



RULES FOR  
CLASSIFICATION OF

# SHIPS / HIGH SPEED, LIGHT CRAFT AND NAVAL SURFACE CRAFT

NEWBUILDINGS

MACHINERY AND SYSTEMS  
MAIN CLASS

PART 4 CHAPTER 7

## PRESSURE VESSELS

JANUARY 2009

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# CHANGES IN THE RULES

## General

The present edition of the rules includes additions and amendments decided by the Board as of December 2008, and supersedes the January 2003 edition of the same chapter, including later amendments.

The rule changes come into force as indicated below.

This chapter is valid until superseded by a revised chapter.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.

## Main changes coming into force 1 July 2009

### • General

- The previous title of this booklet “Boilers, Pressure Vessels, Thermal-Oil Installations and Incinerators” has been replaced by “Pressure Vessels”.

### • Sec.1 General Requirements

- Sub-section B: The definition of a boiler has been adjusted also to include the alternative electric heating.
- Table B1: The references to austenitic stainless steels have been removed, and "Plate heat exchangers" under "Other pressure vessels"/ Class III has been included.
- Sub-section element C400 “Incinerators” has been deleted.
- Previous sub-section D has been replaced by new sub-section D and sub-section E, which are a completely update.

### • Sec.2 Materials

- Sub-section elements A100 and A200 have been updated with regard to plate heat exchangers.

- Items A206 and 207 have been corrected to align with Pt.2 Ch.2.
- Sub-section element A300 “Valves and fittings” has been removed, being covered by Ch.6.

### • Sec.3 Arrangement

- Sub-section C “Incinerators” has been deleted.

### • Sec.4 General Design Requirements

- In item D305, the factor 0.75 has been changed to 0.6.
- In item F101, a reference to Table F1 has been added regarding the minimum wall thickness requirements. Item F104 has been deleted.

### • Sec.5 Particular Design Requirements for Boilers

- In item D205 and item D603, the factor 0.75 has been changed to 0.6.

### • Sec.6 Mounting and Fittings

- In item B101, the requirement for number of safety valves has been changed to 2, independent of heating surface.
- In item B113, the accumulation test requirements have been revised.

### • Sec.7 Instrumentation and Automation

- Sub-section F and Table F1 “Monitoring of oil fired incinerators” have been removed.

### • Sec.8 Manufacture, Workmanship and Testing

- Item D603 has been deleted.

## Corrections and Clarifications

In addition to the above stated rule requirements, a number of corrections and clarifications have been made to the existing rule text.

Comments to the rules may be sent by e-mail to [rules@dnv.com](mailto:rules@dnv.com)

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## 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  $pV \geq 1.5$

$p$  = design pressure in bar  
 $V$  = volume in  $m^3$

- thermal-oil installations.

**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
- oil fired water heaters.

#### A 200 Cross-references

**201** Pressure vessels for liquefied gases shall 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, shall be graded as class I pressure vessels. However, the selections of materials, qualification of welding procedures and production weld tests shall 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, shall meet the requirements of Ch.7.

Boiler installations on liquefied gas carriers with gas operated machinery shall 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.

Superheaters, economisers, reheaters and other pressure parts including valves and fittings, connected directly to the boiler without intervening valves, shall 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.

#### 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
$\sigma_t$	=	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 shall 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 shall 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 shall 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.

<b>Table B1 Grading of pressure vessels</b>				
<i>Class</i>	<i>Boilers</i>	<i>Steam generators</i>	<i>Other pressure vessels</i>	<i>Material limitations</i>
I	$p > 3.5$	$p > \frac{15000}{D_i + 1000}$	$p > 50^1)$ or $t > 38$	All grades permitted
II <sup>2)</sup>	$p \leq 3.5$	$p \leq \frac{15000}{D_i + 1000}$	$\frac{20000}{D_i + 1000} < p \leq 50$ or $16 < t \leq 38$ or material design temperature $> 150^\circ\text{C}$	Carbon and carbon-manganese steels <sup>3)</sup> shall have a specified minimum tensile strength $\leq 520 \text{ N/mm}^2$
III <sup>2)</sup>			Pressure vessels not included in class I and II condensers, vacuum and atmospheric and plate heat exchangers	Carbon and carbon-manganese steels <sup>3)</sup> shall have a specified minimum tensile strength $< 460 \text{ N/mm}^2$

$p$  = 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  $100^\circ\text{C}$  or fluids with temperature above  $220^\circ\text{C}$  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 steels, the limitations for use in class II and III pressure vessels will be specially considered, taking into account the weldability of the materials.

<b>Table B2 Requirements to different classes of pressure vessels.</b>								
<i>Class</i>	<i>Approved manufacturer</i> Sec.8 A101	<i>Material certificates</i>	<i>Visual and dimensional inspection</i>	<i>Welding procedure qualification</i> Sec.8 A102	<i>Non-destructive testing</i> Sec.8 D100	<i>Heat treatment</i>	<i>Welding production tests</i> Sec.8 D400	<i>Hydraulic test</i> 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 $t \geq 16 \text{ mm}$	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
- oil fired hot water heaters.

For requirements to documentation, see Ch.9.

### C 200 Boilers and pressure vessels

**201** The following plans shall 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 shall 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  $95^\circ\text{C}$ .

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

### C 300 Thermal-oil installations

**301** The following plans shall 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 shall be submitted on request:

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

**302** The plans shall 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 shall 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 shall be submitted for approval:

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

### **D. Cylinders for Hydraulic Systems**

#### **D 100 General**

**101** Cylinders under this chapter are defined to be accumulators for hydraulic systems.

#### **D 200 Design**

**201** Cylinders shall be designed according to a recognised international standard: EN-14359, ISO 11120, ISO 9809 or EN 1964, where applicable.

The information or documentation, as required by the standard, shall be submitted for approval.

Corrosion allowance shall be specified in the terms of delivery reflecting the intended use of the gas cylinder, but shall not be less than 1 mm.

#### **D 300 Fabrication**

**301** Seamless Cylinders shall be manufactured by a DNV Approved Manufacturer for class I and II.

The cylinders shall be manufactured to the same standard which form basis of the design.

All materials, forming, heat treatment, prototype testing and product testing shall meet with the requirements of the standard.

#### **D 400 Certification**

**401** Seamless cylinders shall be certified by the Society. DNV product certificate shall be issued based on successfully testing as specified in the standard.

### **E. Cylinders for Fire Extinguishing System**

#### **E 100 General**

**101** Cylinders under this chapter are defined to be mass produced seamless or welded transportable refillable pressure vessels used in fixed extinguishing systems.

#### **E 200 Design**

**201** Mass produced cylinders certified as part of a batch which are  $\pi$ , UN, DOT marked will be accepted for fixed fire fighting systems considered the applicable manufacturing and approval procedure is fully complied with.

**202** Under these certification regimes the following standards are acceptable:

EN1964, EN14208, EN13322, ISO 9809 or CFR 49, as applicable.

#### **E 300 Fabrication**

**301** The cylinders shall be manufactured by a DNV Approved Manufacturer for class I and II.

The cylinders shall be manufactured to the same standard which form basis of the design.

All materials, forming, heat treatment, prototype testing and product testing shall meet with the requirements of the standard.

#### **E 400 Certification**

**401** The cylinders shall be certified by DNV, or by a recognized certification authority according to national regulations and marked accordingly:  $\pi$ , UN, DOT.

**402** When certified by a recognized authority other than DNV, the cylinders shall be documented by means of certificates identifying the serial No. of each cylinder. The certificates shall be made available to the attending surveyor.

**403** When certified by DNV, the design must be approved in each case, or by an obtained type approval. The type approval will be issued on the basis of the design requirements and prototype testing as specified in the standard. The product certification shall be according to the requirements of the standard.

### **F. Signboards**

#### **F 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. shall meet the requirements given in the relevant chapters and sections for pressure vessels in Pt.2 Ch.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 shall 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	W
Pipes and flanges	W	W
Bolts	TR	TR

**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 shall 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 end plates for plate heat exchangers and 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<sup>2</sup>, may be accepted subject to approval in each case. In such cases the values of the mechanical properties used for deriving the allowable stress shall 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 of the ferritic/pearlitic and pearlitic type is in general subject to the limitation of use as grey cast iron as specified in 205.

**207** Nodular cast iron of the ferritic type with specified minimum elongation of 12%, shall not be used for temperatures exceeding 350°C.

#### A 300 Thermal-oil installations

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

**302** Pump housings, valves and fittings shall 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 shall be provided with instrumentation permitting local surveillance.

#### A 200 Inspection openings

**201** Pressure vessels shall 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 shall not 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 shall 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 shall be provided with drainage positioned at the lowest part.

#### A 400 Fuel oil supply

**401** Manual rapid shut-off of fuel oil supply shall be possible locally at the boiler. This quick closing device shall 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 shall be taken in order to prevent fuel oil from penetrating into the steam system.

**403** If electric preheaters are applied, precautions shall 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 shall 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 shall be arranged so that no disturbance in the air supply to the boiler occurs.

**502** At the operating stations for the boilers there shall 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 shall 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

shall 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 shall 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.

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**603** If oil-fired boilers are placed in the engine casing or in the funnel, the arrangements shall 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. shall be of ample height.

The platforms shall be fitted with sufficient drains to a waste-oil tank in the double bottom. These drains shall 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 shall 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 shall be surrounded by coamings of height not less than 150 mm and with drainage to a closed tank.

**103** If oil fired thermal oil heaters are installed in separate room, the room shall 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 shall be possible to close by means of flaps.

**104** Oil piping in the exhaust fired thermal-oil heater area shall 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 shall 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 shall 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 shall be made to ensure a minimum circulation through the heater in case consumers are shut-off. Such arrangements shall be automatically operated.

**202** Each circulation system shall have a minimum of two circulation pumps. One pump shall be in continuous operation, the other in auto stand-by. Starting of the stand-by pump shall 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 shall 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 shall 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 shall 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 shall have liquid relief valves.

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

**402** The heater shall 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 shall 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 shall be possible.

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

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

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

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

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

### **B 500 Insulation and shielding**

**501** All insulation shall 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 shall 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 shall provide sufficient space for satisfactory insulation installations. Flanged pipe connections shall 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 shall 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 shall 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.

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**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, shall be fitted.

**606** Soot cleaning arrangements shall 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 shall be arranged.

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

**703** Further notices shall state:

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

## **C. Exhaust Gas Boiler or Economisers**

### **C 100 Circulation systems**

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

### **C 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 shall have a soot-cleaning arrangement for use in the operation mode. In such cases, the soot cleaners shall 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.

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**202** Exhaust gas collecting pipes shall be provided with drain. The drainage system shall 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 shall be made, so that water can not enter into any of the engines.

The drainage shall 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), shall 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, end plates in plate heat exchangers or parts having geometrical properties outside the limits of application of the calculating formulae, shall be designed and calculated according to a recognised code.

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

The allowable stresses for the bolts shall 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 shall 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 shall not be less than the highest nominal set pressure of the safety valve(s).

The design pressure shall not 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).

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#### 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:

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

$\rho$  = density of fluid in t/m<sup>3</sup>

$g_0$  = standard acceleration of gravity = 9.81 m/s<sup>2</sup>

$h$  = 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 shall 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<sup>8</sup> 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 or Pt.3 Ch.2 Sec.5 and Sec.7.

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 scallings of large vertical low pressure storage tanks, e.g. bulk mud and cement tanks.

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

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#### 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.

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#### 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 shall not 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 ac-

cordance 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 shall be the saturation temperature at design pressure of the internal fluid and the temperature allowance shall not be less than 4 times the material thickness plus 15°C.

For economiser tubes the reference temperature shall be the maximum temperature of the internal fluid and the temperature allowance shall not 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 shall not 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,  $\sigma_b$ , 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 shall not exceed 60% of the value determined according to 501.

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

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

**507** For aluminium alloys the nominal design stress shall not 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 shall be complied with.

**509** For boilers the nominal design stress shall not exceed 170 N/mm<sup>2</sup>.

### 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.

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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	35°C	50°C
	See also 403		

### B 600 Shell thickness

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

For carbon and low-alloy steel:

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

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, shall be added to the calculated thicknesses.

For assessment of a design, e.g. reinforced openings or dished

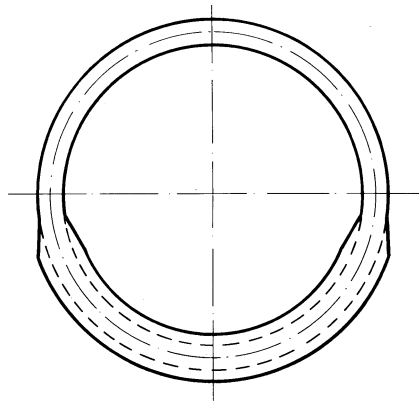
ends, the minus tolerance and fabrication allowance shall be deducted from the design wall thickness.

## 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 shall 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  $l_w$  welded joints,  $e$ , used in the formulae in 200, 300 and 400 shall 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 shall not 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 shall not 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 shall not 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  
 $\alpha$  = 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  $\alpha$  does not exceed  $75^\circ$  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 shall 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 shall be determined by the following formula:

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

$D_0$  = 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:

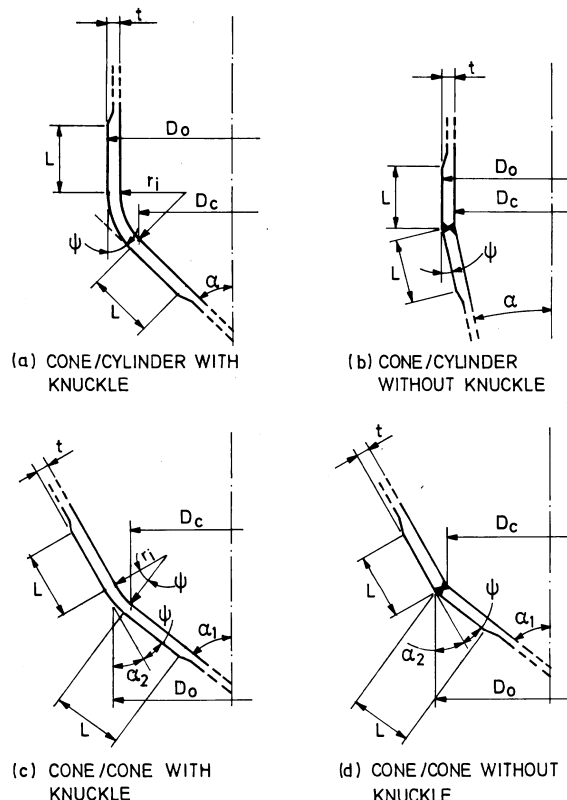
$$0,5 \sqrt{\frac{D_0(t-c)}{\cos \psi}} \quad (\text{mm})$$

$c_1$  = 0 for  $t - c/D_0 \geq 0.005$   
= 1 mm for  $t - c/D_0 < 0.005$

$K$  = a factor taking into account the stress in the junction.

Values of  $K$  are given in Table C1 as a function of  $\psi$  and  $r_i/D_0$ , where:

$\psi$  = difference between angle of slope of the adjoining parts  
 $r_i$  = inside radius of transition knuckle in mm, which shall 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  $D_o$  shall be applied.

Table C1 Values of K as a function of $\psi$ and $r_i/D_o$									
$\psi$	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

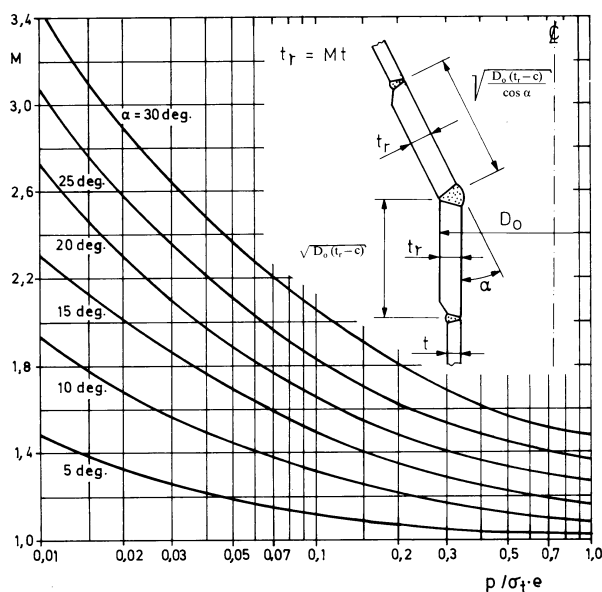
**405** The thickness of conical sections having a half apex angle of more than 75° shall be determined as for a flat plate.

**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

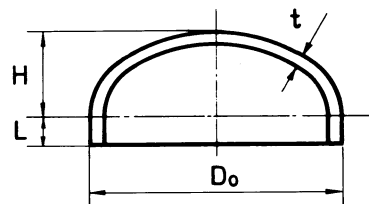
The above formula applies only for junctions with half apex angles of the cone less than 30°.

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  $t_r$  shall extend a minimum distance  $\sqrt{D_o(t_r - c)}$  from the junction and the increased cone thickness  $t_r$  shall extend a minimum distance:

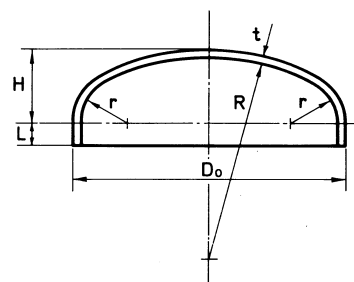
$$\sqrt{\frac{D_o(t_r - c)}{\cos \alpha}} \quad (\text{mm})$$

from the junction.

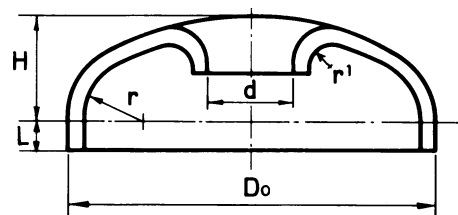
**407** Cone or cylinder connections at the small end of cones with half apex angles exceeding 30° shall be manufactured by means of knuckle transitions. The thickness of the knuckle will be considered in each case.



**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, shall not be less than:

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

$t$  = 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  $t$  shall not 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 shall 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:

$$H \geq 0.18 D_0; R \leq D_0; r \geq 0.1 D_0; r \geq 3 t; L \geq 2 t$$

- 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  $d/D_0 = 0.5$  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 shall be determined from the curves in Fig.7 depending on the ratio  $H/D_0$  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  $(t - c)/D_0$  as well as on the  $H/D_0$  ratio. The unbroken line curves shall be used and trial calculations may be necessary.
- For ends with unreinforced openings and for flanged openings, the shape factor shall be as given in Fig.7, depending on the ratio  $H/D_0$  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 shall be satisfied:

$$\frac{t - c}{D_0} \leq 0.1$$

K shall not be less than given for a plain end with the same  $t - c/D_0$ -ratio.

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

**Guidance note 1:**

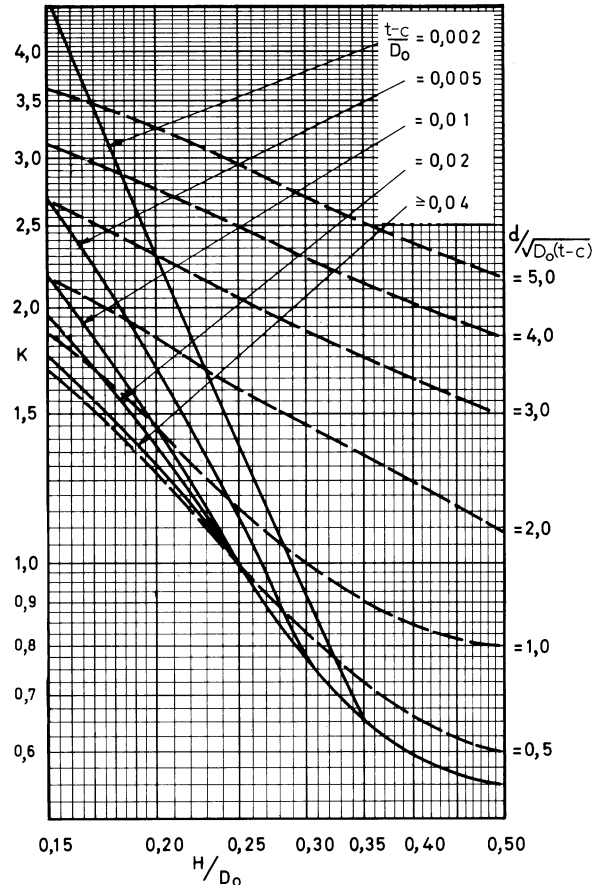
In the case of ends containing only compensated openings, read K from full curves of  $(t - c)/D = 0.002$  to  $(t - c)/D = 0.04$  interpolating as necessary.

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

**Guidance note 2:**

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 shall 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 shall not be less than:

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

t,  $D_0$ , e and K is defined in 501.

In addition the spherical section of the end shall be checked against elastic instability. The pressure,  $p_c$ , corresponding to elastic instability shall 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<sup>2</sup> at design material temperature, see table in Sec.5 E107.

The design pressure shall not exceed:

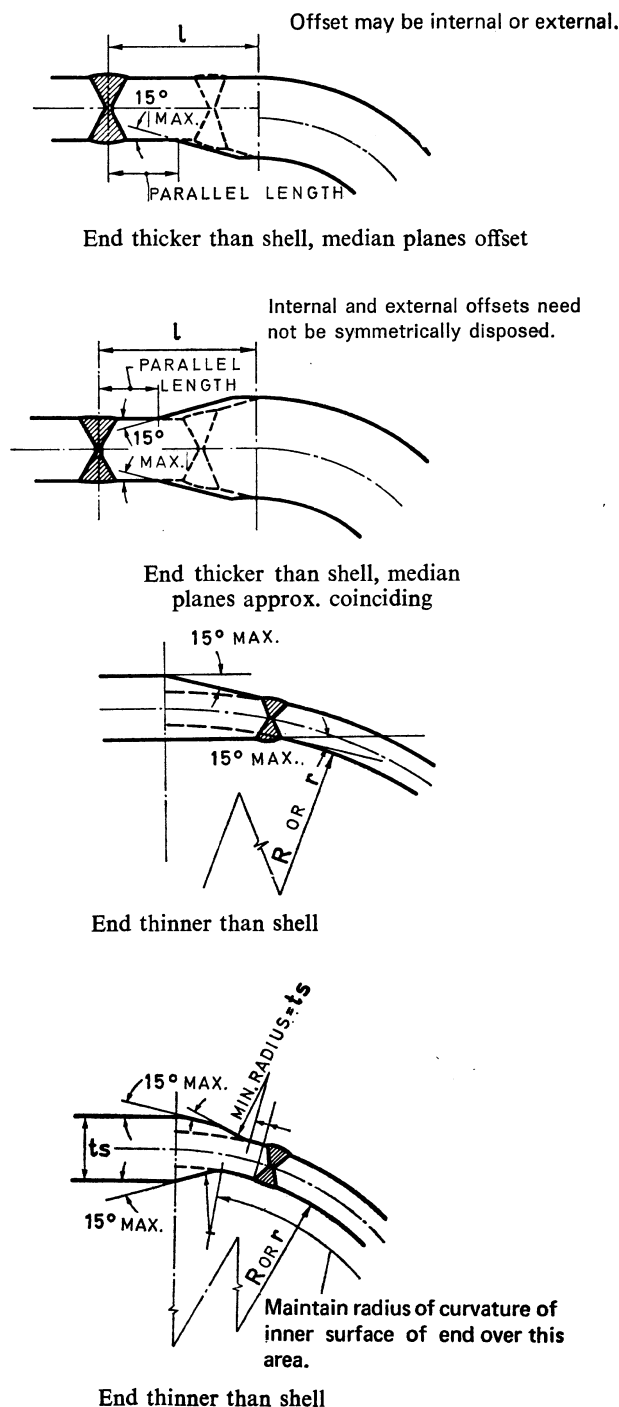
$$p = \frac{p_c}{S_F}$$

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

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

Intermediate values may be interpolated.





**Fig. 8**  
Dished ends — cylindrical shell connections

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

For hemispherical ends,  $e$  shall be taken as given in 102.

For torispherical and elliptical ends made of welded plates,  $e$  shall 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 shall be determined by the following formula:

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

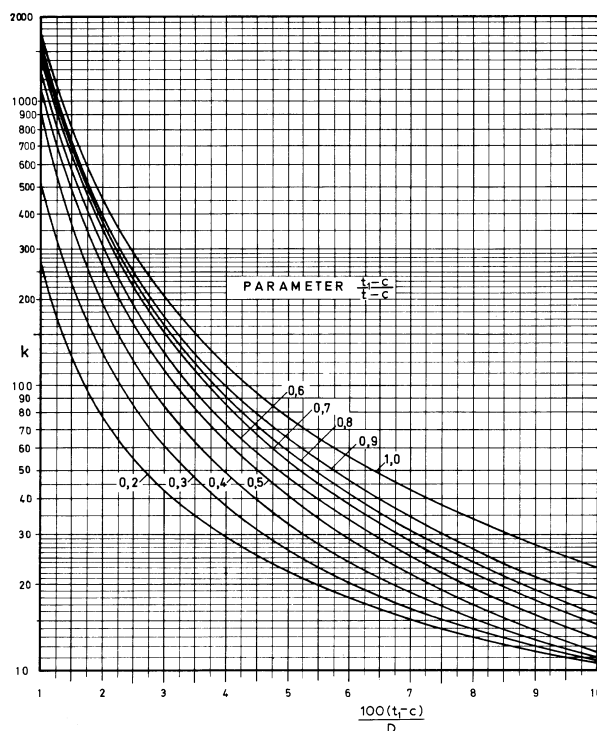
$k$  is a calculation factor depending upon  $t_1 - c/t - c$  and  $100(t_1 - c)/D_1$  where:

$t$  = thickness of end plate, in mm

$t_1$  = thickness of cylindrical shell, in mm

$D_1$  = 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:

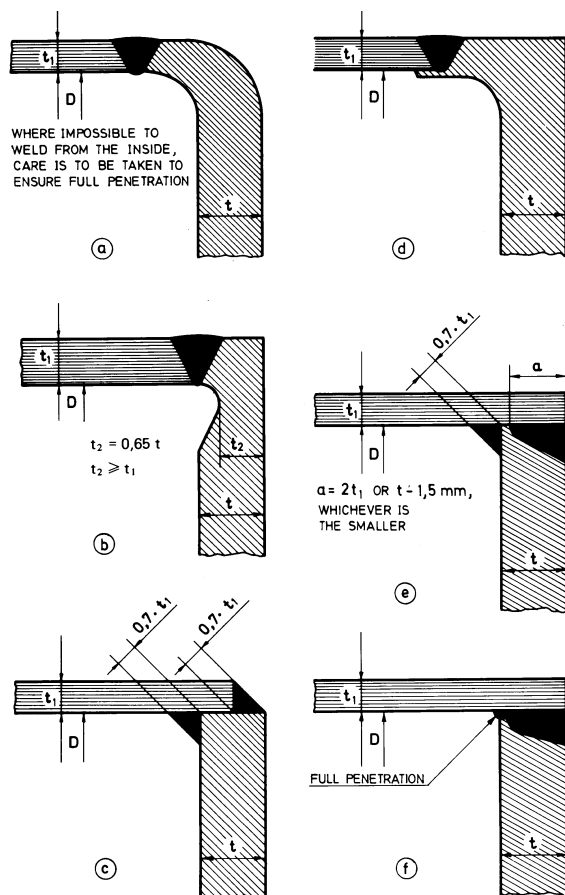
$$p \leq 30 \text{ bar}$$

$$t_1 \leq t \leq 5 t_1$$

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 shall extend at least a length  $\sqrt{D_o(t_1 - c)}$  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

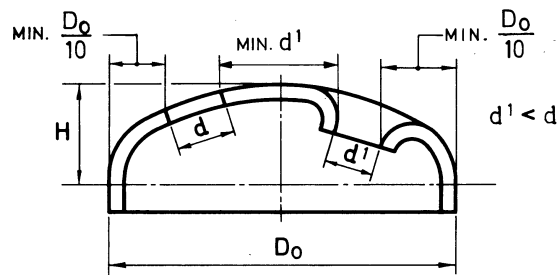
**101** The rules apply only when the following conditions are simultaneously satisfied:

- 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 shall 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 shall 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:

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

$t_b$  = 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 shall 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:

$$\frac{K d_i t}{2} \quad (\text{mm}^2)$$

- 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 shall 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 shall be determined in a plane passing through the major diameter of the opening. All planes shall pass through the centre of the opening and shall 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 shall 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.

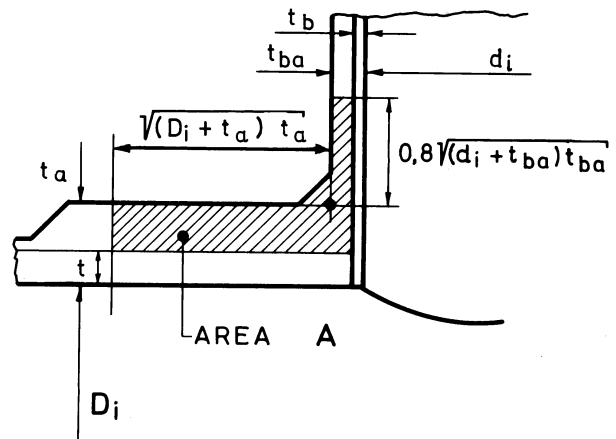
**304** Where two openings or branches are sufficiently closed spaced for the limits of compensation in the shell to overlap, the limits of compensation shall be reduced so that no overlap is present.

**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 0.6 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 shall be assumed reduced in the ratio of the nominal design stresses at design temperature.

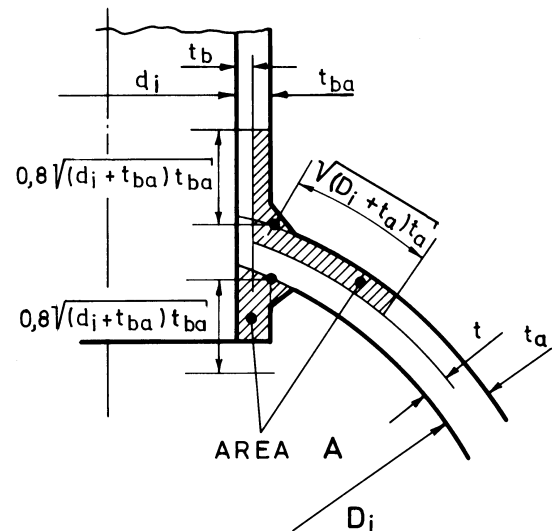
No reduction will be accepted for material with a nominal design stress greater than that of the shell.

**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 shall not 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:

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

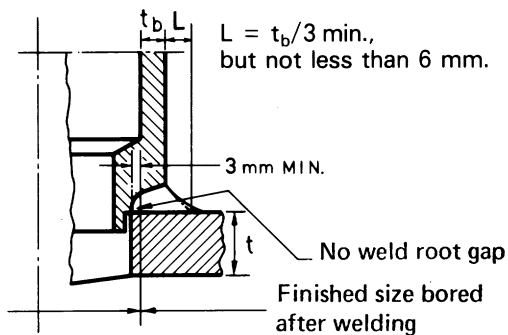
but need not be greater than the shell thickness.

$d_o$  = outer diameter of the branch.

**D 500 Welded branch connections**

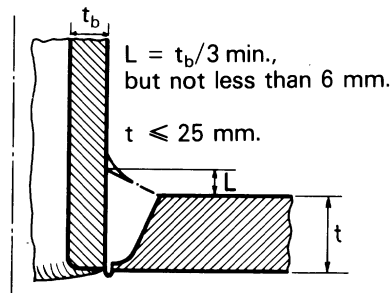
**501** Acceptable welded branch connections are shown in Fig.13.

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



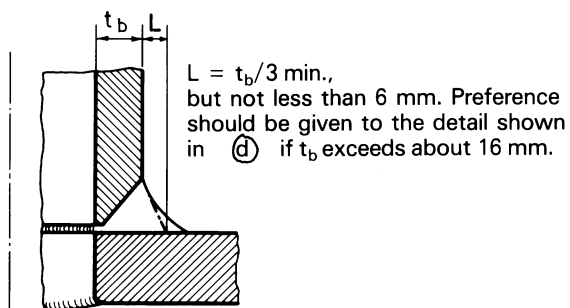
(a)

Generally used for small branch to shell diameter ratios



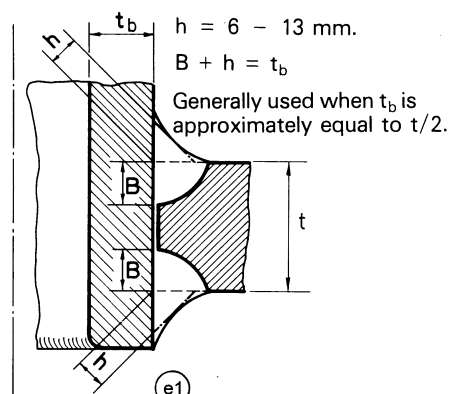
(d)

The welding procedure employed is to ensure sound root conditions

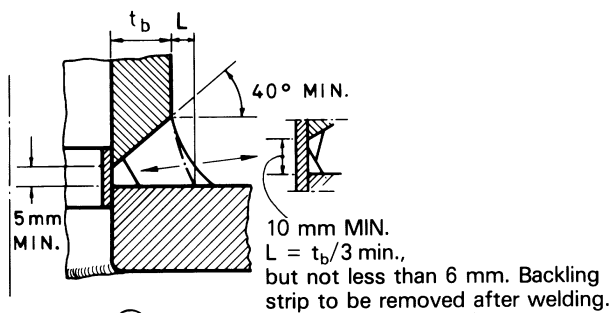


(b)

The welding procedure employed is to ensure sound root condition

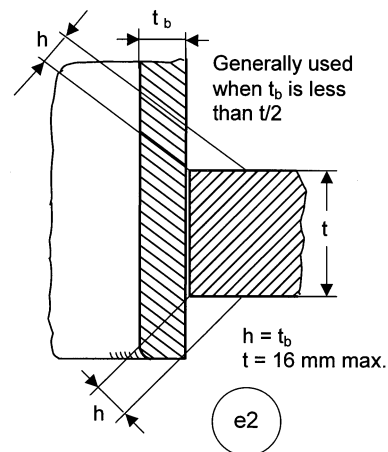


(e1)



(c)

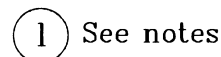
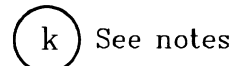
Single root run technique and double root run technique

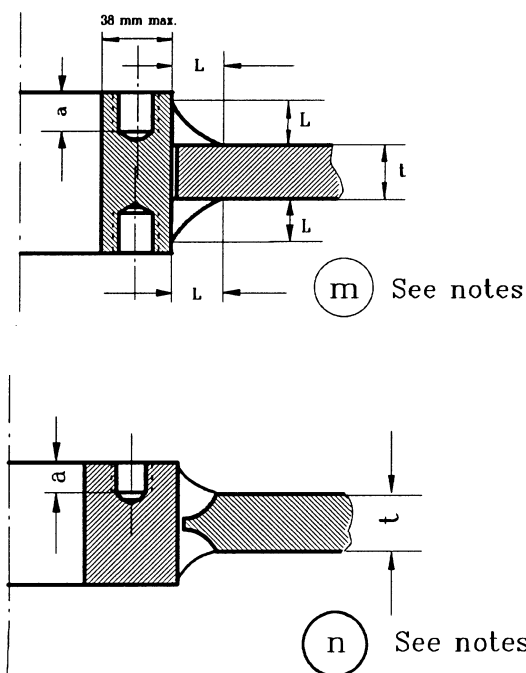


(e2)

Notes to Fig.(e2):

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





**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<sup>2</sup> 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 shall not be used for openings which require reinforcement, i.e. the required reinforcement for the openings shall be integrated in the shell plate.
- 3) The size of fillet welds L as indicated, shall be equal to the smaller of t or t<sub>d</sub> but not be less than 6 mm.
- 4) The threaded depth a shall 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 shall not be less than:

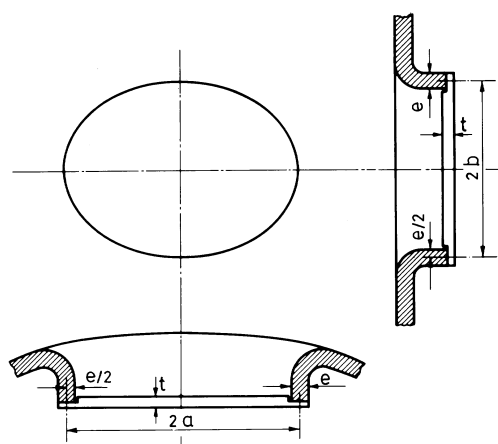
$$t = b \sqrt{\frac{Cp}{10\sigma_t}} + c \quad (\text{mm})$$

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 shall not be less than:

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

or according to Table F1 whichever is greatest

d = outside diameter

c = corrosion allowance.

**102** The corrosion allowance shall 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 shall be increased by the necessary amount.

Where tubes are bent, the thickness of the thinnest part of the tubes shall not 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 shall prove that this condition is satisfied.

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 shall be determined in accordance with the requirements in Sec.4.

For drums and headers in watertube boilers, the joint efficiency factor  $e$  shall 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  $t_2/(t_1 - c) \geq 1.4$

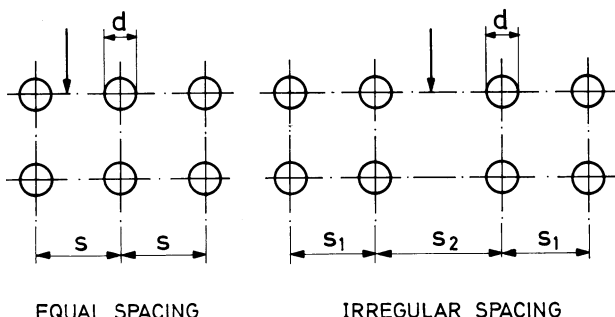
= 1.0 for  $t_2/(t_1 - c) \leq 1.0$

$t_2$  = 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  $X$  shall be found by linear interpolation.

The required shell thickness shall be obtained through an iteration process.

**102** The nominal thickness of a boiler shell shall not 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:

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

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

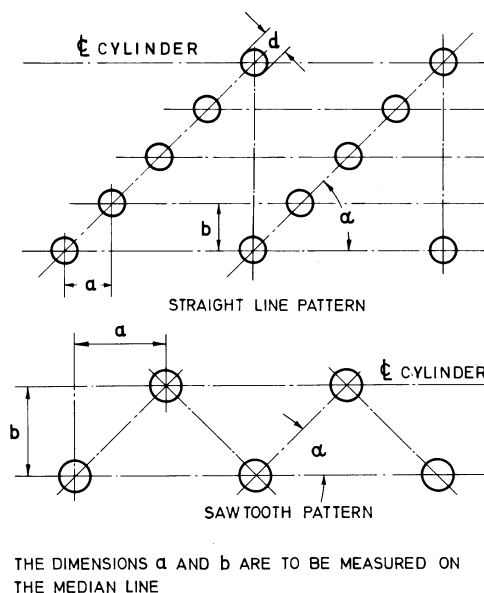
$d$  = mean effective diameter of the tube holes, after allowing for any counterboring or recessing, in mm. For compensating effect of tube stubs, see 301

$s$  = 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, shall 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 shall be used. The pitch of tubes for circumferential drilling shall be measured along the median line.

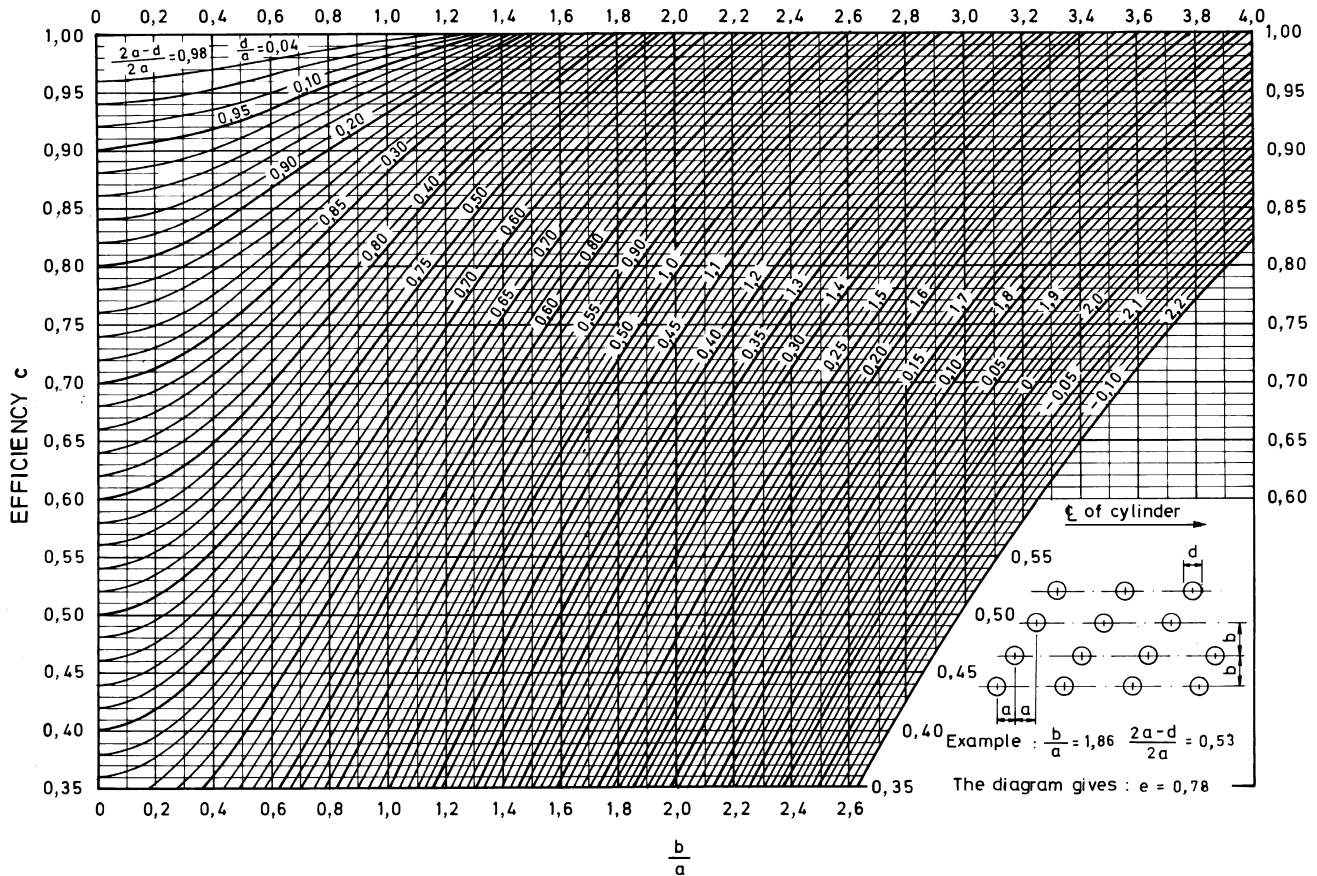


Fig. 3  
Ligament Efficiencies — diagonal drilling

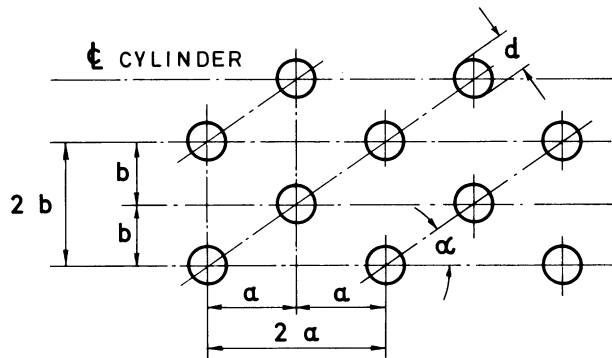


Fig. 4  
Regularly staggered spacing

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

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

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

$\alpha$  = 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:

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

$\frac{2a-d}{2a}$  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 shall be taken as:

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

The compensating area  $A$  shall 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 shall be calculated as follows:

For a set-through stub:

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

For a set-on stub:

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

$A_1$  = 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  $\text{mm}^2$

$A_2$  = sectional area of fillet welds attaching the stub to inside and outside of shell, in  $\text{mm}^2$

$t$  = 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  $G_2$  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 shall 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, shall not be less than

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

$d$  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 shall not be lower than that of the longitudinal weld, otherwise the stays shall be arranged in zig-zag.

Example for determination of efficiency of ligament

$$\frac{b}{a} = 0,7 \quad \frac{2a-d}{2a} = 0,76 \quad e = 0,66$$

Where the point of intersection "A" is outside the field for diagonal ligaments for points of intersection falling to the left, the circumferential pitch, and for points of intersection falling to the right, the longitudinal pitch is decisive for the calculation.

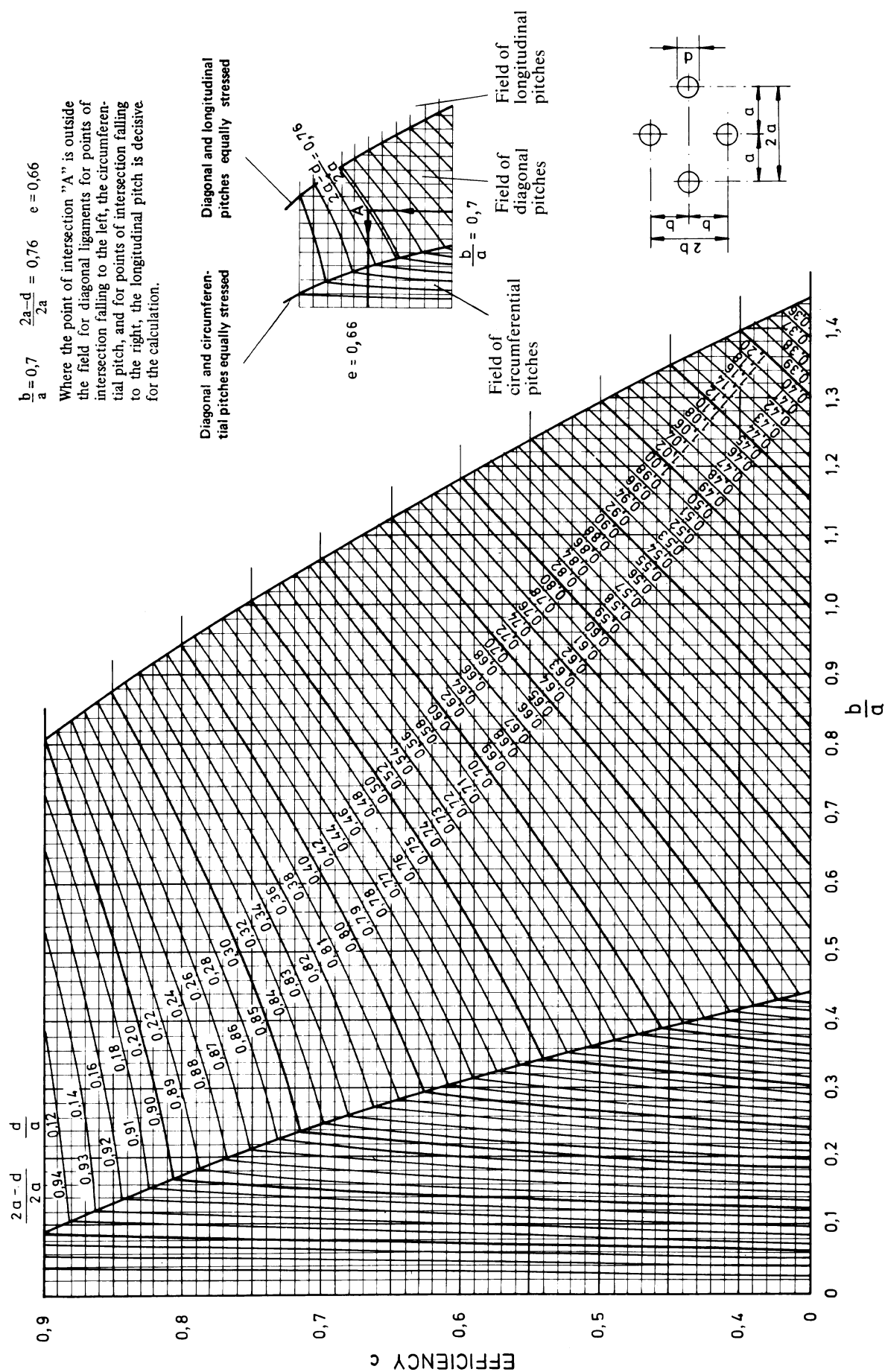


Fig. 5  
Ligament efficiencies — staggered drilling

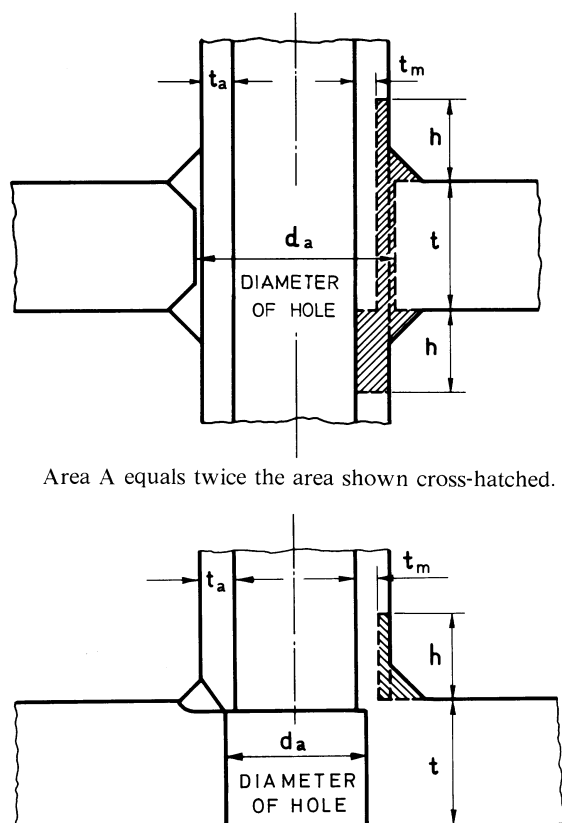


Fig. 6  
Stub connections

## 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 shall not 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  $2m$  and is (the numerical value shall 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

$\alpha$  = 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  $d < 0.6m$  when considering bending stresses:

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

— for  $d \geq 0.6m$  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

$\alpha$  = angle as indicated in the figure

$d$  = diameter of holes, in mm

$r$  = radius of curvature at corners, in mm.

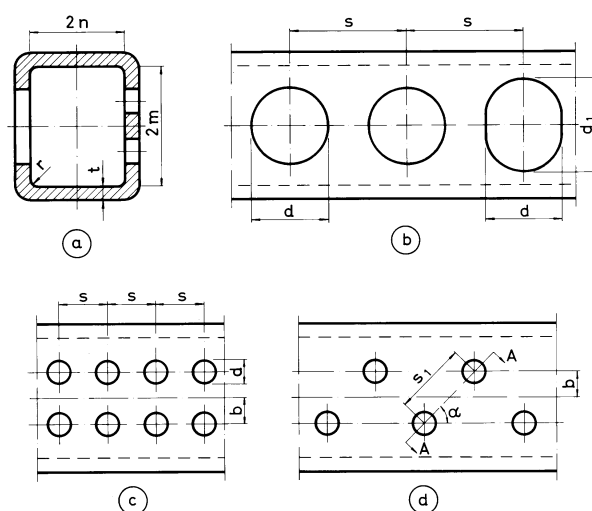


Fig. 7  
Hole arrangement in header

**104** In the case of oval holes, the value of  $d$  used in the formulae for  $e$  and  $e_1$  shall 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 shall be used ( $d_1$  in Fig.7b).

**105** For corners and inspection openings the following shall 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 shall be carried out.

Information on testing method and results obtained shall 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 shall 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, shall be determined from the following formula:

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

$R_i$  = inside radius of curvature.

$R_i$  shall not 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 shall not 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 shall not 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 shall 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 shall 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 shall not 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 shall 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.

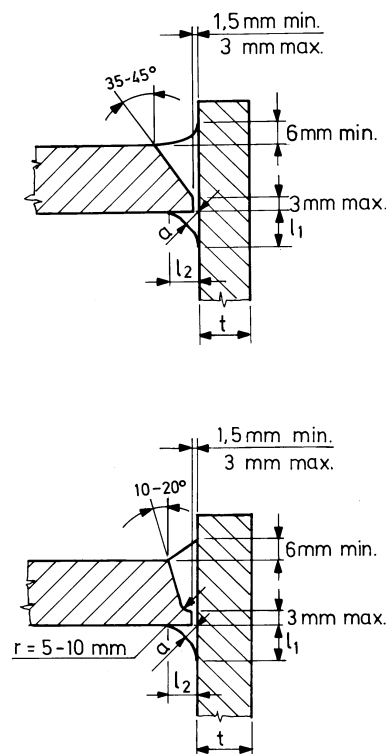
Where a flat plate is welded directly to a shell, the point of support shall be taken at the inside of the shell.

**103** The length of the cylindrical part of the flanged end plate shall not 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 shall be a full penetration weld, normally welded from both sides. The inside fillet weld shall have concave profile and shall merge into the plate without undercutting or abrupt irregularity. The minimum throat thickness shall 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 shall not exceed 2.0. Where inside fillet weld is omitted the ratio shall not exceed 1.4.



**Fig. 8**

**Attachment of unflanged flat end plates or tube plates to shell**

**106** The spacing of tube holes shall 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:

$$0.125 d + 9 \text{ for gas entry temperatures } > 800^\circ\text{C}$$

$$0.125 d + 7 \text{ for gas entry temperatures } \leq 800^\circ\text{C}$$

$d$  = diameter of tube hole.

### Guidance note 1:

The shape of internal fillet weld shall be concave. The ratio of leg lengths  $l_1 / l_2$  should be approximately 4 : 3. The minimum

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

Shell thickness (mm)	Minimum throat thickness (mm)
$t < 12$	4.5
$12 \leq t \leq 16$	5
$16 < t$	6

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

#### Guidance note 2:

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 3:

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 shall not 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  $C$  shall be as given in Table D1. Where different methods of support are used, the factor  $C$  shall be taken as the mean of the values for the respective methods adopted.

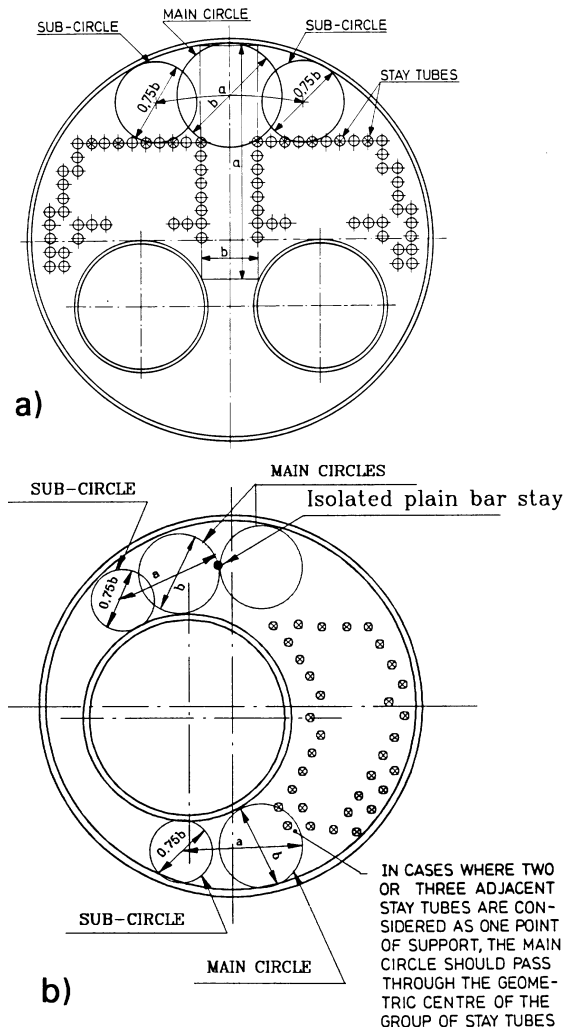
**204** For parts supported by bar stays or stay tubes,  $d_e$  is the diameter of the largest circle passing through not less than three points of support. The three points of support considered shall not be situated on the same side of any diameter of this circle.

**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 shall not 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 0.6 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 shall 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.

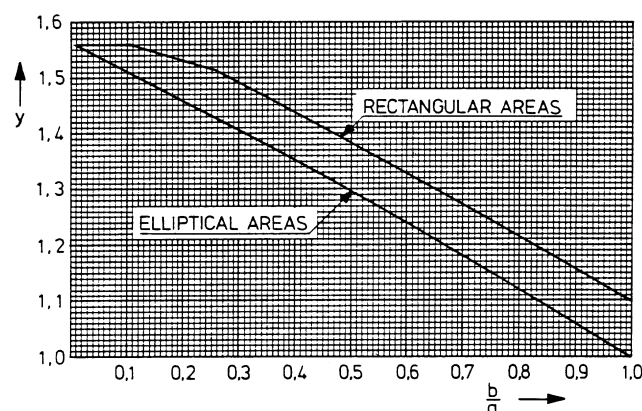
These stay tubes are not required within tube nests except when the tube nests comprise tubes which are expanded only. Stay tubes are however to be used in the boundary rows in sufficient numbers to carry the flat plate loadings outside the tube area.

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

<b>Table D1 Value of factor C</b>	
Type of support	C
Isolated plain bar stays or stay tubes, Fig.11 (a) and Fig.12	
<b>Note:</b> 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
<b>Flat end plate or tubeplate attachment to cylindrical shell</b>	
Flanged end plate	0.32
Set-in end plate with internal fillet weld. End plate thickness divided by shell plate thickness (Fig.8):	
$\leq 1.4$	0.33
$> 1.4 \leq 1.6$	0.36
$> 1.6 \leq 1.8$	0.39
$> 1.8$	0.42
Set in end plate with no internal fillet weld	0.45
<b>Flat end plate attachment to furnace and uptake</b>	
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 $\leq 4$ 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

<b>Table D2 Value of factor y</b>		
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
$\leq 0.1$	1.56	

Intermediate values shall be interpolated.



**Fig. 10**  
**Determination of factor y**

**302** The thickness of tube plates within tube nests with welded plain tubes, Fig.13, shall not 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 shall not be less than 10 mm.

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

12.5 mm when  $d \leq 50$  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 shall be such that the section of metal, taking the load, is sufficient to keep the stress within that allowed for shell plates. The thickness shall not 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 shall be a stay tube.

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

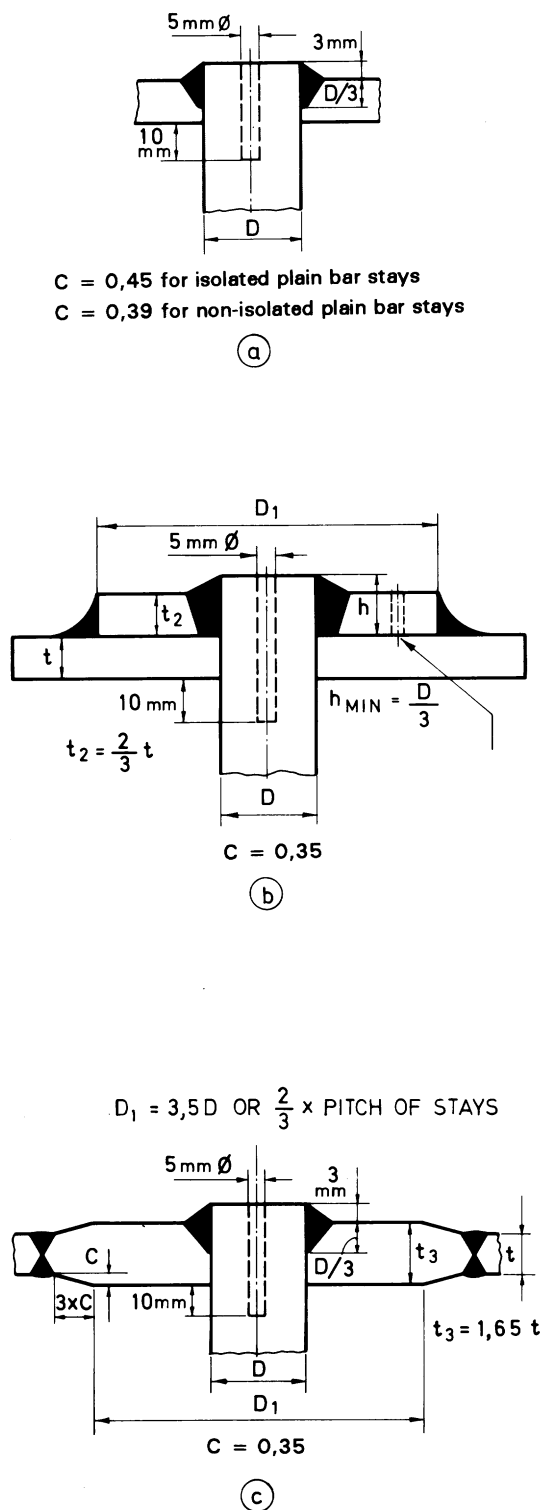


Fig. 11  
Stay connections

**Guidance note 1:**

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 2:**

Tubes should be lightly expanded before and after welding.

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

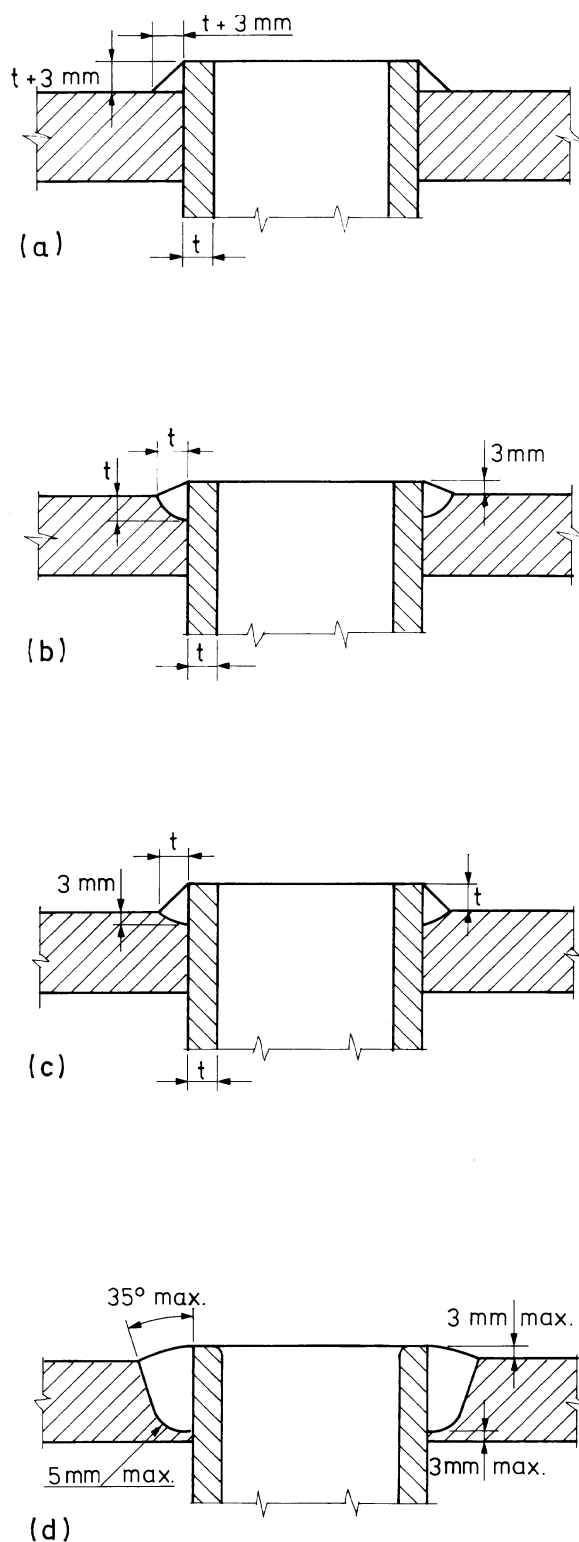


Fig. 12  
Typical attachment of stay tubes

**Guidance note 3:**

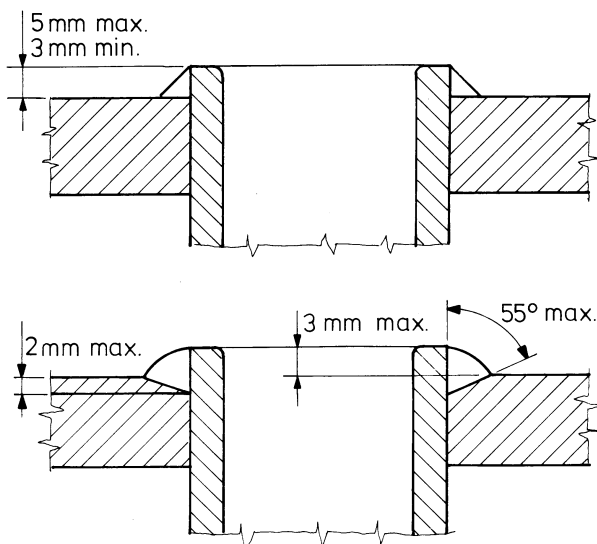
Tubes should be lightly expanded before and after welding.

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

**Guidance note 4:**

For tubes exposed to flame or gas temperatures exceeding 600°C the ends should 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 shall not 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 shall 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  $c = 0$ .

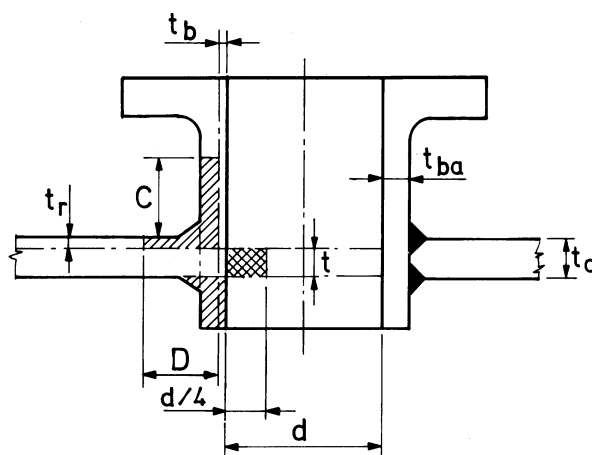
**602** Openings larger than those permitted according to 601 shall be reinforced.

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 0.6 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 shall 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  $(2.5 t_{ba} + t_r)$ .



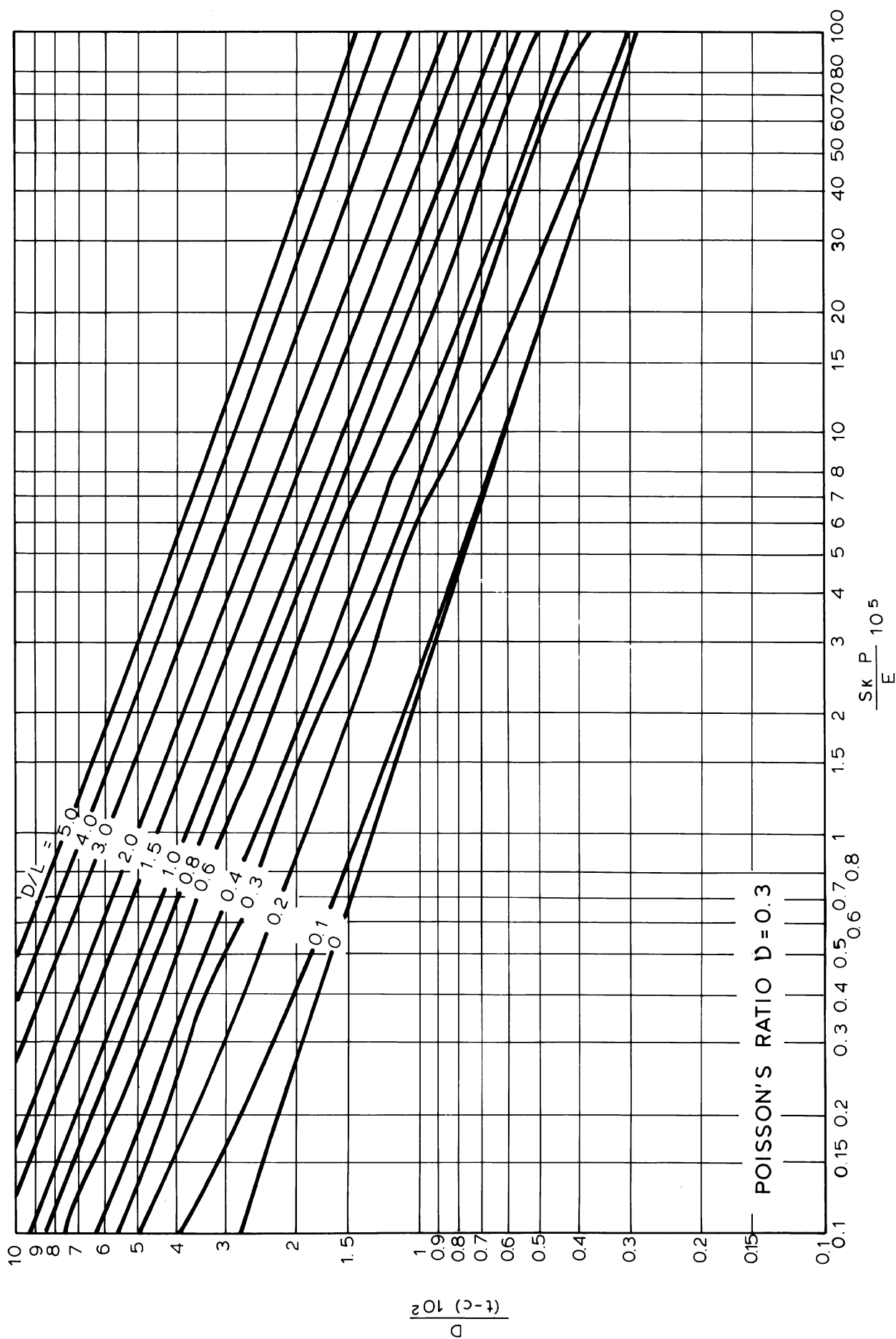


Fig. 15  
Required thickness by calculation against elastic instability

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

### E 100 Plain furnaces

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

**102** For calculation against membrane yield, the design pressure shall not 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 shall be taken as 1.5

S<sub>1</sub> = factor of safety.

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

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

E = modulus of elasticity in N/mm<sup>2</sup> at design material temperatures, see table in 107

n = integral number of waves.  $n \geq 2$  and  $n > z$

z = coefficient =  $\frac{0.5 \pi D_o}{L}$

$\nu$  = Poisson's ratio

S<sub>K</sub> = safety factor

D<sub>o</sub> = outside diameter.

L is defined in 102.

n shall 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 shall not be less than 10 mm for horizontal furnaces and 8 mm for vertical furnaces.

The nominal thickness shall not exceed 22 mm.

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

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

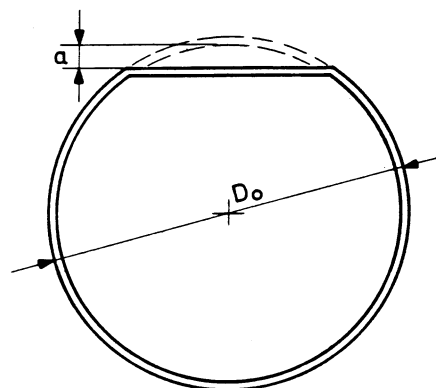
D<sub>max</sub> = the maximum mean diameter of the furnace

D<sub>min</sub> = 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 shall be used for the factor of safety:

— against membrane yield:

— horizontal furnaces: S<sub>1</sub> = 2.75

— vertical furnaces: S<sub>1</sub> = 2.5

— against elastic instability: S<sub>K</sub> = 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/mm <sup>2</sup> · 10 <sup>5</sup>	1.95	1.91	1.86	1.81

For intermediate temperatures linear interpolation shall 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 shall 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<sub>o</sub> = 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 shall not exceed 22 mm and shall not be less than 8 mm.

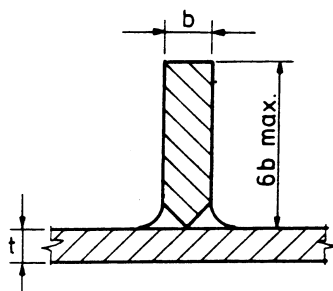
### E 300 Stiffeners

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

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

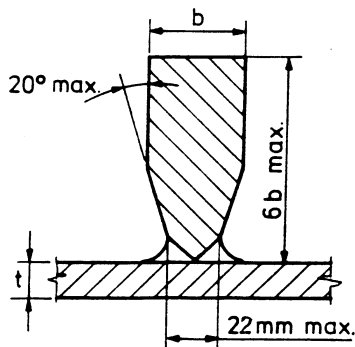
L and D are defined in 102.

**302** The thickness of stiffening rings shall be kept to the minimum required. For limiting dimensions see Fig.17. Stiffening rings shall extend completely around the circumference of the furnace, and shall 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.

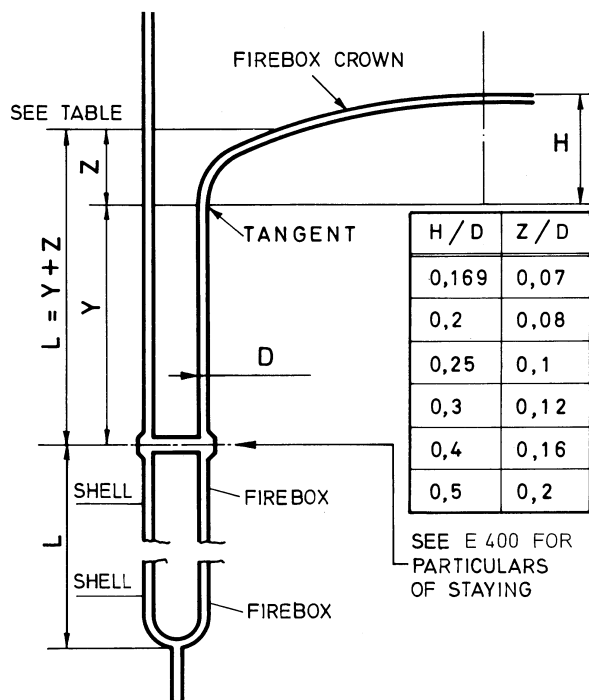
The length of the firebox shall be taken as the length between points of substantial support, as indicated in Fig.18.

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 shall 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 shall not be greater than the external diameter of the cylindrical firebox.

The inside radius of the flange to the cylindrical firebox shall not 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, shall be determined from the following formula:

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

$R_i$  is defined in 601.

The thickness shall not 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 shall 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 shall not be less than determined by the formulae in 100.

The corrosion allowance, c, shall 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 shall not 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 shall not exceed 300 mm.

### E 900 Connection of firebox to shell in vertical boilers

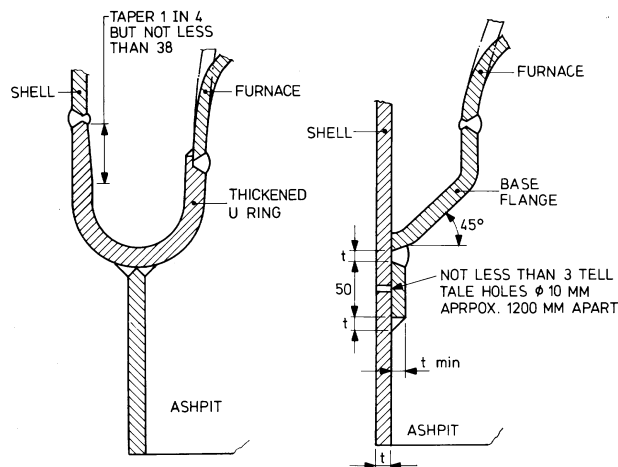
**901** Where the bottom of the firebox is connected to the shell by means of an ogee ring, and the ring sustains the whole vertical load on the firebox, the thickness of the ring shall not be less than:

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

$D_i$  = 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 shall 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 shall be determined from the following formula:

$$f = \frac{F_p}{10 \sigma_t}$$

$\sigma_t$  = 70 N/mm<sup>2</sup> for stay tubes

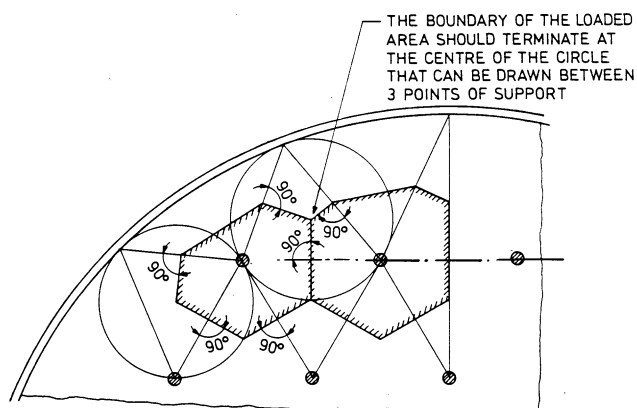
=  $\frac{R_m}{5.9}$  N/mm<sup>2</sup> for stay bolts

$$= \frac{R_m}{5.7} \text{ N/mm}^2 \text{ for longitudinal stays}$$

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

For a stay tube or bar stay, the area to be supported shall 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 shall not 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 shall not 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  $8 t$  shall be inserted in the formula.

## G. Tubes

### G 100 Boiler tubes subjected to internal pressure

**101** The wall thickness of straight tubes shall not be less than:

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

d = outside diameter in mm  
c = corrosion allowance.

**102** The corrosion allowance shall be 1 mm, except for tubes used in boilers with open feed water systems where the corrosion allowance shall 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)
$d \leq 38$	1.75
$38 < d \leq 51$	2.16
$51 < d \leq 70$	2.40
$70 < d \leq 76$	2.60
$76 < d \leq 95$	3.05
$95 < d \leq 102$	3.28
$102 < d \leq 127$	3.50

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

Where tubes are bent, the thickness of the thinnest part of the tubes shall not 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 shall 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, shall 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 shall not 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 shall 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 shall be designed to permit entry of a person and shall 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 shall be provided with a manhole. Otherwise boilers with a shell diameter between 800 mm and 1400 mm shall be provided with a headhole as a minimum requirement.

**103** Special consideration shall 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 shall 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 shall 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 shall be such that it can be seen without difficulty whether they are open or shut.

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

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

**103** Where mountings are secured by studs, the studs shall have full thread holding in the plate for a length of at least one diameter. Holes for studs shall not 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 shall have not less than two safety valves with a total discharge capacity equal to or greater than the total design evaporation in normal and shut-off condition.

**102** Superheaters shall 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 shall 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 shall 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 shall have appropriate safety valves. Such safety valves shall not 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 shall be separate from any other valve chest. The chest shall be connected directly to the shell by a strong and stiff neck. Safety valve chests shall have drain pipes leading the drain to the bilge or to a tank, clear of the boiler. No valves or cocks shall be fitted in these drain pipes.

**104** The design of the safety valves shall 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 shall be provided for lifting the safety valves on a boiler or steam-heated steam generator at the same time and shall 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 shall not be less than:

For saturated steam:

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

For superheated steam:

$$A_2 = A_1 (1 + 0.0018 T_D) \quad (\text{mm}^2)$$

p = design pressure of the boiler, in bar

E = designed evaporation, in kg/hour

T<sub>D</sub> = 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) shall 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 shall 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 shall not be used. For full lift safety valves the inside seat diameter shall not be less than 20 mm.

Where only one safety valve of ordinary type is fitted, the inside diameter of the valve seat shall not 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 shall have a cross-sectional area at least 10% greater than the aggregate valve area calculated by the formulae in 106.

The pipe design must take into consideration possible pressure build up in the line.

For full-lift safety valves, the cross-sectional area of the waste-steam pipe and passages shall not 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 shall not be less than the total cross-sectional areas of the branch waste-steam tube. The valves shall 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 shall 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 shall 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 shall 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 shall be carried out. The boiler pressure shall not rise more than 10% above the design pressure, when the boiler stop valve is closed under full firing conditions. The boiler shall be fired to steady state, and then maintained for 5 minutes. This test is also applicable for exhaust heated smoke tube boilers/economisers with steam space. During this test, no more feed water shall be supplied than is necessary to maintain a safe working water level.

The accumulation tests may upon application, be omitted. Acceptance may be given when design calculations of the discharge piping is found acceptable. If it is desired to omit the tests, this shall 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 shall provide a certificate stating the rated capacity of the safety valves at the approved pressure and temperature of the boilers. The boiler makers shall 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) shall have safety valves, except as provided for in 204.

**202** Pressure vessels intended to operate completely filled with liquid shall 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 shall 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 shall 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, shall 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 shall 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 shall 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 shall have a stop valve and a check valve.

**102** The feed water stop valve shall be attached directly to the boiler or to the economiser, if this forms an integral part of the boiler, and the valve neck shall 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 shall be as short as possible, and shall be of substantial thickness. The check valve shall be placed as near the stop valve as practicable.

**103** Feed water shall 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 shall be provided with a thermal sleeve to minimize thermal stresses. Similar arrangements shall 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, shall 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 shall 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 shall be fitted with stop valves.

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

### D 100 Blow-down valves

**101** Each boiler shall 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 shall be adequately supported, and the pipe, if exposed to furnace heat, shall be protected by brickwork or other heat-resisting material, so arranged that the pipe may be inspected and shall not be constrained against expansion.

**102** The internal diameter of the valve and its connections to the sea shall not 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 shall be of the bolted cover type with separately packed glands, and shall not be used with pressures over 13 bar.

### D 200 Test valves

**201** At least one valve for testing boiler water shall be fitted directly to each boiler in a convenient position. It shall not 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 shall be fitted with at least two independent means of indicating the water level, one of which shall be a glass gauge. The other means shall be either an additional glass gauge or an approved equivalent device.

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

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

**103** The water gauges shall be readily accessible and positioned so that the water level is clearly visible. Water gauges shall 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 shall 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 shall 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 shall 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 shall be clearly marked in a position adjacent to the glass water gauge. Water gauges shall be fitted with cocks or valves at each end of the glass gauge. The cocks shall be accessible for closing from positions free from danger in the event of the glass breaking.

**104** Mountings for glass water gauges shall be fitted directly to the boiler plating or to stand pillars or columns. Stand pillars and columns shall be bolted directly to the boiler shell, but they may also be connected to the boiler by means of pipes. These pipes shall be fitted with terminal valves or cocks secured directly to the boiler shell. Valves and cocks shall have fixed hand-wheels or handles, and shall 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, shall be arranged such that there is no pocket or bend where an accumulation of water can lodge. They shall not 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 shall be provided with a separate steam-pressure gauge. The gauges shall be placed where they can easily be seen. The highest permissible working pressure shall 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 shall 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.

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**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 shall not be supplied before ignition device produces sufficient energy for safe ignition.

**204** The safety device for flame monitoring shall 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)	
	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 shall not 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 shall be ensured. If the fuel oil will be under pressure during shut-off of burners, the shut-off device shall be duplicated. A single shut-off device will be accepted if the burners are drained off.

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

### B. Boilers

#### B 100 Automatic control

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

During all normal load variations, the water level shall 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.

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**102** When combustion control systems is fitted, the steam pressure shall 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 shall 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.

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#### B 200 Monitoring

**201** Monitoring shall 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 shall be according to the Rules for Classification of Ships Pt.6 Ch.3 Sec.3, Table A3.

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

## 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, shall 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 shall be arranged according to Table D1.

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

## E. Thermal-oil Heaters

### E 100 Automatic control

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

**102** The temperature set point shall 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 shall be arranged according to Table E1.

### E 300 Indication

**301** Thermal-oil heaters shall 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.

<b>Table E1 Monitoring of oil-fired thermal-oil heaters</b>				
<i>Item</i>		<i>Alarm and safety action (stated by an x)</i>		<i>Comments</i>
		<i>Alarm</i>	<i>Automatic shutdown of oil burner with alarm</i>	
Thermal-oil	Temperature outlet high		x	
	Flow low		x	Separate for each coil <sup>1)</sup>
	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.				

## SECTION 8 MANUFACTURE, WORKMANSHIP AND TESTING

### A. Manufacture

#### A 100 General

**101** Class I and II pressure vessels shall be manufactured by works approved by the Society.

**102** Welding shall 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 shall 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 shall not 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 shall 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 shall provide full penetration, and it shall 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 shall 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 shall be welded on in the immediate vicinity of a welded joint. If this cannot be avoided, the welds shall cross each other completely.

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

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

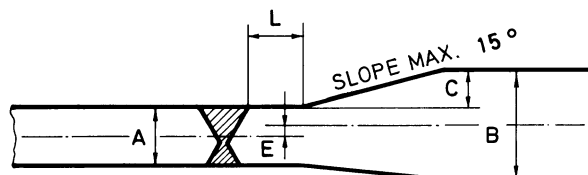
#### Guidance note:

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

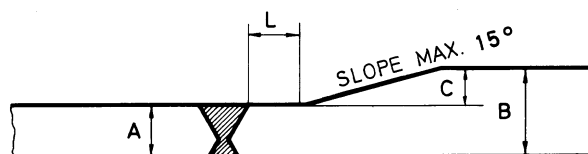
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**206** Before welding is commenced, it shall be ascertained that the plate edges are in alignment within the following limits:

- 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.



LONGITUDINAL JOINTS WHERE C EXCEEDS 10% OF B OR 3 mm



CIRCUMFERENTIAL JOINTS WHERE C EXCEEDS 10% OF B + 1 mm OR 4 mm

**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 shall 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 should not 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 shall be carried out in the downhand position. In the case of circumferential joints in cylindrical shells, means shall be adopted to ensure compliance with this requirement.

**209** Welds shall have a smooth finish and shall 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 shall not 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 shall 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 shall be repeated after turning the shell through 90° about its longitudinal axis. The two measure-

ments for each diameter shall 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 shall 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, shall not exceed 1% of the nominal internal diameter, D, with a maximum of:

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

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

Irregularities in profile, checked by a 20 degree gauge, shall not 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 shall 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 shall 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 shall not be less than 10 mm.

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

**402** The tubes in smoke tube boilers shall 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 shall be in full contact with the tube plate.

#### B 500 Doors and plugs

**501** Doors and crossbars shall be of steel, and jointing surfaces shall be machined. Doors in boilers shall be of the internal type. The clearance between the manhole frame and the spigot or recess shall not 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 shall 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 shall 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 shall 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 shall 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 shall be heat treated by heating as a whole in an enclosed furnace. The furnace shall 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 shall be submitted for consideration.

**106** Thermal stress relieving shall 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 shall 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 shall 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 shall 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 shall be normalised. NV 1 Cr 0.5 Mo and NV 2.25 Cr 1 Mo shall 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.

<b>Table C1 Post-weld heat treatment</b>		
Steel grade	Plate thicknesses above which post-weld heat treatment is required	
	Boilers	Unfired pressure vessels
NV 360-0A-0N	20 mm	30 mm
NV 410-0A-0N	20 mm	30 mm
NV 460-0A-0N	20 mm	30 mm
NV 490-0A-0N	20 mm	30 mm
NV 360-1 FN	20 mm	38 mm
NV 410-1 FN	20 mm	38 mm
NV 460-1 FN	20 mm	38 mm
NV 490-1 FN	20 mm	38 mm
NV 510-1 FN	20 mm	38 mm
NV 0.3 Mo	20 mm	
NV 1 Cr 0.5 Mo	All thicknesses to be heat treated	
NV 2.25 Cr 1 Mo		

<b>Table C2 Soaking temperatures and time at temperature</b>		
Steel grade	Soaking temperature °C	Time at soaking temperature
C and C-Mn steel grades	520 - 580	60 minutes per 25 mm thickness.
NV 0.3 Mo	530 - 580	Minimum 30 minutes
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 shall 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 shall be carried out as follows:

- All longitudinal butt welded joints in drums, shells and headers shall be subjected to 100% radiographic testing.
- 25% of the length of circumferential butt welded joints in drums, shells and headers shall be subjected to radiographic testing.
- 10% of the total number of circumferential butt welded joints in pipes and tubes shall be subjected to radiographic testing.
- For set-in flat plates the cylindrical shell shall 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 shall 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, shall be 100% magnetic particle tested for surface flaws.
- For standpipes and branches with outside diameter exceeding 100 mm, all weld connections to shell and reinforcement rings shall be subjected to magnetic particle testing. For outside diameters 100 mm and less, spot testing shall be carried out. The magnetic particle testing is also to cover weld joints between reinforcement rings and shell.
- All welded joints shall be subjected to visual inspection.

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

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

- All welded joints shall be subjected to visual inspection.

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

**104** For furnaces and fireboxes non-destructive testing shall be carried out as follows:

- 10% of the length of longitudinal butt welded joints shall be subjected to radiographic examination.
- 10% of the length of circumferential butt welded joints shall be subjected to radiographic examination.
- 25% of the length of T-welds and corner welds shall 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 shall 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.

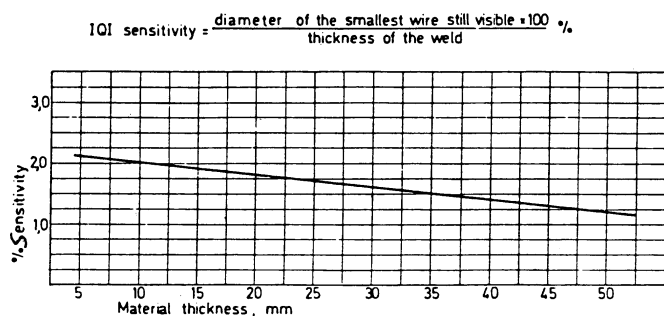
### D 200 Performance of non-destructive testing (NDT)

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

**203** Radiographic testing shall be carried out as specified in Table D1.

<b>Table D1 Radiographic testing</b>	
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 shall 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 shall be used. Care shall be taken to avoid local heating of the test surface. Prods shall be of the type «soft prods», lead tipped or aluminium alloy.

Use of permanent magnets is not permitted.

Required magnetic field strength:

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

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 shall be used.

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

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

The penetration time shall 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 shall be repaired, unless otherwise stated in the Tables D2, D3 or D4.

<b>Table D2 Radiographic testing</b>	
<i>Type of defects</i>	<i>Acceptance criteria</i>
Porosity <sup>1) 2)</sup> 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 <sup>1) 3)</sup> 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 shall 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.	

<b>Table D3 Ultrasonic testing <sup>1)</sup></b>	
<i>Indication</i>	<i>Acceptance criteria</i>
Echo height above: Maximum length <sup>1)</sup> , 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.	

<b>Table D4 Visual, magnetic particle and liquid penetrant testing</b>	
<i>Type of defect</i>	<i>Acceptance criteria</i>
Incomplete penetration or lack of fusion	Not accepted
Cracks	Not accepted
Undercut, maximum depth, mm	0.3 <sup>1)</sup>
1) Provided round shape and insignificant notch effect (regardless of length).	

Indications reaching a level of between 50% and 100% of the reference curve shall 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 shall be repaired.

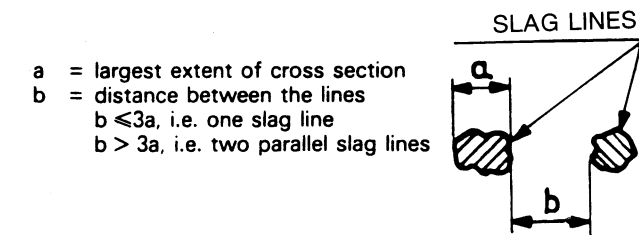
Indications exceeding 20% of the reference curve and having an extent larger than 10 mm shall be reported for consideration if there is a possibility of two-dimensional defects.

**303** NDT shall be reported, and all essential control parameters shall be given.

**304** Defects which exceed the acceptance limits shall 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 shall be tested.

## SECTION NORMAL TO WELD LENGTH



**Fig. 3**  
Slag line(s)

### D 400 Welding production test (WPT)

**401** For class I pressure vessels, welding production test (WPT) shall 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 shall 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 shall 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 shall not differ by more than 5 mm and the thickest plate shall 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 shall 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 shall have a width of minimum 150 mm. The length shall be sufficient for making all test specimens required according to 410 and for possible retest purposes. Plates for the test assembly shall be cut from the plates forming the appropriate part of the vessel, and shall 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 shall 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 shall 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 simulation of the production weld.

**407** The welding of the test assembly shall 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 shall be heat treated together with the vessel or one of the vessels which it represents.

**409** The weld deposit shall be machined flush with the plate surface on both sides of the test assembly.

**410** The following tests are required from each test assembly:

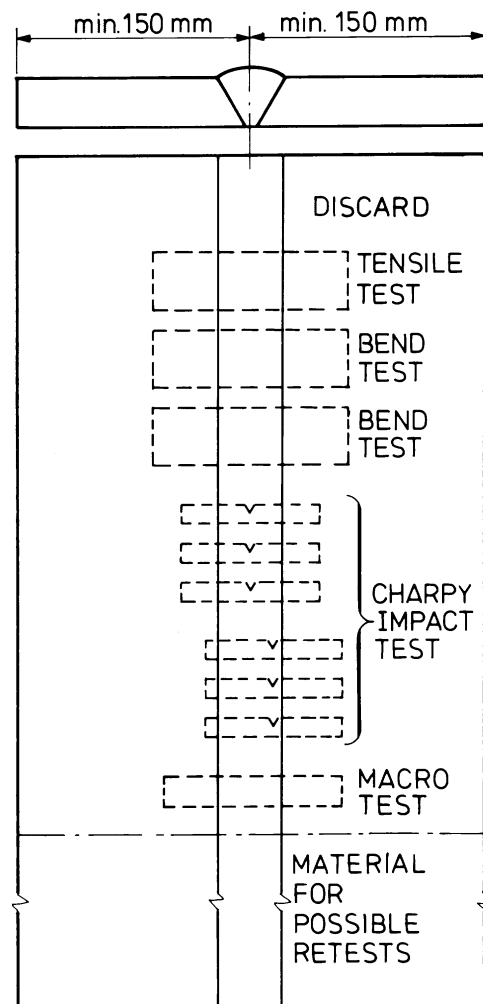
- one root and one face bend test when plate  $\leq 10$  mm thick
- two side bend tests when plate  $> 10$  mm thick

- 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 shall be cut from the welded test assembly as shown in Fig.4.

**411** Bend tests shall be performed as described in Pt.2 Ch.3 Sec.5 E201.

**412** Six Charpy V-notch impact test specimens shall 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 shall 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 shall 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 shall be tested and both specimens shall 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 shall 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 shall be etched for macro-examination. Cracks or lack of fusion are not accepted.

**414** The butt weld tensile test specimen shall 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 shall be tested.

The tensile strength obtained shall be not less than the minimum tensile strength required for the plate material.

#### **D 500 Hydraulic test**

**501** On completion, boilers shall 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 shall 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 shall be tested to 1.25 times the calculating pressure.

**503** Pressure vessels other than boilers shall 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 shall 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. shall 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 shall be performed.

**507** Mountings shall 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 shall 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 shall be function tested. The test shall include the instrumentation, automatic equipment and remote control systems. For boiler accumulation test, see Sec.6 B113.

**602** Thermal-oil heating installations shall be function and capacity tested according to an approved test programme.

The test procedure shall include flow measurements for each coil, covering the whole range of heater loads. The heater system charge shall be a thermal-oil which will allow maximum heater rating to be tested.

### **E. Marking**

#### **E 100 General**

**101** Each boiler and pressure vessel shall 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 shall 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-holes* 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-holes* are holes into which a lamp can be inserted. A hand-hole shall 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 shall not 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 shall not 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 shall 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

shall not exceed 100 mm (3.94 in).

**104** Where neck heights exceed the limiting values given in 101 to 103, the size of hole shall 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 shall not 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 shall 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 shall 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 shall 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 shall not 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.