



GS 126-1

SHELL AND TUBE HEAT EXCHANGERS

July 1997

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BP GROUP RECOMMENDED PRACTICES AND SPECIFICATIONS FOR ENGINEERING											
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SHELL AND TUBE HEAT EXCHANGERS (Replaces BP GS 126-1, April 1995)											
APPLICABILITY Regional Applicability: International											
SCOPE AND PURPOSE GS 126-1 states BP's requirements for the purchase of shell and tube heat exchangers. In this amendment: - comments from BP Chemicals have been included; - the thermal design section has been updated; - changes have been made reflecting the recent revision of the vessel specification, BP GS 146-2, and the tube end fixing specification, GS 118-8; - for simplification, the specification has been made independent of API 660.											
AMENDMENTS <table border="1"> <thead> <tr> <th>Amd</th> <th>Date</th> <th>Page(s)</th> <th>Description</th> </tr> </thead> <tbody> <tr> <td colspan="4"> </td> </tr> </tbody> </table>				Amd	Date	Page(s)	Description				
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CUSTODIAN (See Quarterly Status List for Contact) Pressure Vessels											
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FOREWORD

Introduction to BP Group Recommended Practices and Specifications for Engineering

The Introductory volume contains a series of documents that provide an introduction to the BP Group Recommended Practices and Specifications for Engineering (RPSEs). In particular, the 'General Foreword' sets out the philosophy of the RPSEs. Other documents in the Introductory volume provide general guidance on using the RPSEs and background information to Engineering Standards in BP. There are also recommendations for specific definitions and requirements.

Value of this Guidance for Specification

This Guidance for Specification substitutes, adds to or qualifies certain of the API 660 clauses, using BP's knowledge and experience world wide.

Application

This Guidance for Specification is intended to guide the purchaser in the use or creation of a fit-for-purpose specification for enquiry or purchasing activity.

Text in italics is Commentary. Commentary provides background information which supports the requirements of the Specification, and may discuss alternative options. It also gives guidance on the implementation of any 'Specification' or 'Approval' actions; specific actions are indicated by an asterisk (*) preceding a paragraph number.

This document may refer to certain local, national or international regulations but the responsibility to ensure compliance with legislation and any other statutory requirements lies with the user. The user should adapt or supplement this document to ensure compliance for the specific application.

Specification Ready for Application

A Specification (BP Spec GS 126-1) is available which may be suitable for enquiry or purchasing without modification. It is derived from this BP Group Guidance for Specification by retaining the technical body unaltered but omitting all commentary, omitting the data page and inserting a modified Foreword.

Principal Changes from Previous Edition

BP Chemicals requirements have been included, the thermal design section has been revised and the connection with API 660 has been removed.



Feedback and Further Information

Users are invited to feed back any comments and to detail experiences in the application of BP RPSE's, to assist in the process of their continuous improvement. Please contact Standards Group, BP International or the Custodian. See Quarterly Status List for contacts.



1. INTRODUCTION

1.1 Scope

- 1.1.1 This Specification states BP requirements for the thermal design, mechanical design, materials selection, fabrication, inspection and testing of shell and tube heat exchangers.

This Specification is intended to be used directly for the purchase of all new equipment. Any project specific requirements should be incorporated in the data sheets or requisition.

Excluded from its scope are interconnecting piping and power plant heat exchangers, e.g. turbine surface condensers (which are specified in BP [GS 156-2](#)).

1.2 General

- 1.2.1 Heat exchangers shall be designed and fabricated in accordance with the specified pressure vessel code and [TEMA](#) Class 'R' unless otherwise agreed with BP.

Class 'R' (for refinery) is required in oil and petrochemical service. Class 'B' may be used on minor non-hydrocarbon duties.

- 1.2.2 Shells and channels shall be designed in accordance with the requirements of the specified pressure vessel code and BP [GS 146-2](#).

- 1.2.3 Where the vessel code contains rules for tubesheet design, e.g. [BS 5500](#) and [ASME](#), these shall be used in preference to [TEMA](#).

[TEMA](#) provides rules for the design of all heat exchanger components and also gives fabrication tolerances. It is relevant even if tubesheet design is by another code.

- 1.2.4 Definitions and abbreviations are given in Appendix A of this Specification. References are given in Appendix B.

1.3 Responsibilities of the vendor

The vendor shall be responsible for mechanical design, provision of materials, fabrication, testing and quality of workmanship unless otherwise agreed with BP. Approval of the vendor's drawings by BP, the purchaser or an inspector does not relieve the vendor of any of these responsibilities.

The vendor shall ensure that the technical and QA requirements specified in the enquiry and purchase documents are applied to all materials, equipment and services provided by sub-contractors.



When providing the thermal design, the vendor shall guarantee the thermal performance and vibration resistance of the unit.

1.4 Information to be agreed and documented

1.4.1 Information to be specified by the purchaser

1.4.1.1 Thermal design

- (1) Where the thermal design has been made by the purchaser, completed data sheets in accordance with Appendix C, or equivalent, shall be issued with the enquiry. These shall state the main heat transfer data, geometry and dimensions of the unit.
- (2) Where the thermal design is to be performed by the vendor, the data to be issued by the purchaser shall include as a minimum:-
 - (a) Process duty and required performance
 - (b) Fouling resistances
 - (c) For multi-phase process services, the purchaser's process and physical property data sheet as given in Appendix D.

Simply providing inlet and outlet properties for two phase streams may be inadequate, particularly when there is a phase change e.g. de-superheating followed by sub-cooling. It may also be inadequate for single phase streams which have a large variation in viscosity.

Since most process simulation programs can produce the required physical properties, the data sheet in Appendix D is needed only for certain cases.

1.4.1.2 Mechanical design

The purchaser shall confirm the following:-

- (1) Code and Construction Category ([BS 5500](#)), Degree of Radiographic Examination ([ASME VIII](#)) or equivalent.
- (2) Static design pressures and temperatures; transient and/or cyclic pressures and temperatures; required creep or fatigue life; site environmental conditions, e.g. design wind speed and minimum ambient temperature; emergency external loads such as earthquake loads.



- (3) Materials of construction and corrosion allowance
- (4) Contents
- (5) Nozzle details and orientations; nozzle design loads or external piping loads.
- (6) Preliminary foundation details; bundle removal distance.
- (7) Bolt tensioning equipment
- (8) No of cycles for shellside bellows (if required)
- (9) Name of Inspecting Authority (for [BS5500](#)), Inspector (for [ASME VIII](#)) or equivalent.
- (10) Any requirements on interchangeability (see 4.8.4).
- (11) Paint system

1.4.2 Information to be specified by the vendor

1.4.2.1 With quotation

When quoting, vendors shall confirm compliance with the code and this BP GS, or give any deviations therefrom. They shall also submit:

- (1) Completed data sheets for the design case and any alternative cases.
- (2) The major dimensions of the unit, nozzle sizes and locations.
- (4) The bundle details, arrangement of channels including tube passes and number of tubes per pass.
- (5) Type of shell bellows being offered (where applicable).
- (6) Typical quality plan
- (7) Manufacturing programme.

Where shells and tube bundles are similar, the possibility of standardisation and inter-changeability of parts should be identified.



1.4.2.2 During design and manufacture

If the vendor is carrying out the thermal design, the input data and the results of the thermal design and vibration calculations shall be submitted for review.

Before manufacture commences, the vendor shall submit for review by the purchaser a full set of drawings, mechanical calculations, quality plan, weld and heat treatment procedures.

When aspects of design fall beyond the scope of the code, adequate calculations shall be carried out by the vendor to prove the integrity of the design. These shall be submitted to BP for approval.

The vendor shall resubmit any revisions of drawings for further approval by the purchaser.

No modifications shall be made to the approved design without the approval of the purchaser and the Inspecting Authority (for [BS5500](#)), Inspector (for [ASME VIII](#)) or equivalent.

1.4.2.3 On completion of construction

On completion of construction, the vendor shall assemble and deliver with the heat exchanger a dossier, which shall as a minimum contain the following:-

- (a) Data sheet and list of design requirements
- (b) All drawings, including the 'as built' drawings
- (c) List of the materials used in the construction of the vessel
- (d) Materials test certificates for all pressure containing parts. These shall be to [BS EN 10204:1991 3.1B](#) for heat exchangers to [BS 5500](#), or equivalent for other codes.
- (e) Details of any heat treatments carried out in manufacturing the materials
- (f) Weld seam identification chart
- (g) Qualified welding procedures
- (h) Welders' qualifications



- (i) Radiography and other NDT records. (The radiographs themselves may be required if specified by BP).
- (j) Record of heat treatment during manufacture
- (k) Hydraulic test certificate
- (l) Inspection certificates
- (m) Details of any deviations from code and the acceptance thereof
- (n) Nameplate rubbing or photograph
- (o) Design calculations for pressure containing parts and vessel supports
- (p) Quality Plan signed by all inspection parties
- (q) Engineering concessions
- (r) Details of weld procedure plate when appropriate
- (s) A Certificate of Compliance Form X (for [BS 5500](#)); or Manufacturer's Data Report U-1A ([ASME VIII](#) Division 1); or Manufacturer's Data Report A-1 ([ASME VIII](#) Division 2); or equivalent.
- (t) Any maintenance requirements.

1.5 Quality Assurance

- 1.5.1 The vendor will be expected to operate a quality system to satisfy the design code and this BP GS. It should be in accordance with the relevant part of [ISO 9001](#) or equivalent.

The quality system should ensure that the technical and QA requirements specified in the enquiry and purchase documents are applied to all materials, equipment and services provided by sub-contractors and to any free issue materials.

- 1.5.2 Positive Materials Identification, when required by BP, shall be specified separately.

2. THERMAL DESIGN

2.1 General

- 2.1.1 The TEMA type of the heat exchanger shall be specified by the thermal



designer and approved by BP.

The TEMA type is a three letter classification obtained from [TEMA](#) figure N-1.2.

- 2.1.2 Thermal design shall be performed using either HTFS or HTRI methods and software. Other software may be used only with BP approval.

HTFS and HTRI are industry leaders in heat exchanger thermal design programs.

- 2.1.3 All exchangers shall be free of damaging vibration. HTFS or HTRI software shall be used for vibration analysis unless otherwise agreed with BP.

Vibration can lead to tube failure. To ensure that it cannot occur, the pitch of the baffles and support plates must not exceed that permitted for the process flows and the tube dimensions.

- 2.1.4 Minimum tube thickness shall be as shown in Table 1.

Tube Material	Minimum Thickness	
	mm (in)	BWG
Carbon steel	2.11 (0.083)	14
Low/Medium alloy Steels	2.11 (0.083)	14
Aluminium brass	2.11 (0.083)	14
Aluminium bronze	2.11 (0.083)	14
Aluminium	2.11 (0.083)	14
Austenitic stainless steels	1.65 (0.065)	16
Ni-Fe-Cr alloys	1.65 (0.065)	16
Admiralty brass	1.65 (0.065)	16
Cupro-Nickels	1.65 (0.065)	16
Copper	1.65 (0.065)	16
Monel/Zirconium/Hastelloy	1.22 (0.048)	18
Titanium	0.89 (0.035)	20

TABLE 1 - MINIMUM TUBE WALL THICKNESS

- 2.1.5 Fouling resistances shall be specified by BP. In the absence of plant data or experience, the fouling resistances given in [TEMA](#) Section 10 RGP-T-2.4 shall be used.

Incorrect specification of a fouling resistance can lead to expensive heat exchangers which give operational problems.

- 2.1.6 The number of tubes in any pass shall not be greater than 10% above and below the average number of tubes per pass.



- 2.1.7 For all cooling water applications, design operating velocities in tubes shall be kept within the limits shown in Table 2.

If the water contains suspended solids, the maximum velocity shall be 80% of the limits given in Table 2. Design velocities for tube materials not included in Table 2 shall be specified by BP.

Tube Material	Velocity limit m/s (ft/s)	
	Min.	Max.
Admiralty Brass	0.9 (3.0)	1.5 (5.0)
Aluminium or Copper	0.9 (3.0)	1.5 (5.0)
Aluminium Brass	0.9 (3.0)	2.4 (8.0)
Aluminium Bronze	0.9 (3.0)	3.0 (10.0)
Cupro-Nickel 70/30	0.9 (3.0)	3.0 (10.0)
Cupro-Nickel 90/10	0.9 (3.0)	2.4 (8.0)
Titanium	0.9 (3.0)	4.5 (15.0)
Monel	0.9 (3.0)	3.7 (12.0)
Austenitic Stainless Steel	0.9 (3.0)	4.6 (15.0)
Ni-Fe-Cr Alloys	0.9 (3.0)	4.6 (15.0)
Carbon steel with an organic protective lining	0.9 (3.0)	2.1 (7.0)
Carbon Steel	0.9 (3.0)	2.1 (7.0)

TABLE 2 - FLUID VELOCITY LIMITS WITH DIFFERENT TUBE MATERIALS

2.2 Baffles, by-pass seals and impingement protection

- 2.2.1 For baffles of the single or double segmental type, the baffle cut shall be vertical for horizontal condensers, reboilers and feed/effluent exchangers, and horizontal for single phase exchangers. For vertical exchangers, the baffle cut shall be perpendicular to the nozzle centreline.

For heat exchangers with segmental baffles, the inlet, outlet and central baffle spacing shall be restricted to less than 40% of the unsupported spans given in [TEMA](#) Table R-4.52, but longer unsupported spans are acceptable for a No-Tube-In-Window (NTIW) design.

- 2.2.3 Longitudinal baffles ([TEMA](#) type F) may provide a compact economic design. The baffle must be sealed along its length and access for maintenance of the seal is inevitably restricted. The design shall be used only where removal of the bundle is intended to be infrequent.
- 2.2.4 Impingement protection shall be provided according to [TEMA](#) RCB-4.6. Impingement plates are preferred but, where vibration is probable, rods instead of plates should be used.



Distribution belts also avoid fluid impingement on the tubes but they are costly.

- 2.2.5 Bypass sealing devices (such as seal bars, dummy tubes or tie rods), as permitted by [TEMA RCB-4.8](#) and [API 660](#), shall be specified where tubes have been omitted (to provide adequate entrance and exit areas), or where the radial distance from the outermost tube to the shell inside diameter exceeds 19 mm. Sealing devices shall also be provided in the bundle to block pass partition lanes or the central gap in a U-tube bundle.

By-pass seals may be of considerable importance in obtaining the required performance from a unit.

3. MATERIALS

3.1 General

- 3.1.1 Materials shall comply with the requirements of BP [GS 146-2](#).

Components clad in austenitic stainless steel or nickel alloy shall comply with Appendix BB in BP [GS 146-2](#).

Cast components shall not be used without BP approval.

- 3.1.2 Material specifications for ferrous tube bundles shall be as listed in Table 3, and for non-ferrous tube bundles in Table 4. Other materials may be specified subject to BP approval.

- 3.1.3 ERW (seam welded) tubes shall not be used for onerous duties, where corrosive attack on the weld can occur, or for design pressures in excess of 50 bar (ga).

Duties considered onerous contain the following: hydrogen, hydrogen sulphide, hydrofluoric acid, caustic, cyanide, nitrate, sulphur dioxide, toxic chemicals, and substances likely to promote stress corrosion cracking.

ERW tubes may be considered for non-onerous duties above 50 bar (ga) subject to a review of the tube vendor's manufacturing, QA and QC procedures.

- 3.1.4 Combinations of materials (e.g. for tubes, baffles and channels) shall be critically assessed for the possibility of galvanic corrosion.

Galvanic corrosion can occur both in service and prior to service (e.g. lube and seal oil coolers during the testing, commissioning, and storage period).



3.2 Salt water or aggressive service

Requirements for salt water or aggressive water service are given in Appendix E.





MATERIALS FOR FERROUS TUBE BUNDLES

TABLE 3

(Numbers in brackets refer to notes overleaf).

BASIC TUBE MATERIAL SPECIFICATION AND GRADES FOR TUBE BUNDLE COMPONENTS versus FLUID STREAM ALLOCATION AND TUBE-TO-TUBE SHEET JOINT																									
COMPONENT OF TUBE BUNDLE	CARBON STEEL		1 1/4% Cr-Mo STEEL				5% Cr-Mo STEEL				AUSTENITIC STAINLESS STEEL FOR EXPANDED (ROLLED) TUBE JOINTS (4)		AUSTENITIC STAINLESS STEEL FOR WELDED TUBE JOINTS (4)		MOLYBDENUM-BEARING AUSTENITIC STAINLESS STEEL								9% NICKEL STEEL		
															FOR EXPANDED (ROLLED) TUBE JOINTS				FOR WELDED TUBE JOINTS						
			TUBE SIDE CORROSIVE SERVICE		SHELL SIDE CORROSIVE SERVICE		TUBE SIDE CORROSIVE SERVICE		SHELL SIDE CORROSIVE SERVICE						TUBE SIDE CORROSIVE SERVICE		SHELL SIDE CORROSIVE SERVICE		TUBE SIDE CORROSIVE SERVICE		SHELL SIDE CORROSIVE SERVICE				
	BS	ASTM	BS	ASTM	BS	ASTM	BS	ASTM	BS	ASTM	BS	ASTM	BS	ASTM	BS	ASTM	BS	ASTM	BS	ASTM	BS	ASTM			BS
TUBES (3)	3606 -320 or-440	A179 A214	3606 -621	A199 -T11	3606 -621	A199 -T11	3606 -625	A199 -T5	3606 -625	A199 -T5	3606 304S25	A213 TP 304	3606 321S22 347S17 304S22	A213- 321 347 304L	3606- 316S25	A213- TP316	3606- 316S25	A213- TP316	3606 316S24	A213 TP316L	3606- 316S24	A213 TP316L	-	A334 Gr.8	
TUBESHEETS (1)	EN 10028 -2 P265 1503 -221	A515 Gr.55 or 60 A105	EN 10028 -2 13CrMo 4-5 1503 -621	A387 Gr.11 A336	EN 10028 -2 13CrMo 4-5 1503 -621	A387 Gr.5 A336		A387 Gr.5 A336		A387 Gr.5 A336	1501 Pt.3 -304S31	A240- 304 or A264- 304	1501 Pt.3 -321S31 347S31 304S11	A240- 321 347 304L or A264- 321	1501 Pt.3 -316S33 316	A240- 316 or -316S13 316	1501 Pt.3 -316S13	A240- 316 -316S13	1501 Pt.3 -316S13 or A264- 316L	1501 Pt.3 -316S13	A240- 316 -316S13	1503 316S13	A316	A353 or A553 Type 1 1503 -509	
BAFFLES	EN 10028 -2 FE430	A283	EN 10028 -2 FE430	A283	EN 10028 -2 13Cr Mo 4-5	A387 Gr.11	EN 10028 -2 FE430	A283	-	A387 Gr.5	1501 Pt.3 -304S31	A240- 304	1501 Pt.3 -304S31	A240- 304	1501 Pt.3 -304S31	A240- 304	1501 Pt.3 -316S33	A240- 316	1501 Pt.3 -304S31	A240- 304	1501 Pt.3 -316S33	A240- 316	-	A353 or A553 Type 1	
BAFFLE SPACERS (3)	3601	A53	3601	A53	3604 -621	A335 -P11	3601	A53	3604 -625	A335 -P5	3605 -304S18	A312- TP 304	3605- 304S18	A312- TP 304	3605- 304S18	A312- TP 304	3605 -316S18	A312 TP 304	3605 - 316S18	A312- TP 316	3605- 316S18	A312 TP 316	-	A334- Gr.8 or A333- Gr.8	
TIE RODS	EN 10025 FE430	A675	1502 -151	A675	1506 631	A739 B11	1502 -151	A675	1502 -625	-	1502- 304S31	A479 304	1502- 304S31	A479 304	1502- 304S31	A479 - 304	1502- 316S33	A479- 316	1502- 304S31	A479- 304	1502- 316S33	A479- 316			
FLOATING HEAD COVERS (1)	EN 10028 -2 P265 1503- 221 (7) or 1504- 161	A515 A105 or A216 -WCB	-	A387 Gr.11 A336 or A217 -WC6	-	A387 Gr.11 A336 or A217 -WC6	-	A387 Gr.5 A336 or A217 -C5	-	A387 Gr.5 A336 A217 -C5	1501 Pt.3 -321S31 347S31 304S11	A240 -321 347 304L	1501 Pt.3 -321S31 347S31 304S11	A240 -321 347 304L	1501 Pt.3 -316S13	A240 -316L	1501 Pt.3 -316S13	A240 -316L	1501 Pt.3 -316S13	A240 -316L	1501 Pt.3 -316S13	A240 -316L			
CLAMP RINGS	1503 -221 (6)	A105	1503 -221 (6)	A105	1503 621	A336 F11	1503 -221 (6)	A105	1503 -625	A336 F5	1501 Pt.3 -304S31 or 1503 -304S31	A240 304 or A336 F304	1501 Pt.3 -304S31 or 1503 -304S31	A240 304 or A336- F304	1501 Pt.3 -304S33 or 1503 -304S33	A240 316 or A336- F316	1501 Pt.3 -304S31 or 1503 -304S31	A240 304 or A336- F304	1501 Pt.3 -304S33 or 1503 -304S33	A240 316 or A336- F316	1501 Pt.3 -316S33	A240- 316 or A336- F316			
FLOATING HEAD NUTS (5)	4882 Gr.2H	A194 Gr.2H	4882 Gr.2H	A194 Gr.2H	4882 Gr.7	A194 Gr7	4882 Gr.2H	A194 Gr2H	4882 Gr.6	A194 Gr.3	4882 Gr.8	A194 Gr8	4882 Gr.8	A194 Gr.8	4882 Gr.8	A194 Gr.8	4882 Gr.8M	A194 Gr.8M	4882 Gr.8	A194 Gr.8	4882 Gr.8M	A194 Gr.8M			
FLOATING HEAD BOLTS (5)	4882 B7	A193 B7	4882 B7	A193 B7	4882 B7	A193 B7	4882 B7	A193 B7	4882 B6	A193 B5	4882 B8	A193 B8	4882 B8	A193 B8	4882 B8	A193 B8	4882 B8M	A193 B8M	4882 B8	A193 B8	4882 B8M	A193 B8M			

NOTES ON TABLE 3

1. Generally, where no material grade is listed, all grades are acceptable.

For tubesheet and floating head forgings, the grade is the same as for plate material (with an 'F' prefix for ASTM).
2. Baffle spacers may be made from tube materials listed in the same columns.
3. For ERW (seam welded) tubes, the tube manufacturers' techniques and quality control procedures shall be subject to approval by BP.
4. All austenitic stainless steels for tube bundle fabrication shall be supplied in the solution-annealed condition.
5. See BP [GS 142-9](#).
6. Where [BS 1503-221](#) is listed, only 410, 430, 460, 490 and 510 types are acceptable.





MATERIALS FOR NON-FERROUS TUBE BUNDLES

TABLE 4

(Numbers in brackets refer to notes overleaf).

BASIC TUBE MATERIAL SPECIFICATION AND GRADES FOR TUBE BUNDLE COMPONENTS - TUBESIDE CORROSIVE SERVICE																		
(ASSUMING LINED CHANNELS AND FLOATING HEAD)																		
COMPONENT OF TUBE BUNDLE	ADMIRALTY BRASS		ALUMINIUM BRASS		ALUMINIUM BRONZE (3)		70-30 CUPRO- NICKEL (3)		90-10 CUPRO- NICKEL (3)		MONEL (3)		TITANIUM (3)		COPPER		ALUMINIUM	
	BS	ASTM	BS	ASTM	BS	ASTM	BS	ASTM	BS	ASTM	BS	ASTM	BS	ASTM	BS	ASTM	BS	ASTM
TUBES (1) (4)	2871 Pt.3 CZ111	B111- C44300	2871 Pt.3 CZ110	B111- C68700	2871 Pt.3 CA102	B111- C60800	2871 Pt.3 CN107	B111- C71500	2871 Pt.3 CN102	B111- C70600	3074 NA13	B163- N04400	(7)	B338- Gr.2 or 7	2871 Pt.3 C1-06	B111- C12200	1471- 1050A	B234- 1060
TUBE SHEETS (2)	2875- CZ112	B171- C46400	2875- CZ112	B171- C46400	2875- CA106	B171- C61400	2875- CX112 or CN107	B171- C46400 or C71500	2875- CZ112 or CN102	B171- C70600 or C46400	3072- NA13	B127 or A265	Ti or Ti-clad (7)	B265 (Solid or clad) Gr.1, 2 or 7	2875- C106	B152 C12200	1470- 1050A	B209- 1060
BAFFLES (8)	2875 CZ112	B171- C46400	2875- CZ112	B171- C46400	2875- CZ112 or CA106	B171- C46400 or C61400	2875- CZ112 or CN107	B171- C46400 or B402- C71500	2875- CZ112 or CN102	B171- C46400 or B402- C70600	2875- CZ112 or 3072 NA13	B127 or B171- C46400	Ti (7) or 2875- CZ112	B265- Gr.2 or 7, or B171- C46400	2870- C106 or 2875 -C106	B152- C12200	1470- 1050A	B209- 1060
BAFFLE SPACERS (8)	AS TUBES																	
TIE RODS (8)	2874- CZ112	B124- C46400	2874- CZ112	B124- C46400	2874- CZ112 or CA104	B124- C46400 or C63000	2874- CN107	B124- C46400 or B151- C71500	2874- CN102	B124- C46400 or B151- C70600	2874- CZ112 or 3076- NA13	B124- C46400 or B164- N04400	Ti (7) or 2874- CZ112	B348- Gr.2 or 7, or B124- C67500	2874- C106	B152- C12200 (9)	1474- 1050A	B211- 1060 (10)
FLOATING HEAD COVERS	BS 1501 Pt.1 - 151 1503 - 221 1504 - 161 ASTM A234 - WPB A105 A216 - WCB																	
CLAMP RINGS	1501 Pt.1 - 151 1503 - 221 A105																	
FLOATING HEAD NUTS (5)	4882 Gr.2H A194 Gr.2H																	
FLOATING HEAT BOLTS (5)	4882 B7 A193 B7																	

NOTES ON TABLE 4

1. All brass, bronze, cupro-nickel and Monel tubes for expanded tube-to-tubesheet joints shall be supplied in the 'annealed' condition.

When tubes in one of the above copper alloys are used with one end ferruled, the other end shall be annealed for a distance of 150 mm (6 in) and the annealed end painted for identification, clear of the annealed portion.

Copper tubes for expanded tubesheet joints shall be supplied either in the 'annealed' condition or the 'as-drawn end-annealed' condition.

2. For requirements on clad tubesheets, refer to 3.1.1 of this Specification and [GS 146-2](#).
3. These materials are suitable for welded tube joints.
4. On all U-tubes, the bends plus at least 300 mm (12 in) of each straight leg shall be stress relieved after forming, except for: copper and aluminium for which requirements are to be specified by the vendor for approval by BP; and for titanium for which no stress relief is necessary.
5. See BP [GS 142-9](#).
6. Where no material grade is listed, all grades are acceptable.
7. There are at present (1997) no British Standards for titanium heat exchanger components. However, suitable tubing (both seamless and longitudinally welded), forgings, sheet and bar of commercial purity titanium and of the grade containing palladium are available as proprietary materials.

Shell side conditions will determine whether titanium or other alloy trim is required.
8. Where shell-side conditions are non-corrosive, carbon steel bundle trim may be proposed by the vendor.
9. For copper bundles, this grade in 'HO3' condition shall be used for tie-rods.
10. For aluminium bundles, this grade in 'H18' condition may be unacceptable due to low strength. A higher strength aluminium alloy (e.g. [ASTM B211-2011](#)) may be used, provided it is suitable for the service and not susceptible to stress corrosion cracking. Proposals shall be specified by the vendor for approval by BP.



4. MECHANICAL DESIGN

4.1 General

- 4.1.1 Components subject to both shell and tubeside fluids (e.g. tubes, tubesheets, floating heads) shall be designed for the most severe combination of pressure and temperature which can apply.
- 4.1.2 Consideration shall be given to design for start-up and shutdown, for upset conditions (e.g. loss of flow) and for high temperature water or steam cleaning.
- 4.1.3 Differential pressure designs are not acceptable unless specifically approved. When such designs are used, the differential pressure for the hydrotest shall be stamped on the nameplate.
- 4.1.4 When determining the shell side design pressure, consideration shall be given to pressure relief in the event of either a fire or tube rupture.
- 4.1.5 A nameplate shall be provided on every heat exchanger. It shall be in accordance with [GS 146-2](#), except that the required data shall be given for both the shellside and tubeside.

4.2 Main flanges

- 4.2.1 With flanges of diameter greater than 1.5m, the vendor shall either demonstrate previous satisfactory experience of resistance to leakage on similar designs or provide stiffness/leakage calculations.

Code calculations are concerned primarily with ensuring adequate flange strength rather than negligible leakage. An initial check of flange flexibility (to check for the likelihood of leakage) may be made to [ASME VIII](#) Division 1 Appendix S, section S-2.

The likelihood of leakage increases with diameter but not necessarily pressure (i.e. flanges for low pressure may be vulnerable to leakage). It also depends on the type of gasket and the method of tightening. Stress relaxation or over-stressing of the bolts due to temperature effects may be significant and the following cases should be subject to special consideration:

- (a) a combination of dissimilar materials at elevated or low temperatures;*
- (b) a flange with through bolting at temperatures above 400°C or below -50°C;*
- (c) a flange assembly subject to cyclic temperature conditions.*

- 4.2.2 Space shall be provided for the use of air-operated impact wrenches or hydraulic bolt tensioners as required by [BP GS 146-2](#), with particular attention to multi-shell arrangements. The nozzle orientations and support saddle locations shall be checked to ensure that adequate clearance is provided.



- 4.2.3 With rubber and fibre gaskets, all main flanged joints shall be provided with jacking screws. A minimum of four screws is required on flanges 450mm and larger; two screws are required on smaller units. Screw diameters shall be 16 mm.

4.3 Nozzles

- 4.3.1 Nozzles shall conform to the requirements of BP [GS 146-2](#).
- 4.3.2 Vent and drain connections shall be flanged and 1 1/2 NPS minimum. Threaded pressure gauge and thermowell connections shall not be required unless otherwise specified by BP.

Instrument connections are normally located in the attached pipework.

- 4.3.3 Flange facing type shall be specified by the purchaser. Surface finish shall be in accordance with [BS 5500](#) table 3.8-3 or equivalent.

Raised face type are generally required for Classes 150 to 900.

- 4.3.4 For nozzle loadings, refer to BP [GS 146-2](#).

4.4 Gaskets

- 4.4.1 Jointing shall be in accordance with the requirements of BP [GS 142-7](#).
- 4.4.2 Gaskets shall be of one-piece construction.
- 4.4.3 Spiral wound gaskets shall be supplied only by vendors specifically approved by BP.

4.5 Channels and floating heads

- 4.5.1 The minimum pass partition plate thickness shall be calculated to [TEMA RCB-9.132](#) and the tubeside corrosion allowance added to it.

This corresponds to one-half of the tubeside corrosion allowance on each exposed surface of the plate and is considered adequate for an internal accessible component.

For duties involving heavy fouling (i.e. where fouling resistance $> 0.0008 \text{ m}^2 \text{ K/ W}$), the pressure differential to be used in calculating the pass partition thickness (using [TEMA](#) paragraph RCB-9.132) shall be that which would occur if only 25% of the tubeside design flow area were available.

- 4.5.2 Floating head covers shall comprise a spherical dish welded to the inside of a bolting ring.



A machined forging may be used for small diameter (<450 mm) heads.

A backing ring keyed into the back of the tubesheet shall be used for large diameters (>900 mm) or high tubeside pressures (>17 bar(ga)).

- 4.5.3 Floating head depth shall provide a cross-over area at least equal to 1.5 times the tube pass area.

Small cross-over areas and high velocities can cause erosion problems, hence the value give in [TEMA R-5.11](#) is not considered adequate. For designs using high flowrates, a cross-over area of twice the tube pass area is recommended.

- 4.5.4 On floating heads, bolt spacing and clearances shall not be less than the [TEMA](#) minimum. Corrosion allowance shall be added to each wetted surface except the gasket face.

4.6 Bellows

- 4.6.1 When shell bellows are required in the design of fixed tubesheet exchangers, an estimate of the cyclic life of the bellows should be provided by the purchaser.

Shell bellows are needed where the differential thermal expansion cannot be accommodated by suitable design of the tubes and tubesheet.

Shell bellows should preferably be thick-walled and made from the same material as the shell.

Thin-walled bellows may be used with specific approval from BP. For these, suitable protection shall be fitted to prevent damage to the bellows during fabrication, transport, installation and operation. A locking device shall be fitted to ensure that damage cannot occur during lifting of the exchanger.

Thin walled bellows must be made in a material which is corrosion resistant to both the process conditions and the external environment. As stresses in bellows convolutions are high, stress corrosion cracking is a mechanism which should be considered. Thin-walled bellows provide greater flexibility than thick-walled but are not as robust. They are generally more readily obtainable.

Rules for the design of thick-walled bellows are given in AD Merkblatt and [TEMA](#). Rules for the design of thin-walled bellows are given in the EJMA standard. The rules to be applied should be agreed between purchaser and vendor.

For both thick and thin-walled bellows, a quality plan for the manufacture of the bellows shall be prepared for purchaser approval.

4.6.2 Internal bellows

In the design of certain floating head exchangers, thin-walled bellows may be required on the nozzle connection to the floating head. They shall be subject to the requirements for thin-walled bellows in 4.6.1.

4.7 Shell supports and attachments

4.7.1 Supports for non-ferrous shells shall be submitted by the vendor for BP approval.

4.7.2 All exchangers and their supports shall be designed to permit full hydrostatic testing.

4.7.3 For stacked shells, the design for superimposed loads shall be proven by calculation.

4.7.4 Slotted holes shall be fitted in all sliding saddles to permit unrestrained thermal expansion and contraction of the shell.

4.7.5 Fixed saddles shall be designed for a longitudinal pulling force of 150% of the bundle weight.

4.7.6 Insulation supports shall be to BP [GS 146-2](#).

4.8 Tubes and tubesheets

4.8.1 When the thinning associated with U-tube bending cannot be tolerated due to in-service corrosion, the inner two rows with the smallest bend radius shall have tubes with a wall thickness 0.6 mm thicker than the remaining tubes.

4.8.2 Tube holes in tubesheets ([TEMA RCB-7.41](#)) shall be 'special close fit' for austenitic stainless steel and titanium tubes; and for other materials prone to work hardening or corrosion.

4.8.3 On bonnet type heads ([TEMA type B](#)) for chemical service, a bundle retainer (see [API 660 4.6.2.1](#)) shall be used to enable the head to be removed or replaced in service, without movement or relaxation of the tubesheet joint.

4.8.4 On exchangers with identical removable bundles, bundles shall be interchangeable.

When specified, removable bundles shall be designed for 180° rotation, except that an impingement plate shall not be installed opposite the outlet nozzle.



4.9 Tube end fixing

4.9.1 The attachment of the tubes to the tubesheet shall be in accordance with [GS 118-8](#).

The combination of welding and expansion required on each exchanger shall be specified by the purchaser. The following combinations of tube expansion and tube end welding may be adopted depending on service conditions:

- expanded only;
- strength welded only;
- expanded and seal welded;
- strength welded and lightly expanded;
- strength welded and expanded;
- back face welded.

A strength weld is defined as a weld in which the minimum throat thickness is not less than the tube wall thickness. A weld having a smaller throat thickness than this is considered to be a seal weld and its function is solely to seal the tube and the tubesheet.

For exchanger applications involving non-corrosive and non-penetrative services, expanded tube-to-tubesheet joints shall be used.

In many applications, for example condensers and low pressure reboilers, tube expansion into grooves in the tubesheet without welding is satisfactory and economic

The maximum projection of the tube end shall be 3 mm. For vertical thermosiphon heat exchangers, there shall be no projection of the tube ends at the top tubesheet.

For services where total leak tightness is required, welded tube-to-tubesheet joints shall be used. The type of welded joint required (i.e. strength weld or seal weld) shall be specified by the purchaser.

With properly applied strength welds, tube expansion is frequently unnecessary as it does not significantly add to the mechanical strength of the tube end fixing.

Where the crevice between tube and tubesheet must be minimised (e.g. to avoid crevice corrosion, or when fretting is anticipated, or when good heat transfer must be maintained between the tubes and the tubesheet), the tube may be expanded after welding. This provides intimate contact between the outside diameter of the tubes and the bore of the tubesheet holes and may be done after welding and leak testing, but before final pressure testing.

Where light expansion after strength welding is specified ([TEMA RCB7.522](#)), tube hole grooving is not required.



Where the crevice is to be eliminated (e.g. due to high thermal gradients), back face welding shall be considered. This is an expensive technique because of the handling of the bundle which is required and the complex welding equipment.

Where the additional security provided by strength welds in combination with tube expansion into grooves is considered necessary, the sequence of operations and the technique employed for tube location is important. Porosity can occur in the welds if the tubes are fully expanded prior to welding and weld cracking may be encountered with expansion after welding. Generally, expansion after welding is more satisfactory.

Particular attention shall be given to tube end fixing where any of the following could occur: thermal shock, thermal cycling or a large difference in thermal expansion between the tubes and tubesheet.

Failure of tube-to-tubesheet attachments is extremely costly and by no means uncommon. Selection of the optimum materials for both tubes and tubesheet together with the correct combination of expansion and welding is essential to ensure maximum integrity and service reliability.

4.10 Transverse baffles and support plates

- 4.10.1 Minimum baffle thickness shall be twice the corrosion allowance; alloy baffle thickness shall be as per TEMA.

Transverse baffles and support plates shall have notches at least 10 mm high to facilitate drainage.

- 4.10.3 Floating head support plates to [TEMA RCB - 5.14](#) shall be located at 100 - 150 mm from the inside face of the tubesheet.

- 4.10.4 Tube holes in baffles to [TEMA RCB-4.2](#) with a close tolerance on diameter (1/64 in) shall be used as stated in TEMA, and additionally when the tube gauge is 16 BWG or thinner, or when vibration is a concern.

Close fitting tolerances will provide better tube support and reduce vibration damage.

4.11 Impingement Baffles

- 4.11.1 The minimum thickness of the impingement plate shall be 6.5 mm or twice the shellside corrosion allowance whichever is the greater. It shall project at least 25 mm beyond the edge of the nozzle bore.

- 4.11.2 Perforated impingement plates shall not be used.

An impingement plate may cause excessive velocities around its edge and hence tube vibration. The tubes under the plate may also be less effective for heat transfer, leading to a loss of performance.



Perforated plates may attempt to solve this, but the impinging velocities will still be high. The use of dummy impingement rods may offer an acceptable solution.

4.12 Handling Devices

- 4.12.1 Provision for lifting shall be included for all channels, bonnets and covers. (Refer also to [TEMA G-7.2](#)).
- 4.12.2 For bundle pulling, tapped holes for pulling eyes shall be provided. They shall be designed for a load of 1.5 times the bundle weight and fitted with a plug for operation.
- 4.12.3 Bundle runner bars shall be provided on all removable bundles. Their ends shall be bevelled to prevent damage during bundle insertion.

In kettle type reboilers or chillers, the floating head or the U-tube support (end) plate shall be provided with a rigid frame to prevent movement and damage to tube bundles during shipping or installation.

5. FABRICATION

5.1 Welding

- 5.1.1 Welding and fabrication shall be in accordance with the specified vessel code and BP Group [GS 146-2](#).
- 5.1.2 Refer to BP Group [GS 146-2](#) for Charpy V impact test requirements.

Tube-to-tubesheet welds shall be made in accordance with BP Group [GS 118-8](#).

5.2 Heat Treatment

- 5.2.1 Heat treatment of U-bends shall be as follows:-

For U-tube bundles, the bends, plus at least 300 mm of each straight leg shall be heat treated as detailed in (a) and (b) below, except that for chemical plant services all requirements for the heat treatment of austenitic stainless steel shall be specified by the vendor for approval by BP.

(a) Carbon and Low Alloy Steel Tubes

Carbon Steel - 15 minutes in the range 580-620°C
(1075-1150°F)

1/4% Cr 1/2% Mo and 5% Cr 1/2% Mo - 15 minutes in the
range 700-750°C (1290-1380°F)



In each case, the heat treatment at the temperatures stated shall be followed by slow air cooling.

(b) Austenitic Stainless Steel Tubes

Types 304 and 316 - these grades are not acceptable for U-tubes requiring heat treatment.

Types 321, 347, 304L and 316L - either rapid heating to 900-950°C (1650-1740°F), hold in this range for 15 minutes and follow by rapid cooling, or rapid heating by a conductive process to 1050°C (1920°F) followed by rapid cooling. The finished tubes shall be free from scale, and a sample from each lot (as defined in [ASTM A 213](#)) shall be required to pass the acidified copper sulphate intergranular corrosion test as specified in [ASTM A 262](#) Practice E.

5.3 Assembly

- 5.3.1 Matchmarks shall be made by a 1.5 mm deep scribed line at the 12 and 3 o'clock positions on the outer face of components.

6. INSPECTION AND TESTING

6.1 Inspection

- 6.1.1 Inspection and testing shall be in accordance with BP [GS 146-2](#).
- 6.1.2 Removable tube bundles shall be checked for insertion and withdrawal. For rotatable bundles, the check shall be in both positions. Vibration devices or excessive force shall not be used.

6.2 Pressure test

- 6.2.1 (a) Pressure testing shall be in accordance with the requirements of BP [GS 146-2](#), and BP [GS 118-8](#) as appropriate. Requirements for leak detection of welded tube-to-tubesheet joints, shall be in accordance with BP [GS 118-8](#).
- (b) If special tests are specified for tube-to-tubesheet joints, e.g. helium leak tests, the methods and procedures shall be proposed by the vendor for review by the purchaser.
- (c) Support of units during testing shall be similar to that in service; this includes stacked units.



- 6.2.2 Bonnets or channel covers shall be removed for the shellside test.
- 6.2.3 The vendor shall provide test rings for each size of floating head exchanger and test flanges for each size of exchanger with bonnet-type stationary heads. Any additional requirement for multiple units will be as specified or agreed. Test shells, if required, will be specified by the purchaser.

Where the use of a floating head type bundle for a kettle type reboiler is proposed, the method for testing the bundle and the test equipment to be supplied shall be specified by the vendor.

7. PREPARATION FOR SHIPMENT

- 7.1 Painting of all external surfaces shall be in accordance with BP [GS 106-2](#) and the paint system numbers shall be specified by the purchaser.
- 7.2 Shipping gaskets (at nozzles) shall be physically identified and indicated in the documentation.
- Heat exchangers are usually shipped with service gaskets in place; any gaskets for shipping only need to be identified to avoid them being used for service.*
- 7.3 All exchangers shall be dry (Ref. [TEMA G-6.2](#)), thoroughly cleaned and free from loose scale and other foreign matter before shipment from the vendor's works.
- 7.4 Any special requirements (skids, export shipment, etc.), will be specified by the purchaser.



DEFINITIONS AND ABBREVIATIONS**Definitions**

Standardised definitions may be found in the BP Group RPSEs Introductory Volume.

Abbreviations

API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
BS	British Standard
BWG	Birmingham wire gauge
EJMA	Expansion Joint Manufacturers Association
ERW	Electric resistance welded
HTFS	Heat Transfer and Fluid Flow
HTRI	Heat Transfer Research Inc.
NDT	Non-destructive testing
NPS	Nominal pipe size
OD	Outside diameter
TEMA	Tubular Exchanger Manufacturers Association



LIST OF REFERENCED DOCUMENTS

A reference invokes the latest published issue or amendment unless stated otherwise.

Referenced standards may be replaced by equivalent standards that are internationally or otherwise recognised provided that it can be shown to the satisfaction of the purchaser's professional engineer that they meet or exceed the requirements of the referenced standards.

International Documents

[ISO 8501](#) Preparation of Steel Substrates before Application of Paints and Related Products

American Documents

[API 660](#) Shell-and-tube heat exchangers for general refinery services. 5th Edition, June 1993

[ASME VIII](#) ASME Boiler and Pressure Vessel Code Division 1

[EJMA](#) Standard of Expansion Joint Manufacturers Association

[TEMA](#) Standard of Tubular Exchanger Manufacturers Association

European documents

[AD-Merkblatt B13](#) Bellows

[BS 5500](#) Specification for unfired fusion welded pressure vessels

[BS EN 10028](#) Specification for flat products made of steels for pressure purposes

[BS EN 10028-2](#) Non-alloy and alloy steels with specified elevated temperature properties

[BS EN 10204](#) Metallic Products - Types of Inspection Documents

BP Group Documents

[BP GS 106-2](#) Painting of Metal Surfaces

[BP GS 118-8](#) Tube End Welding of Heat Exchanger Tubes



BP GS 136-1	Materials for Sour Service to NACE Std MR0175-90
BP GS 142-7	Gaskets and Jointing
BP GS 142-9	Bolting for Flanged Joints (Unified Inch Series)
BP GS 146-2	Pressure Vessels
BP GS 156-2	Surface Condensers for Steam Turbines



C 1 - SHELL AND TUBE HEAT EXCHANGER SPECIFICATION SHEET METRIC UNITS

1	SERVICE OF UNIT										ITEM NO.																																		
2	SIZE (Dia x Length)					TEMA TYPE					(HORIZ.VERT)					CONNECTED IN					PARALLEL					SERIES																			
3	SURF/UNIT (GROSS) (EFF)					m2					SHELLS/UNIT					SURF/SHELL (GROSS) (EFF)					m2																								
4	OVER AREA/DUTY RATIO:										THERMAL RATING DESIGN CASE NO.																																		
5	PERFORMANCE OF ONE UNIT																																												
6	FLUID ALLOCATION					SHELL SIDE IN					SHELL SIDE OUT					TUBE SIDE IN					TUBE SIDE OUT																								
7	FLUID NAME																																												
8	TOTAL FLUID QUANTITY					kg/h																																							
9	VAPOUR (IN/OUT)																																												
10	LIQUID (IN/OUT)																																												
11	STEAM/WATER																																												
12	NON CONDENSABLE																																												
13	TEMPERATURE (IN-OUT)					°C																																							
14						LIQUID					VAPOUR					LIQUID					VAPOUR					LIQUID					VAPOUR														
15	DENSITY					kg/m ³					/					/					/					/																			
16	SPECIFIC HEAT					kJ/kg °C					/					/					/					/																			
17	VISCOSITY					cP					/					/					/					/																			
18	THERMAL CONDUCTIVITY					W/m °C					/					/					/					/																			
19	MOLECULAR WEIGHT																																												
20	LATENT HEAT					MJ/kg@°C					AT					AT					AT					AT																			
21	INLET PRESSURE					bar abs																																							
22	VELOCITY					m/s																																							
23	PRESSURE DROP (ALLOW/ACT)					bar					/										/																								
24	MEAN METAL TEMP.					°C																																							
25	FOULING RESISTANCE					m ² °C/W																																							
26	HEAT EXCHANGED					kW					CORRECTED MEAN TEMP DIFF.					°C																													
27	TRANSFER RATE					W/m ² °C					SERVICE					CLEAN																													
28	CONSTRUCTION OF EACH SHELL										SKETCH/BUNDLE/NOZZLE ORIENTATION																																		
29						SHELL SIDE					TUBE SIDE																																		
30	DESIGN/TEST PRESSURE					bar abs																																							
31	DESIGN TEMPERATURE					°C																																							
32	NO. PASSES PER SHELL																																												
33	CORROSION ALLOWANCE					mm																																							
34	CONNECTIONS					INLET																																							
35	NUMBER/SIZE					OUTLET																																							
36	AND RATING					INTERMEDIATE																																							
37	TUBE NO.					OD.mm					THK (MIN) mm					LENGTH m					PITCH mm					-30					-60					-90					-45				
38	TUBE TYPE (WELDED/SEAMLESS)																																												
39	SHELL					ID.mm					OD.mm					SHELL COVER (INTEG/REMOV)																													
40	SHELL MATERIAL					(CLAD)					CHANNEL COVER																																		
41	CHANNEL OR BONNET					(CLAD)					TUBESHEET(S)					(CLAD)																													
42	FLOATING HEAD COVER										IMPINGEMENT PROTECTION TYPE																																		
43	BAFFLES - NUMBER					TYPE					% CUT (DIAMETER)					SPACING C/C					mm																								
44	BAFFLES - LONGITUDINAL (Y/N)										SEAL TYPE																																		
45	SUPPORTS - TUBE					U-BEND					TYPE																																		
46	BYPASS SEAL PHERIPHERAL (Y/N)					PASS LANE Y/N					TUBE - TUBESHEET JOINT																																		
47	EXPANSION JOINT (SHELL) (FLOATING HEAD/SHELL COVER)										TYPE/MATERIAL																																		
48	KINETIC ENERGY FACTOR					rho-v ²					INLET NOZZLE					BUNDLE ENTRANCE					BUNDLE EXIT																								
49	GASKETS					SHELLSIDE					TUBESIDE																																		
50	FLOATING HEAD																																												
51	CODE REQUIREMENTS										STAMP Y/N					TEMA CLASS																													
52	WEIGHT/SHELL					DRY					kg					FILLED WITH WATER					kg					BUNDLE					kg														
53																																													
54																																													
55	INSULATION					SHELLSIDE (Y/N)					OPER. TEMP. °C					THKmm					TUBESIDE REQ (Y/N)					OPER. TEMP. °C					THK mm														
56	TUBESHEET DESIGN TEMPERATURE BASIS																																												
57	NOTES																																												
58	(1)																																												
59	(2)																																												
60	(3)																																												
61	(4)																																												
62	(5)																																												
63	PURCHASER'S REF. NO																																												
64	PURCHASER'S REF. NO																																												
65	CONTRACTOR/PURCHASER																																												
66	CONTRACTOR'S REF.NO																																												
67																																													
68																																													
69																																													
70											REVISION					DATE					REMARKS					BY					APPROVED														
71	DOCUMENT					CLIENT																																							
72						PROJECT															SHELL-AND-TUBE HEAT EXCHANGERS					SHEET																			
73						LOCATION																				OF																			



C 2 - SHELL AND TUBE HEAT EXCHANGER

SPECIFICATION SHEET IMPERIAL UNITS

1	SERVICE OF UNIT				ITEM NO.					
2	SIZE (Dia x Length)		TEMA TYPE		(HORIZ.VERT)		CONNECTED IN	PARALLEL	SERIES	
3	SURF/UNIT (GROSS) (EFF)		ft ²		SHELLS/UNIT		SURF/SHELL (GROSS) (EFF)		ft ²	
4	OVER AREA/DUTY RATIO:				THERMAL RATING DESIGN CASE NO.					
5	PERFORMANCE OF ONE UNIT									
6	FLUID ALLOCATION		SHELL SIDE IN		SHELL SIDE OUT		TUBE SIDE IN		TUBE SIDE OUT	
7	FLUID NAME									
8	TOTAL FLUID QUANTITY		lb/h							
9	VAPOUR (IN/OUT)									
10	LIQUID (IN/OUT)									
11	STEAM/WATER									
12	NON CONDENSABLE									
13	TEMPERATURE (IN-OUT)		°F							
14					LIQUID		VAPOUR			
15	DENSITY		lb/ft ³		/		/		/	
16	SPECIFIC HEAT		Btu/lb °F		/		/		/	
17	VISCOSITY		cP		/		/		/	
18	THERMAL CONDUCTIVITY		Btu/h ft °F		/		/		/	
19	MOLECULAR WEIGHT									
20	LATENT HEAT		Btu/lb @ °F		AT		AT		AT	
21	INLET PRESSURE		psi abs							
22	VELOCITY		ft/s							
23	PRESSURE DROP (ALLOWABLE)		psi		/				/	
24	MEAN METAL TEMP.		°F							
25	FOULING RESISTANCE		hft ² °F/Btu							
26	HEAT EXCHANGED		MM Btu/h		CORRECTED MEAN TEMP DIFF.		°F			
27	TRANSFER RATE		Btu/h ft ² °F		SERVICE		CLEAN			
28	CONSTRUCTION OF EACH SHELL				SKETCH/BUNDLE/NOZZLE ORIENTATION					
29			SHELL SIDE		TUBE SIDE					
30	DESIGN/TEST PRESSURE		psi abs							
31	DESIGN TEMPERATURE		°F							
32	NO. PASSES PER SHELL									
33	CORROSION ALLOWANCE		in							
34	CONNECTIONS	INLET								
35	NUMBER/SIZE	OUTLET								
36	AND RATING	INTERMEDIATE								
37	TUBE NO.	OD.in	THK (MIN) in	LENGTH ft	PITCH in		≤ -30	Δ -60	-90	◇ -45
38	TUBE TYPE (WELDED/SEAMLESS)				MATERIAL					
39	SHELL		ID.in	OD.in	SHELL COVER (INTEG/REMOV)					
40	SHELL MATERIAL		(CLAD)		CHANNEL COVER					
41	CHANNEL OR BONNET		(CLAD)		TUBESHEET(S) (CLAD)					
42	FLOATING HEAD COVER				IMPINGEMENT PROTECTION TYPE					
43	BAFFLES - NUMBER		TYPE		% CUT (DIAMETER)		SPACING C/C in			
44	BAFFLES - LONGITUDINAL (Y/N)				SEAL TYPE					
45	SUPPORTS - TUBE		U-BEND		TYPE					
46	BYPASS SEAL PHERIPHERAL (Y/N)		PASS LANE Y/N		TUBE - TUBESHEET JOINT					
47	EXPANSION JOINT (SHELL) (FLOATING HEAD/SHELL COVER)				TYPE/MATERIAL					
48	KINETIC ENERGY FACTOR		rho-v ²		INLET NOZZLE		BUNDLE ENTRANCE BUNDLE EXIT			
49	GASKETS		SHELLSIDE		TUBESIDE					
50	FLOATING HEAD									
51	CODE REQUIREMENTS				STAMP Y/N		TEMA CLASS			
52	WEIGHT/SHELL		DRY lb		FILLED WITH WATER lb		BUNDLE lb			
53										
54										
55	INSULATION SHELLSIDE (Y/N)		OPER. TEMP. °F		THK in		TUBESIDE REQ (Y/N) OPER. TEMP. °F		THK in	
56	TUBESHEET DESIGN TEMPERATURE BASIS									
57	NOTES									
58	(1)									
59	(2)									
60	(3)									
61	(4)									
62	(5)									
63	PURCHASER'S REF. NO									
64	PURCHASER'S REF. NO									
65	CONTRACTOR/PURCHASER									
66	CONTRACTOR'S REF.NO									
67										
68										
69										
70			REVISION		DATE		REMARKS		BY	APPROVED
71	DOCUMENT		CLIENT				SHELL-AND-TUBE HEAT EXCHANGERS		SHEET	
72			PROJECT							
73			LOCATION						OF	



C 3 - TUBESHEET DESIGN CONDITIONS FOR FIXED TUBE HEAT EXCHANGER

1	ITEM TITLE	ITEM NO.				REV
2	PLANT	LOCATION				
3						
4						
5						
6						
7						
8						
9	DESIGN CONDITIONS					
10		UNITS	PRESSURE		TEMPERATURE	
11			SHELL	TUBE	SHELL	TUBE
12	SHELL					
13	CHANNEL/BONNETS					
14	TUBESHEET DESIGN CONDITIONS				PROCESS	METAL
15	NORMAL OPERATION					
16	FAILURE SHELL SIDE	PRESS FAIL				
17	WITH TUBE SIDE AT	TEMP. FAIL				
18	NORMAL OPERATION	BOTH FAIL				
19	FAILURE TUBE SIDE	PRESS FAIL				
20	WITH SHELL AT	TEMP FAIL				
21	NORMAL OPERATION	BOTH FAIL				
22	PUMP SHUT OFF HEAD SHELL SIDE. WITH TUBE SIDE NORMAL OP.					
23	PUMP SHUT OFF HEAD TUBE SIDE. WITH SHELL SIDE NORMAL OP.					
24	DESUPERHEATER FAILURE WITH OTHER SIDE NORMAL OP.					
25	SHELL SIDE AT SYSTEM RV SETTING WITH TUBE SIDE NORMAL OP.					
26	TUBE SIDE AT SYSTEM RV SETTING WITH SHELL SIDE NORMAL OP.					
27	STEAM OUT SHELL SIDE	AMBIENT	AMBIENT			
28	STEAM OUT TUBE SIDE	AMBIENT	AMBIENT	AMBIENT		
29	START UP/SHUT DOWN					
30	COMISSIONING WITH WATER					
31	HYDROTEST SHELL SIDE			AMBIENT	AMB	AMBIENT
32	HYDROTEST TUBE SIDE			AMBIENT	AMB	AMBIENT
33	ANY OTHER ARDUOUS CONDITIONS					
34	IS MIXING OF SHELL AND TUBE FLUIDS HAZARDOUS	YES/NO				
35	WORST CONSEQUENCES OF MIXING					
36						
37	NOTE: IN THE ABOVE, ENTER "NOT APPLICABLE" IF BOX IS NOT RELEVANT. COMPLETE THE WHOLE TABLE					
38						
39						
40						
41						
42						
43						
44						
45						
46						
47						
48						
49						
50						
51						
52						
53						
54						
55						
56						

REVISION	0	1	2	3	4	5
DATE						
PREPARED BY						
CHECKED BY						
APPROVED BY						



APPENDIX D

D 1 - PURCHASER'S PROCESS AND PHYSICAL PROPERTY SHEET METRIC UNITS

	PROCESS DATA		HOT STREAM		COLD STREAM	
	Fluid Name					
			Inlet	Outlet	Inlet	Outlet
1	Total Fluid Quantity	kg/h				
2	Vapour	kg/h				
3	Liquid	kg/h				
4	Steam/Water	kg/h				
5	Non-Condensable	kg/h				
6	Temperature	°C				
7	Inlet Pressure (abs)	bar				
8	Pressure Drop	bar				
9	Fouling Resistance	m ³ C/W				
10	Maximum Velocity	m/s				
11	Minimum Velocity	m/s				

HOT STEAM PROPERTY DATA			Note 1						
1	Fluid								
2	Reference Flowrate	kg/h							
3	Reference Pressure	bar							
Enthalpy Curve				1	2	3	4	5	6
4	Temperature	°C	required						
5a	Specific Enthalpy, or	kJ/kg	Note 2,3						
5b	Heat Load	kW	Note 2,3						
6	Vapour Mass Fraction	-	required						
Liquid Properties									
7	Temperature	°C	required						
8	Density	kg/m ³	required						
9	Viscosity	cP	required						
10	Thermal Conductivity	W/m°C	required						
11	Specific Heat Capacity	kJ/kg°C	required						
12	Surface Tension	dyne/cm	Note 4						
13	Pseudo Critical Pressure	bar	Note 5						
14	Pseudo Critical Temperature	°C	Note 5						
Vapour Properties									
15	Temperature	°C	required						
16	Density	kg/m ³	required						
17	Viscosity	cP	required						
18	Thermal Conductivity	W/m°C	required						
19	Specific Heat Capacity	kJ/kg°C	required						

COLD STREAM PROPERTY DATA			Note 1						
1	Fluid								
2	Reference Flowrate	kg/h							
3	Reference Pressure	bar							
Enthalpy Curve				1	2	3	4	5	6
4	Temperature	°C	required						
5a	Specific Enthalpy, or	kJ/kg	Note 2,3						
5b	Heat Load	kW	Note 2, 3						
6	Vapour Mass Fraction	-	required						
Liquid Properties									
7	Temperature	°C	required						
8	Density	kg/m ³	required						
9	Viscosity	cP	required						
10	Thermal Conductivity	W/m°C	required						
11	Specific Heat Capacity	kJ/kg°C	required						
12	Surface Tension	dyne/cm	Note 4						
13	Pseudo Critical Pressure	bar	Note 5						
14	Pseudo Critical Temperature	°C	Note 5						
Vapour Properties									
15	Temperature	°C	required						
16	Density	kg/m ³	required						
17	Viscosity	cP	required						
18	Thermal Conductivity	W/m°C	required						
19	Specific Heat Capacity	kJ/kg°C	required						

NOTES	
1	For single phase streams only relevant property section needs to be filled in.
2	Heat load or specific enthalpy (preferred option) may be supplied and both increase with temperature.
3	If heat load is supplied, the reference flowrate (usually stream flowrate) relevant to enthalpy curve is needed.
4	Surface tension is normally only required if a boiling stream, or if condensing on fins.
5	Only required for boiling streams.



D 2 - PURCHASER'S PROCESS AND PHYSICAL PROPERTY

SHEET IMPERIAL UNITS

	PROCESS DATA		HOT STREAM		COLD STREAM	
	Fluid Name					
			Inlet	Outlet	Inlet	Outlet
1	Total Fluid Quantity	lb/h				
2	Vapour	lb/h				
3	Liquid	lb/h				
4	Steam/Water	kg/h				
5	Non-Condensable	lb/h				
6	Temperature	°F				
7	Inlet Pressure (abs)	psi				
8	Pressure Drop	psi				
9	Fouling Resistance	ft ² /h F/Btu				
10	Maximum Velocity	ft/s				
11	Minimum Velocity	ft/s				

HOT STEAM PROPERTY DATA				Note 1						
1	Fluid									
2	Reference Flowrate	lb/h								
3	Reference Pressure	psi								
Enthalpy Curve					1	2	3	4	5	6
4	Temperature	°F	required							
5a	Specific Enthalpy, or	Btu/lb	Note 2,3							
5b	Heat Load	MM Btu/h	Note 2,3							
6	Vapour Mass Fraction	-	required							
Liquid Properties										
7	Temperature	°F	required							
8	Density	lb/ft ³	required							
9	Viscosity	cP	required							
10	Thermal Conductivity	Btu/ft h°F	required							
11	Specific Heat Capacity	Btu/lb °F	required							
12	Surface Tension	dyne/cm	Note 4							
13	Pseudo Critical Pressure	psi	Note 5							
14	Pseudo Critical Temperature	°F	Note 5							
Vapour Properties										
15	Temperature	°F	required							
16	Density	lb/ft ³	required							
17	Viscosity	cP	required							
18	Thermal Conductivity	Btu/ft h°F	required							
19	Specific Heat Capacity	Btu/lb°F	required							

COLD STREAM PROPERTY DATA				Note 1						
1	Fluid									
2	Reference Flowrate	lb/h								
3	Reference Pressure	psi								
Enthalpy Curve					1	2	3	4	5	6
4	Temperature	°F	required							
5a	Specific Enthalpy, or	Btu/lb	Note 2,3							
5b	Heat Load	MM Btu/h	Note 2, 3							
6	Vapour Mass Fraction	-	required							
Liquid Properties										
7	Temperature	°F	required							
8	Density	lb/ft ³	required							
9	Viscosity	cP	required							
10	Thermal Conductivity	Btu/ft h°F	required							
11	Specific Heat Capacity	Btu/lb°F	required							
12	Surface Tension	dyne/cm	Note 4							
13	Pseudo Critical Pressure	psi	Note 5							
14	Pseudo Critical Temperature	°F	Note 5							
Vapour Properties										
15	Temperature	°F	required							
16	Density	lb/ft ³	required							
17	Viscosity	cP	required							
18	Thermal Conductivity	Btu/ft°F	required							
19	Specific Heat Capacity	Btu/lb°F	required							

NOTES	
1	For single phase streams only relevant property section needs to be filled in.
2	Heat load or specific enthalpy (preferred option) may be supplied and both increase with temperature.
3	If heat load is supplied, the reference flowrate (usually stream flowrate) relevant to enthalpy curve is needed.
4	Surface tension is normally only required if a boiling stream, or if condensing on fins.
5	Only required for boiling streams.



ADDITIONAL REQUIREMENTS FOR SALT OR AGGRESSIVE WATER SERVICE

E.1 Gaskets

Metal jacketing and wire mesh reinforcement shall be stainless steel type 316, or Monel.

E.2 Protection of carbon steel headers

Where process fluid is untreated salt water the headers shall be protected to the requirements of E.2.1 and E.2.2. For units having salt water of lower chloride content, or other aggressive water as the process fluid, these requirements shall be applied as specified by the purchaser.

E.2.1 Internal Coating (Lining)

When lining is specified, the following requirements apply:-

- (a) Lining to be Glass Flake Polyester with a minimum dry film thickness of:
 - 1500 micron (.06 in) - internal surfaces of the channels including nozzles and cover.
 - 500 micron (.02 in) - water side of tube sheet and one diameter distance inside the tubes, and the gasket faces exposed to the water.
- (b) Areas to be lined shall have all internal and external corners finished with a minimum radius of 3 mm (1/8 in), and surface preparation in accordance with [ISO 8501](#).

For non-ferrous surfaces, the surface preparation shall be by degreasing followed by fine abrasive blasting using a non-metallic abrasive.

- (c) Continuity testing (by spark test) is required.
- (d) Hydrotest shall be prior to lining.



- (e) Refer to Figure E.1 for the extent of lining at anode fixings.

E.2.2 Sacrificial Anodes

When anodes are specified, the following requirements apply:-

- (a) Zinc anodes shall be provided inside the channel cover and floating head (or return channel), in accordance with Figures E.1 & E.2.
- (b) The minimum weight of zinc to be installed initially at each location shall be as given by the formula:-

$$W = \frac{D^2}{12800}$$

W = Nett weight of zinc, (kg).

D = Nominal diameter of exchanger, (mm).

The weight of zinc in each pass shall be in approximate proportion to the pass area.

- (c) The electrical contact resistance between anode and the channel or floating head shall not exceed 0.2 ohms.
- (d) On inlet channels, the distance from the tubesheet to the start of the inlet nozzle bore shall not be less than 100 mm (4 in).

The dimensional restrictions are required to avoid excessive turbulence, and to provide space for the standard anodes.

- (e) On floating heads, the depth of the cover at the crown shall not be less than 150 mm (6 in), and the crossover area in each pass shall not be less than 3 times the maximum tube pass area.



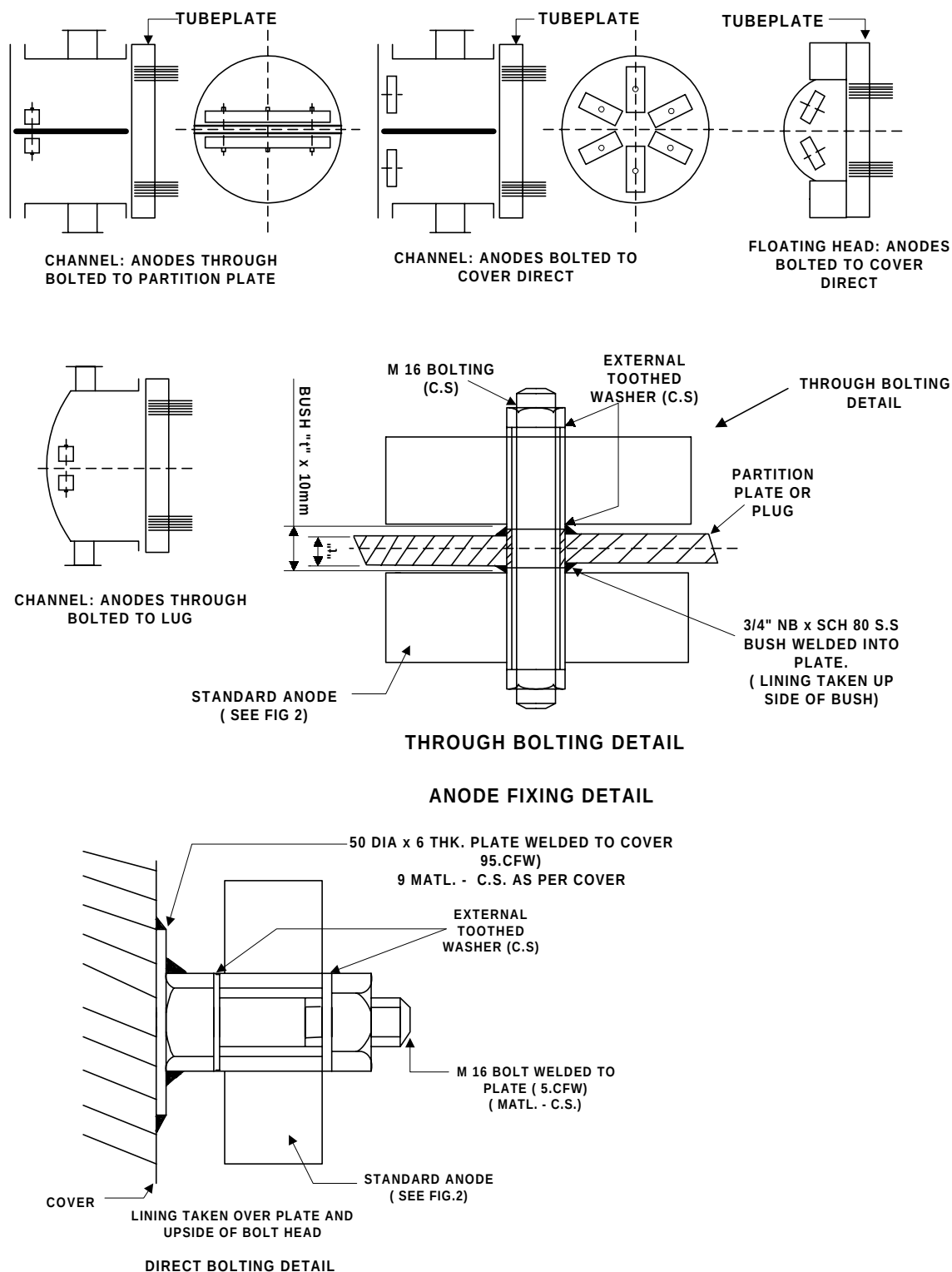
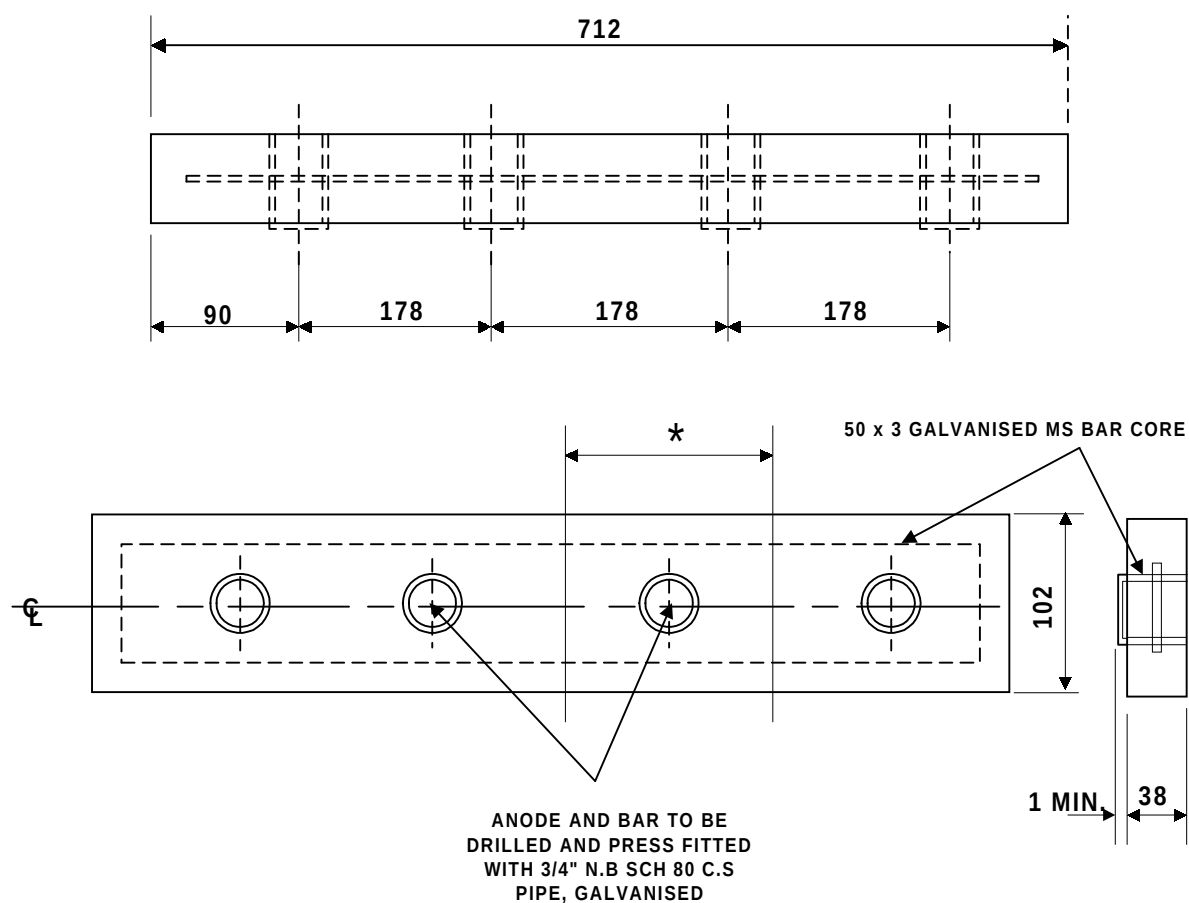


FIGURE E.1

CATHODIC PROTECTION - ANODE ARRANGEMENT AND FIXING



NOTE:

1. PIPE ZINC GALVANISING TO BE 13 MICRON (0.0005") THICK (MIN.)
2. ZINC ANODE COMPOSITION:

LEAD	0.006% MAX.
IRON	0.005% MAX.
CADMIUM	0.025 - 0.15% RANGE
COPPER	0.005% MAX.
ALUMINIUM	0.100 - 0.50% RANGE
SILICON	0.125% MAX.
ZINC	REMAINDER
3. DRAWING SHOWS A 21KG ANODE. USE IN MULTIPLES OF 178 LENGTH FOR OTHER WEIGHTS, OR USE LENGTH (*) TO SUIT FOR 'DIRECT' CONNECTION TO COVERS - SEE FIGURE 1.

FIGURE E.2

CATHODIC PROTECTION - STANDARD BOLTED ZINC ANODE