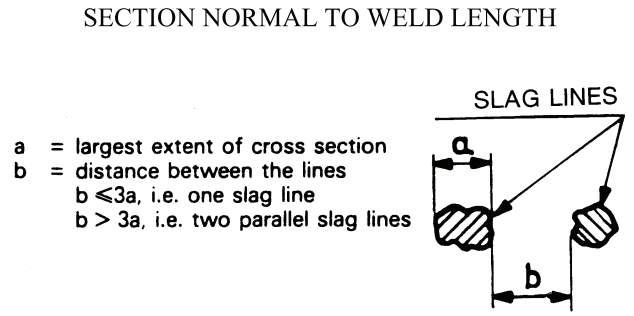


Fig. 3
Slag line(s)

D 400 Welding production test (WPT)

401 For class I pressure vessels, welding production test (WPT) is to be performed for approximately each 50 m of longitudinal welded joint. For large units, having more than 50 m of longitudinal welded joint, the number of tests may be reduced to one for each 100 m of production welded joint, provided the tests show uniform and satisfactory results. In any case at least one WPT is to be carried out for each vessel.

402 For class II pressure vessels with shell thickness equal to or greater than 16 mm, one WPT representing the longitudinal welded joints is to be performed for each vessel. Where similar vessels are produced in series, one WPT may represent a test group of 5 vessels, but not more than 50 m of production weld joint. In such cases, the plate thicknesses in the test group are not to differ by more than 5 mm and the thickest plate is to be used for preparation of the test assembly.

403 WPT for circumferential seams is not required, except where a pressure vessel has circumferential joints only or where the process for welding the circumferential joints is significantly different from that used for the longitudinal joints. In such cases the number of tests is to be the same as specified for longitudinal weld joints in 401 and 402.

404 The test assembly for WPT consists of two plates, and each plate is to have a width of minimum 150 mm. The length is to be sufficient for making all test specimens required according to 410 and for possible retest purposes. Plates for the test assembly are to be cut from the plates forming the appropriate part of the vessel, and are to be stamped by the surveyor before being detached. Alternatively the test plates may be cut from another plate from the same cast, with the same thickness and in the same heat treatment condition as the plate used for the vessel.

405 For longitudinal welded joints, the two plates forming the test assembly are to be tackwelded to the vessel and welded together so that the joint of the test plates forms a direct continuation of the production weld joint. The orientation of the test plates is to be so that the rolling direction is parallel to the rolling direction of the adjacent plates of the vessel.

406 For circumferential joints the joint of the test assembly is as far as possible to be a simultation of the production weld.

407 The welding of the test assembly is to be carried out at the same time as the production welding and by the same welder, using the same welding parameters.

408 The test assembly is to be heat treated together with the vessel or one of the vessels which it represents.

409 The weld deposit is to be machined flush with the plate surface on both sides of the test assembly.

410 The following tests are required from each test assembly:

— one root and one face bend test when plate ≤10 mm thick
— two side bend tests when plate >10 mm thick
— Charpy V-notch impact tests with the notch located in the centre of the weld and in the fusion line
— macrosection examination.

In addition one butt weld tensile test is required from one test assembly for each vessel. Where one test assembly represents more vessels, only one tensile test is required. The necessary test specimens are to be cut from the welded test assembly as shown in Fig.4.

411 Bend tests are to be performed as described in Pt.2 Ch.3 Sec.5 E201.

412 Six Charpy V-notch impact test specimens are to be cut transversely to the weld with the center of the specimen as near as practicable to a point midway between the surface and the center of the thickness. Three specimens are to be located with the notch in the center of the weld and three specimens with the notch in the fusion line. The average value and single specimen values for absorbed energy in fusion line are normally to be in accordance with the transverse and longitudinal requirements of the base material, whichever is applicable. The results of weld metal impact tests are to be in accordance with the transverse test requirements given for the base material.

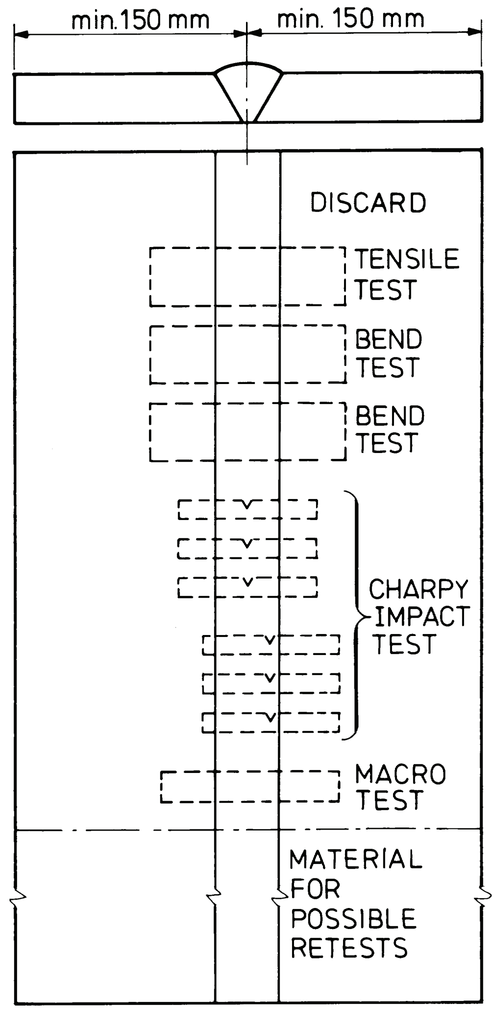


Fig. 4
Welding production tests (WPT)

Impact tests which do not meet the prescribed energy requirements in fusion line may still be accepted provided drop-weight tests are carried out with satisfactory results. When drop-weight test is used, two test specimens from the weld are to be tested and both specimens are to show no-break performance.

Where the thickness of the material does not permit standard Charpy V-notch test specimens with width 10 mm, the largest obtainable of subsize specimens with width 7.5 or 5 mm is to be used. In that case the requirement on absorbed energy will be reduced to respectively 5/6 and 2/3 of the value specified for standard test specimens.

413 The complete cross section of the welded joint is to be etched for macro-examination. Cracks or lack of fusion are not accepted.

414 The butt weld tensile test specimen is to be in compliance with Pt.2 Ch.3 Sec.5 K201, type B for testing of the weld as a whole. Where the thickness of the plate exceeds 30 mm, the tensile test may be performed using several test specimens, each with a thickness of at least 30 mm. The whole thickness of the joint is to be tested.

The tensile strength obtained is to be not less than the minimum tensile strength required for the plate material.

D 500 Hydraulic test

501 On completion, boilers are to be tested to a pressure of 1.5 times the calculating pressure.

502 As an alternative to the test prescribed in 501 the following pressure tests may be carried out for boilers where feasible:

Each component of the boiler is to be tested on completion of the work, including heat treatment, to 1.5 times the calculating pressure. In the case of drums and headers fitted with tubes, this test may be made before drilling tube holes, but after the attachment of nozzles and similar fittings. When all components have been tested as prescribed above, the completed boiler is to be tested to 1.25 times the calculating pressure.

503 Pressure vessels other than boilers are to be tested on completion to 1.3 times the calculating pressure.

504 The pressure test shall be such that it does not result in general membrane stress in any part of the vessel during the test exceeding 90% of the lower yield stress at room temperature.

505 Hydraulic testing is to be performed in the presence of a surveyor, unless otherwise agreed. The test pressure shall be applied and maintained for at least 30 minutes to permit visual examination of all surfaces and joints. The vessel shall exhibit no sign of general plastic yielding or leakage.

506 Thermal-oil installations, with their system vessels, headers, heat exchangers etc. are to be pressure tested to 1.5 times the calculating pressure, minimum 10 bar, the test being carried out at the manufacturers.

After assembly, but before insulation work on board commences, a pneumatic tightness test with a pressure of 1.5 to 2 bar is to be performed.

507 Mountings are to be tested by hydraulic pressure twice the approved calculating pressure, with the exception of feed check and feed stop valves for boilers and steam-heated steam generators, which are to be tested to 2.5 times the approved calculating pressure, or twice the maximum pressure which can be developed in the feed line in normal service, whichever is the greater. The test pressure need not exceed the working pressure by more than 70 bar.

D 600 Performance test

601 After installation on board, boilers and steam-heated steam generators are to be function tested. The test is to include the instrumentation, automatic equipment and remote control systems. For boiler accumulation test, see Sec.6 B113.

602 Thermal-oil heating installations are to be function and capacity tested according to an approved test programme.

The test procedure is to include flow measurements for each coil, covering the whole range of heater loads. The heater system charge is to be a thermal-oil which will allow maximum heater rating to be tested.

603 Incinerators of new design are to fulfil an approved test program before installation. All incinerators are to undergo a test run in the presence of the surveyor after installation on board.

E. Marking

E 100 General

101 Each boiler and pressure vessel is to be permanently and legibly marked on the boiler or vessel or on a nameplate permanently attached to a principal pressure part to show its identity and origin.

102 The marking is to show the following particulars:

a) the name and domicile of the manufacturer
b) the manufacturer's type designation and serial number
c) the year of manufacture
d) the design pressure
e) the design temperature (s) in °C
f) the hydraulic test pressure
g) DNV's identifying mark.

APPENDIX A
TYPES AND MINIMUM DIMENSIONS OF THE INSPECTION OPENINGS IN BOILERS AND PRESSURE VESSELS

A. Definitions and Dimensions

A 100 Examination holes

101 *Sight-hole*s are holes whose inside diameter is at least 50 mm (1.97 in) and whose neck height does not exceed 50 mm (1.97 in).

102 *Hand-hole*s are holes into which a lamp can be inserted. A hand-hole is to have a width of span of at least 80 x 100 mm (3.15 x 3.94 in) or an inside diameter of 100 mm (3.94 in). The height of the neck or ring is not to exceed 65 mm (2.45 in) and in the case of a conical shape 100 mm (3.94 in). If only one hand-hole is provided, it is not to be less than 100 x 120 mm (3.94 x 4.02 in).

103 *Head-holes* are holes into which the head, an arm and a lamp can be introduced simultaneously. Their dimensions are to be at least 220 x 320 mm (8.66 x 12.60 in) or 320 mm (12.60 in) in inside diameter. The height of the neck or ring is not to exceed 100 mm (3.94 in).

104 Where neck heights exceed the limiting values given in 101 to 103, the size of hole is to be increased to give an adequate inspection facility.

A 200 Man-holes

201 *Man-holes* are holes permitting entry and exit of a person not carrying any auxiliary equipment. They are not to be less than 300 x 400 mm (11.81 x 15.75 in) or 400 mm (15.75 in) in inside diameter. Where the neck height of a man-hole is excessive, the size of the man-hole is to be suitably increased.

Guidance note:
The number, type and locations of openings should be as given in Table A1.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

Table A1 Examination holes and man-holes for pressure vessels or boilers

No.	*Internal diameter*	*Form of vessel*	*Types and number of holes*
1	450 mm (17.72 in) and less	Length of cylindrical body or diameter of spherical shape up to 1500 mm (59.1 in) inclusive	2 SIGHT-HOLES. Where the length is more than 1500 mm (59.1 in), additional sight-holes are to be provided.
2 a)	More than 450 mm (17.72 in) up to 800 mm (31.50 in) inclusive	Length of cylindrical body or diameter of spherical shape up to 1500 mm (59.1 in) inclusive	1 HAND-HOLE suitably placed or 2 SIGHT-HOLES, in the case of a cylindrical body the latter could each be sited either near the ends (within sight of the longitudinal joint and of the base) or else at the centre of the ends.
2 b)		Length of cylindrical body greater than 1500 mm (59.1 in) up to 2000 mm (78.7 in) inclusive	1 HEAD-HOLE in the central third of the length of the cylindrical body or 2 HAND-HOLES each located either near or on the ends.
2 c)		Length of cylindrical body greater than 2000 mm (78.7 in)	The number of inspection holes is to be increased accordingly. For a length of less than 3000 mm (118 in) it is, however, sufficient to site a head-hole in the centre of the cylindrical body. On the cylindrical body the greatest distance between the head-holes is not to exceed 3000 mm (118 in), those between hand-holes 2000 mm (78.7 in). The latter is each to be located either near or in the ends.
3 a)	More than 800 mm (31.50 in) up to 1500 mm (59.1 in) inclusive	Length of cylindrical body or spherical shape up to 2000 mm (78.7 in)	1 HEAD-HOLE (in the case of a cylindrical body this is located in the central third of its length) or 2 HAND-HOLES near or in the ends.
3 b)		Length of cylindrical body more than 2000 mm (78.7 in)	1 MAN-HOLE or siting of inspection holes as in the case of 2c) above.
4	More than 1500 mm (59.1 in)	Length of cylindrical body unlimited	1 MAN-HOLE.