TECHNICAL SPECIFICATION

PRESSURE VESSELS (AMENDEMENTS/SUPPLEMENTS TO ASME SECTION VIII DIVISION 1 AND DIVISION 2)

DEP 31.22.20.31-Gen.

December 1996
(DEP Circulars 08/97, 62/97 and 38/99 have been incorporated)

DESIGN AND ENGINEERING PRACTICE

USED BY

COMPANIES OF THE ROYAL DUTCH/SHELL GROUP

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PART I INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for unfired fusion welded pressure vessels in the form of amendments and supplements to ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 and Division 2, issue July 1995 including addenda up to and including December 1995.

Cr-Mo vessels (regardless of grade) in services having a hydrogen partial pressure greater than 100 bar (abs), and/or having a thickness over 60 mm, are outside the scope of this DEP.

This DEP is a revision of the DEP with the same number dated July 1994.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by SIOP and SIEP, the distribution of this DEP is confined to companies forming part of the Royal Dutch/Shell Group or managed by a Group company, and to Contractors and Manufacturers/Suppliers nominated by them (i.e. the distribution code is "F", as described in DEP 00.00.05.05-Gen.).

This DEP is intended for use in oil refineries, chemical plants, gas plants, exploration and production facilities and supply/marketing installations.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable as regards safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned with the object of obtaining agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party which carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party which manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party which initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

Hydrogen service refers to all process conditions with a hydrogen partial pressure greater than 7 bar (abs).

Very toxic substances are those which produce serious harm to health as a result of a single or short term exposure. The following shall be considered very toxic:

- Levels of $H_2S \geq 1000$ ppm mole in process streams.
- Other substances specified by the Principal to be "very toxic".

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets. Other standards referenced in this DEP are listed in (Part V).

PART II GENERAL INFORMATION

1. GENERAL

This DEP is written in six parts. Part III gives amendments and supplements to ASME VIII, Division 1. Part IV gives amendments and supplements to ASME VIII, Division 2.

In the event of conflict between documents relating to the enquiry or order, the following hierarchy of documents shall apply:

first level - purchase order and variations thereto.

second level - data/requisition sheets and drawings referred to where explicit deviations from this specification are indicated. In all other cases any discrepancy between the data/requisition sheets and this specification shall be brought to the attention of the Principal.

third level - this DEP.

For easy reference, the clause numbering of ASME VIII has been used in Part III and Part IV of this DEP. ASME VIII clauses not mentioned in this DEP shall apply without restrictions.

2. CONSTRUCTION CATEGORIES AND CHOICE BETWEEN DIVISION 1 AND 2

The selection of the construction category is subject to review by the Principal, but unless otherwise specified, the following shall apply:

Category 1 shall be selected if one or more of the following conditions apply:
- Very toxic substances (Part I, 1.3.2);
- Liquefied gas;
- Hydrogen service (Part I, 1.3.2);
- A Lower Design Temperature below 0 °C;
- Vessels operating at a pressure exceeding 5 bar (ga) and with a P*V value exceeding 100 MJ (1000 bar (ga) m^3);
- Vessels operating in cyclic service;
- Nominal wall thickness > 35 mm;
- Cr-Mo steels and other ferritic alloy steels and carbon steels having a tensile strength greater than 460 N/mm^2;
- Austenitic stainless steel and nickel alloys (design pressure > 20 bar (ga));
- Vessels which operate in the creep range of the materials of construction.

Category 2 shall be selected for all services which are not covered by either Category 1 or Category 3.

Category 3 shall be selected for:
- Utilities (low pressure steam < 10 bar (ga), air, water, inert gas);
- Atmospheric (storage) vessels.

Amended per Circular 38/99

Category 1 vessels shall be in accordance with ASME VIII Division 2 unless the use of ASME VIII Division 1 is approved by the Principal (in which case any additional requirements shall be agreed with the Principal).

For Category 2 and Category 3 vessels, the selection of Division 1 or Division 2 shall be based on code requirements and economic considerations.

NOTE: These definitions and classification of construction categories based on service conditions do not interfere with the definition of special services in UG-120 (d) for the construction of ASME VIII Division 1 vessels.

PART III AMENDMENTS/SUPPLEMENTS TO ASME VIII, DIVISION 1

Vessels designed to ASME VIII Division 1 shall satisfy the rules set out in this part. The relevant Division 1 clauses and their titles are given.

INTRODUCTION

GENERAL

U-1 SCOPE

Delete U-1 (j)

Add to U-1 (k):
The additional requirements are specified in these amendments.

U-2 GENERAL

Add to U-2 (a) (1):
See amendment to UG-25

Add to U-2 (a) (2):
See Part I, clause 1.3.2. Vessels in this service shall be fabricated in accordance with Division 2.

Add to U-2 (a) (3):
For PWHT requirements per service condition the materials/corrosion engineer shall be consulted.

Add to U-2 (a) (4):
If fabrication in accordance with Division 1 of a vessel for such a service is envisaged, additional requirements, if any, shall be specified on the data/requisition sheets

Add -2 (a) (5):
The Principal shall state the year of issue of any additional standards or codes to be used and, where applicable, the published amendments thereto.

Add U-2 (a) (6):
The materials to be used shall be stated on the data/requisition sheets. See also the ammendments made to UG-4 (b) and (f), UG-8 (a), UG-11 (a) (1) and UG-12 and 13.

SUBSECTION A GENERAL REQUIREMENTS

PART UG GENERAL REQUIREMENTS FOR ALL METHODS OF CONSTRUCTION AND ALL MATERIALS

UG-1 SCOPE

Add to UG-1:
The external surface of pressure vessels shall be prepared and painted in accordance with DEP 30.48.00.31-Gen. Internal surfaces shall not be painted unless specified by the Principal, in which case a paint system selected from DEP 30.48.00.31-Gen. shall be indicated on the data/requisition sheets.

Machined parts shall be treated with an easily removable anti-corrosion compound, e.g. 'Shell Ensis Fluid'. All flange surfaces not fitted with a mating flange cover shall be treated similarly and protected with wooden blanks. These blanks shall be securely attached to the flanges with bolts through at least four bolt holes.

MATERIALS

UG-4 GENERAL

Add to UG-4 (b):
Materials for supporting lugs, skirts, baffles and similar non-pressure parts welded to the vessel shall be of established identity and shall at least be compatible with the material to which they are attached.

Add to UG-4 (f):
The materials shall be in accordance with DEP 30.10.02.11-Gen., including the additional requirements as specified in the notes to a specific material. These notes to a specific material shall be included on the data/requisition sheets. (For the adherence to notes added to Cr-Mo materials, see also here below).

P1 Materials groups 1, 2 and 3 with specified minimum tensile strength exceeding 460 N/mm^2 may be used provided that the Manufacturer can prove that satisfactory welding results have been achieved previously (e.g. regarding formation of cracks, final hardness, detoriation of mechanical properties caused by any heat treatment); this shall be subject to the approval of the Principal.

Castings shall not be used unless approved by the Principal.

A materials/corrosion engineer shall judge whether additional requirements shall be specified for metallic materials for equipment containing process streams with hydrogen sulphide (H_2S) in concentrations which might cause sulphide stress cracking (SSC) and hydrogen induced cracking (HIC), see (Appendix 4).

If hardness results exceed the maximum specified values appropriate corrective actions shall be proposed for the approval of the Principal. For hardness requirements and extent of hardness checks, see Appendix 1 of this DEP.

Materials selection for hydrogen service (Part I, 1.3.2) shall be in accordance with API 941. Plates for equipment in hydrogen service shall be ultrasonically examined in accordance with BS 5996 B4E2. For clad materials in this service see Appendix 2.

Plates for equipment in hydrofluoric acid service shall comply with ASTM A 770 S3 (with a minimum area reduction of 35%) or with EN 10164 (Quality Class Z 35). Furthermore these plates shall be ultrasonically examined in accordance with BS 5996 B4E2.

Cr-Mo hydroprocessing equipment:

For 1Cr-0.5Mo, 1.25Cr-0.5Mo, 2.25Cr-1Mo and 3Cr-1Mo hydroprocessing equipment with a maximum operating temperature above 350 °C and with a primary membrane design stress greater than 50 MPa, the following requirements shall apply in addition to the other requirements of this DEP:

- the base material shall be vacuum degassed and aluminium killed;
- in the quenched and tempered condition, the base material shall have a Charpy V notch energy absorption value of 55 joules average and 48 joules minimum at minus 30 °C;
- the chemical composition of the base material shall comply with DEP 30.10.02.11-Gen., **including the restrictions given in the Notes therein**;
- welding consumables shall produce deposited weld metal with the following restrictions on chemical composition:

$$\frac{(10\ P\ +\ 5\ Sb\ +\ 4\ Sn\ +\ As)}{100} \leq\ 15$$

in which the constituents are expressed in mg/kg;

and:

$Mn + Si \leq 1.10$ in which the constituents are expressed in wt%.

- formed heads shall be inspected in the same way as the base plate material and shall be delivered in the quenched and tempered condition;
- in the quotation the Manufacturer shall provide complete information on temperatures and soaking periods for austenitizing, quenching and tempering and for both intermediate and final heat treatments envisaged and how he intends to guarantee the as-built properties, taking these heat treatments into account.

NOTE: Equipment built according to the above requirements will provide maximum operational flexibility with respect to starting up and shutting down provided the materials' properties are monitored by the use of test blocks placed in the equipment (see Appendix 5).

For 1.25Cr-0.5Mo hydroprocessing equipment with a maximum operating temperature above 450° C and with a primary membrane design stress less than 50 MPa, the following requirements shall apply:

- phosphorus content shall be less than 0.005%;
- carbon content shall be less than 0.14%;
- for plate, forgings and fittings ASTM/ASME Class 1 materials should be specified;
- materials should be supplied in the normalised and tempered condition;
- a minimum preheat for welding of 150°C should be used; and
- final PWHT should be in the range 700-720°C.

Add new clause:

UG-4 (g):

Amended per Circular 38/99

Materials which, due to the service conditions, require impact testing (as specified by the Principal) shall be tested in accordance with ASTM A 20 and clause UG-84.

Material inspection certificates shall be in accordance with ISO 10474 type 3.1.B for construction category 2 vessels. Material test reports shall be in accordance with ISO 10474 type 2.2 for construction category 3 vessels.

UG-8 PIPES AND TUBES

Add to UG-8 a):
Electric-resistance-welded or induction-welded tubes may be used only within the restrictions of DEP 30.10.02.11-Gen., and only with the approval of the Principal.

UG-10 MATERIAL IDENTIFIED WITH OR PRODUCED TO A SPECIFICATION NOT PERMITTED BY THIS DIVISION, AND MATERIAL NOT FULLY IDENTIFIED.

Replace this clause by:

Materials shall be in accordance with DEP 30.10.02.11-Gen.

Materials shall be certified as specified in this DEP.

UG-11 PREFABRICATED OR PREFORMED PRESSURE PARTS

Add to UG-11 (a) (1), (2) and (c):
See UG-10 amendment

UG-12 BOLTS AND STUDS UG-13 NUTS AND WASHERS

Add to UG-12 and 13:
Bolting materials shall be selected from DEP 30.10.02.11-Gen. or DEP 30.10.02.31-Gen. (as applicable), otherwise approval of the Principal is required.

Bolts coated with zinc or cadmium shall not be used. Aluminium coatings or suitable non-metallic coatings are permitted. Carbon steel and low-alloy steel bolting for aluminium vessels shall be aluminized or the bolting shall be made from stainless steel, selected from DEP 30.10.02.11-Gen.

UG-14 RODS AND BARS

Replace the words "pressure parts" by "non-pressure parts".

UG-15 SEE UG-10

DESIGN

UG-16 GENERAL

Add UG-16 (b):
(5) Unless other precautions are taken to prevent deformation or damage during transport and handling, no vessel shall have a wall thickness less than as specified above or:

- 3 mm for high-alloy steel vessels;
- t_{min} (including the corrosion allowance) for carbon and low-alloy steel vessels transported as one unit or in cylindrical parts. t_{min} shall be derived from the following equation, with a minimum of 6 mm:

$$t_{min} = \frac{D}{650} + 1.8 \qquad \text{(mm)}$$

where D = mean vessel diameter in mm.

UG-17 METHODS OF FABRICATION IN COMBINATION

Add to this clause:
The following methods of fabrication shall not be used:

- Brazing (see part UB);
- Cast Iron (See part UCI);
- Cast ductile iron (See UCD).

The following methods may be used only with the approval of the Principal:

- Forging (see UF);
- Layered construction (see ULW).

NOTE: The above amendment is applicable for all further clauses in ASME VIII related to these subjects.

UG-20 DESIGN TEMPERATURE

Add to this clause:
See the amendment to UG-21.

UG-21 DESIGN PRESSURE

Add to this clause:
DEP 01.00.01.30-Gen. shall apply.

The Principal shall specify on the data/requisition sheets if a fatigue detail analysis is required to be performed by the Manufacturer. (To decide whether such an analysis is required, the Principal may use the provisions of article AD-160.2 and article AD-160.3 of Division 2). If a fatigue detail analysis is specified, the Principal shall specify the required fatigue service lifetime and the Principal shall provide all operating data necessary for the Manufacturer to perform the analysis. If a vessel is intended to be used in a service where more than one set of operating parameters (pressure and temperature) is envisaged (e.g. catalyst regeneration, batch processes, etc.) the data shall include this information and shall state the duration of each envisaged operating mode.

For insulated flanges the design temperature shall be equal to the design temperature of the vessel. For uninsulated flanges the design temperature may be 85% of the design temperature of the vessel for lap-joint flanges, and 90% of the design temperature of the vessel for all other types of flanges, in accordance with ASME B31.3.

For insulated flanges, the design temperature of the bolting shall be taken as equal to the design temperature of the vessel, for uninsulated flanges the design temperature of the bolting may be taken as equal to 80% of the design temperature of the vessel.

UG-22 LOADINGS

Add to UG-22 (c):
External nozzle loadings shall be specified on the data/requisition sheets.

Add to UG 22 (d):

Amended per Circular 38/99

All vertical vessels shall be provided with lifting trunnions, attached by full penetration welds, or lifting lugs as specified on the data/requisition sheets. The tail end of vertical vessels that have a mass greater than 20 tonnes shall be provided with a tailing lug (or lugs).

Lifting lugs and trunnions shall be designed for a total load of 1.5 times the lifted weight of the equipment to allow for dynamic effects etc., except lifting lugs and trunnions on vessels liable to be lifted from an offshore barge, etc., which shall be designed for a total load of 3 times the lifted weight. See for lifting trunnions for vertical vessels over 50 tonnes Standard Drawing S 10.115. To avoid corrosion, heat loss and thermal stress, on insulated pressure vessels the protruding part of lifting trunnions should be removed after erection.

If davits are to be provided for servicing components having a mass greater than 25 kg, mounted at the top or attached to the sides of columns higher than 20 m, this shall be specified on the data/requisition sheets. If required davits shall be provided in accordance with Standard Drawing S 28.015.

Add to UG-22 (f):
Wind loads shall be determined in accordance with Appendix 1 of DEP 34.00.01.30-Gen., unless deviation is necessary to comply with national and/or local regulations. The contractor shall state on the data/requisition sheets the wind pressure either at the top of the equipment or, for equipment with an overall height over 30 metres and/or having a length to diameter ratio larger than 10, at different specific elevations. The calculation of the stated wind pressure shall take into account the applicable correction factor for the aspect ratio (K) of the equipment and assuming the shape factor (Cf) to be 1.

The Manufacturer shall check the static deflection and the stresses due to the wind pressure during operation and the stress during shutdown. The deflection at the top of the equipment is restricted to 1/500 of the overall height for brick-lined equipment and to 1/200

for all other equipment. The calculation of the deflection during operational conditions shall take into account insulation, steel structures and piping that are guided or supported by the equipment.

The shape factors (Cf) shall be as follows:

ITEM		SHAPE FACTOR, Cf
equipment (if cylindrical)		0.7
steel structures (platforms, ladders etc)		1.0
piping supported or guided by the equipment	if the distance between the pipe and the equipment is more than 20 percent of the average diameter*	0.7
	if the distance between the pipe and the equipment is not more than 20 percent of the average diameter*	1.5

NOTE: Average diameter = (diameter of equipment + diameter of pipe) / 2

The area to be taken into account for steel structures shall be:
1.1 m^2 for a full, round platform
1.7 m^2 for a full, square platform
0.33 m^2 per metre for a cage ladder
0.11 m^2 per metre for a flush ladder

Equipment having an overall height to diameter ratio larger than 10 may be prone to vortex shedding, and the following shall be considered:

- piping and platforms shall be distributed around the circumference of the equipment, especially within the top part (one third of overall height) to prevent vortices being formed.
- if the above is not possible (e.g. only one overhead line and only rest platforms every 6 metres) and if the frequency of shedding of eddies is within 70% of the natural frequency of the equipment, three wind deflectors shall be installed with a width of $^1/_{10}$ of the equipment diameter, evenly spaced in circumference and having a pitch of 5 times the diameter of the equipment within the top third part of the equipment.

UG-25 CORROSION

Add to UG-25 (a):
The corrosion allowance for carbon and low-alloy steel in general process service shall be 3 mm unless otherwise specified by the Principal.

For non-corrosive or very mildly corrosive conditions (e.g. steam, dry compressed air, LPG, LNG and dry natural gas service) the corrosion allowance shall be 1 mm.

Corrosion allowances for equipment in services where the operating temperature is always below zero °C shall be as follows:

- fine grained carbon steel, 3.5% Ni steel and 9% Ni steel: 1 mm
- aluminium and stainless steel: no corrosion allowance

Prevention of corrosion by application of cladding or liners:

The effective thickness of a cladding will depend on the corrosion rate expected, and shall be subject to the approval of the Principal. Unless specified by the Principal, no additional corrosion allowance is required for the base materials. Reference is made to part UCL, which has been amended by Appendix 1 of this DEP, for the required clad thickness.

The following corrosion allowances shall be applied to removable internals in pressure vessels:
- No corrosion allowance on stainless steel internals, unless specified.
- Heavily-loaded components (catalyst grids, etc.) in non-clad equipment made from

carbon or low-alloy steel shall have a corrosion allowance on each surface equal to half the required corrosion allowance for the equipment.

UG-26 LININGS

Add to UG-26:
For the requirements for process equipment with internal chemical-resistant brick lining, see DEP 30.48.60.13-Gen.

UG-30 ATTACHMENT OF STIFFENING RINGS

Replace UG-30 (b) by:
Stiffening rings shall be attached to the shell by continuous welds. Details of figure UG-30 shall show continuous welds only.

FIG UG-34

Add to this Figure:
Details (c), (e), (f), (h), (l), (n), (o), (q), (r) and (s) shall not be used for construction category 2 vessels.

UG-36 OPENINGS IN PRESSURE VESSELS

Add to UG-36 (c) (3) (b):
Threaded and expanded openings shall not be used for construction category 2 vessels. This amendment shall also apply to UG-43.

Add to UG-36 (d):
The minimum distance between the edge of any attachment weld of a pressure part (e.g. a nozzle) to the edge of a another pressure weld of the vessel shall be 50 mm or twice the thickness of the pressure part, whichever is the greater. Similarly, the minimum distance between the edge of a non-pressure attachment weld to the edge of a a pressure weld of the vessel shall also be 50 mm or twice the thickness of the pressure part, whichever is the greater.

Amended per Circular 38/99

However, if this is not possible the attachment weld shall cross the pressure weld completely by a length of at least 50 mm or twice the wall thickness (whichever is the greater) in order to avoid stress concentration. Prior to making the attachment weld, 100% NDE in accordance with UW-11 shall be performed on the adjacent pressure weld in the area where the attachment weld will cross.

UG-38 FLUED OPENINGS IN SHELLS AND FORMED HEADS

Add UG-38 (e):
Flued openings shall not be used for construction category 2 vessels.

UG-40 LIMITS OF REINFORCEMENT

Amended per Circular 08/97

Add to UG-40:
Reinforcing pad thickness shall not exceed 40 mm or the as-built shell thickness, whichever is the lesser.

Reinforcing pads shall not be used in hydrogen service above 230 °C (Part I, 1.3.2).

The required thickness of an integrally reinforced branch shall not be greater than twice the vessel wall thickness at the location of the attachment.

FIG UG-40

Add to this Figure:
Details (a), (b-2) and (c) shall not be used for construction category 2 vessels.

UG-44 FLANGES AND PIPE FITTINGS

Amended per Circular 08/97

Add to UG-44 (a) and (i):
Flanges shall comply with ASME B16.5 (UG-44(a)) or ASME B16.47 (UG-44(i)).

Flange facing finish shall comply with ASME B16.5.

NOTE: The Principal may specify the use of DIN flanges (e.g. if the site is standardized on the use of DIN flanges), in which case the ratings and the design requirements specified by the applicable DIN standard shall apply. All further requirements stated below are applicable only to ANSI B16.5 and ANSI B16.47 flanges. The additional requirements for DIN flanges, if any, shall be specified on the data/requisition sheets.

Unless otherwise approved by the Principal, only raised-face (narrow-faced) flanges shall be used.

Welding neck flanges shall be used for vessels.

For austenitic stainless steel and non-ferrous vessels, lap-joint flanges may be used, subject to approval by the Principal.

UG-46 INSPECTION OPENINGS

Add to UG-46:
Davits shall be provided for all openings DN 300 mm (12") nominal up to and including DN 750 mm (30"). Typical details are shown in Standard Drawing S 10.070, except for vessels in low-temperature service, for which the covers shall be hinged.

Hand hole covers shall be provided with a grip, see Standard Drawings S 10.039, S 10.053 and S 10.054.

Replace UG-46 (g) 1 by:
Manholes shall have a minimum clear inside diameter of 460 mm; however, nominal pipe sizes DN 500 (20"), DN 600 (24") and DN 750 (30") are preferred.

For the required sizes of openings in columns with removable trays, see DEP 31.20.20.31-Gen.

Replace UG-46 (g) 2 by:
The nominal minimum diameter for inspection openings (handholes) is DN 150 (6").

UG-54 SUPPORTS

Add to UG-54 (a):
All vessel supports shall be provided with at least 2 earthing bosses in accordance with Standard Drawing S 68 004.

The design of supports shall be such that the metal temperature of the part of the support resting on concrete will not exceed 100 °C. For vessels with operating temperatures below ambient, this temperature shall be such that no condensation will occur under normal operating conditions. The mechanical design should provide for insulation sealing, adequate surface protection and prevention of condensate collecting areas.

If full skirts are specified they shall be constructed in accordance with Standard Drawing S 20.001. There shall not be any flanged connections inside full skirts.

If half skirts are specified they shall be constructed in accordance with Standard Drawing S 22.005. Half skirts shall not be used for vessels with fire proofing or for vessels connected to piping that is prone to vibration.

If saddles are specified they shall be constructed in accordance with Standard Drawings S

22.001 or S 22.002.

Legs are permissible as supporting structures in proven applications.

UG-55 LUGS FOR PLATFORMS, LADDERS AND OTHER ATTACHMENTS TO VESSEL WALLS

Amended per Circular 38/99

Add to UG-55 (a):
Continuous liquid outlets on columns and vessels shall be provided with a vortex breaker, see Standard Drawing S 10.010, and in the following cases internally extended vortex breakers shall be used:

- in fouling service;
- for hydrocarbon liquid outlet of separators where the liquid is separated from water or aqueous solutions, except where this would give rise to corrosion problems in the bottom.

Continuous fillet welds shall be used for all internal structures, supports and fittings to be welded to the vessel wall.

FABRICATION

UG-75 GENERAL

Add to UG-75:
A pre-manufacturing meeting shall be held if considered necessary by the Manufacturer or the Purchaser.

UG-77 MATERIAL IDENTIFICATION (SEE UG-85)

See UG-10 amendment

UG-82 LUGS AND FITTING ATTACHMENTS

Add to UG-82 (a):

Amended per Circular 38/99

See UG-36 (d) amendment

Add to UG-82 (b):
The notch shall provide a distance between the weld edges at both sides of at least 5t, where t is the vessel wall thickness.

UG-84 CHARPY IMPACT TESTS

Delete UG-84 (e) (3)

INSPECTION AND TESTS

UG-90 GENERAL

Add to UG-90:
The Principal shall specify if he (or his nominee) will perform shop surveillance, and if so the Principal shall specify the scope.

The Principal should tailor the scope of the Principal's inspection to avoid duplication with the Inspecting Authority.

Add to UG-90 (b):
For the despatch of drawings and documents, approval drawing specification form DEP 05.00.54.81-Gen. and final drawing specification form DEP 05.00.54.82-Gen. shall be used, except that the Contractor's own despatch standard forms may be used if approved by the

Principal.

The Manufacturer shall submit approved drawings to the Inspecting Authority.

NOTE: Certified drawings shall be understood to mean drawing(s) bearing an approval stamp of the approval office and, where applicable, an official stamp of the authorities concerned, signed and dated.

UG-93 INSPECTION OF MATERIALS

Add to UG-93 (a):
In addition to (1) and (2) below the Manufacturer shall prove that in the as-built condition material grades actually used for the construction of low-alloy vessels and of vessels comply with the requirements of the purchase order. For this purpose, a non-destructive positive alloy material identification shall be carried out, such as an X-ray fluorescence analysis.

Add to UG-93 (d) (3):
For Cr-Mo equipment with a maximum operating temperature above 350 °C, all the cut edges shall be given 100% magnetic particle examination and there shall be no indications.

UG 96 DIMENSIONAL CHECK OF COMPONENT PARTS

Add to UG-96 (c):
For tolerances not covered by code requirements, see Appendix 3 of this DEP.

UG-99 STANDARD HYDROSTATIC TEST

Add to UG-99(h):
For test water quality see DEP 61.10.08.11-Gen.

MARKING AND REPORTS

UG-119 NAMEPLATES

Add to UG-119:
Nameplate standard drawing S 10.114 shall be used. Bronze nameplates shall not be used on stainless steel equipment. For vessels required for low-temperature service (0 °C or lower) and for equipment containing liquefied gas or very toxic substances, the nameplates shall include the upper design temperature and pressure and the lower design temperature and pressure.

UG-120 DATA REPORTS

Add to UG-120 (a):
The manufacturer's data report for ASME VIII, Div. 1 vessels shall be made and forwarded in accordance with the applicable sections of Appendix W, regardless of whether code stamping is required. The manufacturer shall also list all agreed and authorized technical deviations and concessions from the original purchase order requirements in the form U-4 (supplementary sheet) and include it in the data report. Form U-4 shall also be used for certifying the results of positive alloy material identification (PAMI), when specified by the purchaser.

In exceptional cases, when statutory requirements such as national or local governmental regulations demand more information and evidence in terms of certification to be supplied as compared to what the ASME data report provides, the Purchaser may specify DEP 31.22.10.35-Gen. as the basis of the manufacturer's data report. In such cases, the Manufacturer shall follow the conditions of the purchase order for making the report.

SUBSECTION B REQUIREMENTS PERTAINING TO METHODS OF FABRICATION OF PRESSURE VESSELS

PART UW REQUIREMENTS FOR PRESSURE VESSELS FABRICATED BY WELDING

UW-2 SERVICE RESTRICTIONS

Add to UW-2 (a):
See Part I, 1.3.2.
Delete from UW-2 (a)1(b): "type No. (2)"
Delete from UW-2 (b)1: All text after "UW-12"
Delete from UW-2 (b)2 and (c): "type No. (2)"
Delete from UW-2 (d)1: "when the thickness exceeds 5/8 in." and "type No. (2)"

MATERIALS

UW-5 GENERAL

Add to this clause:
Allowable materials and required certification shall be in accordance with this DEP.

DESIGN

UW-9 DESIGN OF WELDED JOINTS

Add to UW-9 (a):
Types (2)(3)(4)(5)(6) in table UW-12 are not permitted for pressure parts of construction category 2 vessels.

Replace UW-9 (d) by:
The minimum distance between two longitudinal seams in one course shall be 200 mm or five times the wall thickness, whichever is the larger.

Amended per Circular 38/99

The minimum distance between the staggered longitudinal seams of two adjacent courses shall be 200 mm or five times the wall thickness, whichever is the greater. However, where this cannot be achieved, the last 30 cm of the adjacent longitudinal seams shall be subjected to 100% NDE in accordance with UW-11.

UW-11 RADIOGRAPHIC AND ULTRASONIC EXAMINATION

Add to UW-11:

Amended per Circular 38/99

In addition, the following shall apply:

100% visual inspection shall be performed. The construction category specified determines the degree of radiographic and or ultrasonic examination, as follows:

Construction category 2:
All categories of welds (A, B, C and D) shall be examined by radiography or ultrasonics in accordance with clause UW-11, the minimum extent being 10% of each welder/welding operator and category of weld. Clause UW-52 shall also apply.

Construction category 3:
A minimum amount of 2% radiography shall be performed. Clause UW-52 shall also apply.

NOTE: If radiography is not feasible, ultrasonic examination shall apply. This is valid for category C and D welds on nozzles where radiography is not possible (in such cases, ultrasonic examination of the welds shall be performed before the reinforcing pad is installed).

Full penetration tee or corner-type joints including nozzle attachment welds shall be non-destructively examined by either radiography (preferred) or ultrasonics, to the degree of the applicable construction category.

For construction category 2 vessels all tee and corner joints shall have full penetration welds.

Radiography may be used for a plate thickness up to 50 mm (or 25 mm if the double-wall technique is being used). For a plate thickness greater than 50 mm, a mechanized ultrasonic inspection technique shall be used which is capable of producing hard copy inspection results.

If the time of flight defraction technique is applied, operators and acceptance criteria shall be subject to the approval of the Principal.

The final non-destructive examination of welds for acceptance purposes shall be carried out after completion of PWHT, if any. At the Manufacturer's option, radiography may be performed before PWHT, in which case an ultrasonic examination shall be performed after PWHT for acceptance purposes.

Delete UW-11 (c)

UW-13 ATTACHMENT DETAILS

FIG. UW-13.1

Add to this Figure:
Details (a) up to and including (c), and (e) up to and including (k), shall not be used for construction category 2 vessels.

FIG. UW-13.2

Add to this Figure:
Details (d), (e-1), (g), (h), (l), (m) shall not be used for construction category 2 vessels.

UW-14 OPENINGS IN OR ADJACENT TO WELDS

See amendments to UG-36 (d).

UW-15 WELDED CONNECTIONS

Add to UW-15 (a):
For nozzles, Standard Drawing S 10.101 shall apply.

Nozzle types shall be as follows:

Type of service	vessel wall thickness, t (mm)		Nozzle type
all	t < 50		set-in
	t ≥ 100		forged saddle type
cyclic	t ≥ 50		forged saddle type
non-cyclic	50 ≥ t <≥ 100	nozzle thickness ≥ t/2	set-in
		nozzle thickness < t/2	set-on (Notes 1 and 2) or set-in

NOTES: 1. For set-on nozzles, the following conditions shall apply to the plate material of the shell:
- The plate material shall meet ASTM A 770 S3 (with a minimum area reduction of 35%) or EN 10164 (Quality Class Z35); and
- 100% ultrasonic examination shall be performed on a 100 mm wide band around the nozzle opening before attachment of the nozzle. Acceptance criteria shall be BS 5996 B4E2.

2. Set-on nozzles shall not be used in hydrogen service above 230 °C (Part I, 1.3.2).

For both set-in and set-on nozzles, the fillet of the attachment weld shall blend smoothly with both vessel and nozzle wall without any notch, sharp corner or undercut.

All inside edges of nozzles and connections, whether flush or extended, shall be rounded off to a radius of at least 3 mm.

Add to UW-15 (d):
Reinforcing pads shall have one hole, tapped $^{1}/_{4}$ " NPT, per closed compartment.

UW-16 MINIMUM REQUIREMENTS FOR ATTACHMENT WELDS AT OPENINGS

Replace UW-16 (c) by:
See UW-15.

FIG. UW-16.1

Add to this Figure:
Details (a-2), (a-3), (c), (h) up to and including (z-2), (aa) and (bb) shall not be used for construction category 2 vessels.

NOTE: The above amendment is applicable to all further clauses in ASME VIII in which the above details are referenced.

FIG. UW-16.2

Add to this Figure:
Details (a) up to and including (c), and (e) up to and including (k), shall not be used for construction category 2 vessels.

NOTE: The above amendment is applicable to all further clauses in ASME VIII in which the above details are referenced.

UW-17 PLUG WELDS

Add to UW-17:
Plug welds shall not be used for construction category 2 vessels, except for the attachment of liners.

UW-27 WELDING PROCESSES

Add to this clause:
See amendment to UW-5.

UW-39 PEENING

Delete UW-39

UW-40 PROCEDURES FOR POSTWELD HEAT TREATMENT

Add to UW-40 (a):
For Cr-Mo equipment with a maximum operating temperature above 350 °C, the following requirements shall apply in addition to the other requirements of this DEP:

- The preheat temperature shall be maintained during flame cutting, welding (i.e. interpass), arc gouging, welding of temporary attachments and other thermal applications;
- If, for fabrication reasons, the final required heat treatment is not performed directly after welding, a post-weld soaking heat treatment shall be performed at a temperature of 350 °C for 3 hours, without cooling down below the preheat temperature, prior to cooling down to ambient temperature. However, nozzle welds shall receive an intermediate post-weld heat treatment.
- The final PWHT temperature shall be at least 20 °C below the tempering temperature, with a minimum holding time of 1 hour per 25 mm of thickness (with a minimum of 1 hour). Soaking periods shall be based on the heaviest welded section, including the total thickness of the vessel wall.

Add to UW-40 (c):
The PWHT procedure shall clearly indicate the type and location of calibrated thermocouples to be used. This procedure shall form part of the heat treatment procedure to be submitted for approval.

A PWHT certificate, stating actual temperature/time parameters, shall be included in the Manufacturer's report. The original temperature/time indicator recorder charts shall be retained by the Manufacturer.

UW-41 SECTIONING OF WELDED JOINTS

Delete UW-41

UW-50 NONDESTRUCTIVE EXAMINATION OF WELDS ON PNEUMATICALLY TESTED VESSELS

Add to UW-50:
All non-excluded welds shall be non-destructively examined as specified by this clause.

Add new clause:

UW-95 WELDING TEST PLATES

Production control test plates are not required for materials P1 groups 1, 2 and 3, unless the specified minimum tensile strength exceeds 460 N/mm^2. In all other cases, production control test plates shall be provided at the rate of two test plates per 100 m of butt weld or part thereof (circumferential plus longitudinal) and shall represent the welding on the vessel or on a group of similar vessels made of the same material, ordered to the same

specification and with the same welding procedure/welder/welding operator qualification. Production control test plates are also required in those cases where the chemical composition of the weld deposit of welds in alloy materials has to be checked, i.e. where a minimum alloy content is required to meet the service conditions (creep, corrosion, hydrogen service). Production control test plates are also required for weld-deposited cladding.

The test plates shall be made at an early stage of production welding with a thickness equal to the thickness of the shell.

In the case of spherical vessels, the test plates shall be welded separately and they shall represent each type of seam and welding position. For site-constructed vessels, the test plates shall be welded at the construction site.

One plate (or, if more than two plates were required, half the total number of plates) shall be selected and tested at an early stage. The required tests shall be in accordance with those required for Welding Procedure Qualification as described in ASME IX. If the vessel will be post-weld heat treated, then this test plate(s) shall be given a simulated heat treatment before testing, and a permanent time/temperature record shall be retained by the Manufacturer. This test plate(s) result shall be considered valid if the eventual vessel post-weld heat treatment is within the specified time/temperature range. The other test plate(s) shall be placed inside the vessel during its post-weld heat treatment, and shall be retained in case later testing may be required.

NOTE: As an alternative to the above, unless otherwise specified by the Principal, the Manufacturer may choose to post weld heat treat all the production control test plates inside the vessel, rather than performing a simulated post weld heat treatment.

A post-weld heat treatment certificate stating actual temperature/time parameters shall be included in the Manufacturer's report. The original temperature/time indicator recorder charts shall be retained by the Manufacturer.

For Cr-Mo equipment with a maximum operating temperature above 350 °C and with a primary membrane design stress greater than 50 MPa, two of the untested welding production control test plates shall be used to prepare four test blocks for installation in the equipment. For the details of preparation and installation of test blocks, see Appendix 5.

PART UF REQUIREMENTS FOR PRESSURE VESSELS FABRICATED BY FORGING

UF-1 SCOPE

Add to this clause:
If equipment is specified to be fabricated by forging, additional requirements, if any, shall be incorporated on the data/requisition sheets (e.g. nitrogen and hydrogen bottles).

SUBSECTION C REQUIREMENTS PERTAINING TO CLASSES OF MATERIALS

PART UCS REQUIREMENTS FOR PRESSURE VESSELS CONSTRUCTED OF CARBON AND LOW ALLOY STEEL

UCS-5 GENERAL

In UCS-5 (b), replace "0.35" **by** "0.23 or, for forgings, 0.25".

UCS-6 STEEL PLATES

Delete UCS-6 (b)

UCS-19 WELDED JOINTS

Delete "type No. (2)"

UCS-79 FORMING SHELL SECTIONS AND HEADS

Replace UCS-79 (d) by:
All parts which have been cold formed by more than 5% shall be subjected to an appropriate normalizing treatment and, if necessary, a tempering treatment.

Normalizing of CS components and base materials shall be performed separately, not as part of the hot-forming operation, unless the finishing hot-forming temperature is in the normalising temperature range of 850 °C to 960 °C. In both cases, the temperature shall be recorded and documented by a temperature recording chart.

UCS-85 HEAT TREATMENT OF TEST SPECIMENS

Add to this clause:
Test specimens shall have had the same heat treatments as the materials they represent.

PART UNF REQUIREMENTS FOR PRESSURE VESSELS CONSTRUCTED OF NONFERROUS MATERIALS

UNF-5 GENERAL

Add to UNF-5 (a):
The aluminium grades to be used shall be as indicated in DEP 30.10.02.11-Gen. for the application concerned.

Aluminium grades having a magnesium content of 3% or higher shall not be used for design temperatures above 65 °C.

PART UHA REQUIREMENTS FOR WELDED PRESSURE VESSELS CONSTRUCTED OF HIGH ALLOY STEEL

UHA-21 WELDED JOINTS

Delete: "type No. (2)"

UHA-34 LIQUID PENETRANT EXAMINATION

Delete: "which exceed a nominal size of 3/4 in., as defined in UW-40(f),"

UHA-52 WELDED TEST PLATES

Add to this clause:
For all other types, see the amendment of UW-95.

UHA-105 HEAT TREATMENT OF AUSTENITIC CHROMIUM-NICKEL STEELS

Add to this clause:
All hot formed stainless steel heads shall be separately solution annealed after the hot forming operation.

PART UCL REQUIREMENTS FOR WELDED PRESSURE VESSELS CONSTRUCTED OF MATERIAL WITH CORROSION RESISTANT INTERGRAL CLADDING, WELD METAL OVERLAY CLADDING OR APPLIED LININGS

UCL-1 SCOPE

Add to this clause:
Pressure vessels constructed of material with corrosion resistant integral cladding, weld metal overlay cladding or applied linings shall comply with Part UCL of this Division, as modified by Appendix 2 of this DEP. Loose linings shall not be applied.

PART UHT REQUIREMENTS FOR WELDED PRESSURE VESSELS CONSTRUCTED OF FERRITIC STEELS WITH TENSILE PROPERTIES ENHANCED BY HEAT TREATMENT

This Part may be used only with the approval of the Principal.
Additional requirements shall be specified on the data/requisition sheets.

PART ULW REQUIREMENTS FOR WELDED PRESSURE VESSELS FABRICATED BY LAYERED CONSTRUCTION

This Part may be used only with the approval of the Principal.
Additional requirements shall be specified on the data/requisition sheets.

PART ULT REQUIREMENTS FOR WELDED PRESSURE VESSELS CONSTRUCTED OF MATERIALS HAVING HIGHER ALLOWABLE STRESSES AT LOW TEMPERATURE

This Part may be used only with the approval of the Principal.
Additional requirements shall be specified on the data/requisition sheets.

APPENDIX 2 RULES FOR BOLTED FLANGE CONNECTIONS WITH RING TYPE GASKETS

2-2 MATERIALS

Add to 2-2 (e):
For bolt tensioning applications see DEP 31.38.01.11-Gen. and for bolt tensioning equipment see DEP 70.08.10.11-Gen. Bolt pitch and flange hub details shall allow for the use of bolt tensioning equipment where specified.

Bolting of less than 16 mm diameter ($^5/_8$") shall not be used for flanged connections. The height of the nut shall be equal to the bolt diameter.

Bolting up to 25 mm (1") shall have UNC standard thread and bolting 28 mm (1 $^1/_8$") and larger shall have UN threading (8-thread series). However, bolting and threads shall comply with ISO metric standards when this is standard practice for the location (which shall be stated on the data/requisition sheets). See also Standard Drawings S 10.035 and S 10.116.

All bolt holes shall straddle the normal centre lines of the vessel.

Add to 2-2 (f):
Gasket, jointing and packing materials shall be purchased only from suppliers approved by the purchaser. The purchaser shall seek the approval of the Principal regarding preferred gasket suppliers.

Spiral wound gaskets shall be provided with a compression stop. A centring and/or inner ring shall be specified for this purpose, unless the flange geometry provides such a compression stop (e.g. confined gaskets for heat exchangers). Tongue and groove jointing shall not be used.

Sheet gaskets shall be 1.5 mm thick unless otherwise approved by the Principal.

APPENDIX 9 JACKETED VESSELS

FIG. 9-5

Add to this Figure:
Details (a), (b) with backing strip, (d), (e), (f-1), (f-2), (g-1), (g-2) with backing strip, (g-3) with backing strip, (g-4), (g-5), (g-6) and (i-2) shall not be used for construction category 2 vessels.

FIG. 9-6

Add to this Figure:
None of these details shall be used for construction category 2 vessels.

APPENDIX 17 DIMPLED OR EMBOSSED ASSEMBLIES

Add to this Appendix:
This Appendix shall not be used for construction category 2 vessels.

APPENDIX 21 JACKETED VESSELS CONSTRUCTED OF WORK-HARDENED NICKEL

Replace this Appendix by:

These vessels shall not be used.

APPENDIX 29 REQUIREMENTS FOR STEEL BARS OF SPECIAL SECTION FOR HELICALLY WOUND INTERLOCKING STRIP LAYERED PRESSURE VESSELS

Replace this Appendix by:

These vessels shall not be used.

PART IV AMENDMENTS/SUPPLEMENTS TO ASME VIII, DIVISION 2

Vessels designed to ASME VIII Division 2 shall satisfy the rules set out in this Part. The relevant Division 2 clauses and their titles are given.

PART AG GENERAL REQUIREMENTS

ARTICLE G-1 SCOPE AND JURISDICTION

AG-140 REQUIREMENTS FOR PRESSURE VESSELS FABRICATED BY LAYERED CONSTRUCTION

Add to this clause:
Layered pressure vessels shall not be used unless specified by the Principal.

AG-150 STANDARDS REFERENCED BY THIS DIVISION

Add to AG-150:
c) The Principal shall state the year of issue of any additional standards or codes to be used and, where applicable, any published amendments thereto.

ARTICLE G-3 RESPONSIBILITIES AND DUTIES

AG-301 USER'S RESPONSIBILITY

Amended per Circular 08/97

Add to AG-301.1:
The completed data/requisition sheets shall be considered to be the User's Design Specification.

The external surface of pressure vessels shall be prepared and painted in accordance with DEP 30.48.00.31-Gen. Internal surfaces shall not be painted unless specified by the Principal, in which case a paint system selected from DEP 30.48.00.31-Gen shall be indicated on the data/requisition sheets.

Machined parts shall be treated with an easily removable anti-corrosion compound, e.g. 'Shell Ensis Fluid'. All flange surfaces not fitted with a mating flange cover shall be treated similarly and protected with wooden blanks. These blanks shall be securely attached to the flanges with bolts through at least four bolt holes.

The materials to be used shall be specified on the data/requisition sheets. The following clauses shall be used as a guide to complete the material specifications on the data/requisition sheets.

For the prevention of brittle fracture, DEP 30.10.02.31-Gen. shall apply to the services and conditions specified therein.

Materials shall be in accordance with DEP 30.10.02.11-Gen., including the additional requirements specified in the Notes therein. (For the adherence to notes applicable to Cr-Mo materials, see here below.) This DEP also contains a comprehensive list of materials identified to ASTM standards with reference to various other standards including BS material standards. The selected materials standard (and the afore-mentioned Notes) shall be indicated on the data/requisition sheets. The use of any other material not listed in the above mentioned DEP is subject to the approval of the Principal.

P1 Materials groups 1, 2 and 3 with specified minimum tensile strength exceeding 460 N/mm^2 may be used provided that the Manufacturer can prove that satisfactory welding results have been achieved previously (e.g. regarding formation of cracks, final hardness, detoriation of mechanical properties caused by any heat treatment); this shall be subject to the approval of the Principal.

Castings shall not be used unless approved by the Principal.

A materials/corrosion engineer shall judge whether additional requirements shall be specified for metallic materials for equipment containing process streams with hydrogen

sulphide (H_2S) in concentrations which could cause sulphide stress cracking (SSC) and/or hydrogen induced cracking (HIC), see (Appendix 7).

If hardness results exceed the maximum specified values appropriate corrective actions shall be proposed for the approval of the Principal. For hardness requirements and extent of hardness checks, see Appendix 1 of this DEP.

Materials selection for hydrogen service (Part I, 1.3.2) shall be in accordance with API 941.

Cr-Mo vessels (regardless of grade) in services having a hydrogen partial pressure greater than 100 bar (abs), and/or having a thickness over 60 mm, are outside the scope of this DEP.

Plates for equipment in hydrofluoric acid service shall comply with ASTM A 770 S3 (with a minimum area reduction of 35%) or with EN 10164 (Quality Class Z 35). Furthermore, these plates shall be ultrasonically examined in accordance with BS 5996 B4E2.

Cr-Mo hydroprocessing equipment:

For 1Cr-0.5Mo, 1.25Cr-0.5Mo, 2.25Cr-1Mo and 3Cr-1Mo hydroprocessing equipment with a maximum operating temperature above 350 °C and with a primary membrane design stress greater than 50 MPa, the following requirements shall apply in addition to the other requirements of this DEP:

- the base material shall be vacuum degassed and aluminium killed;
- in the quenched and tempered condition, the base material shall have a Charpy V notch energy absorption value of 55 joules average and 48 joules minimum at minus 30 °C;
- the chemical composition of the base material shall comply with DEP 30.10.02.11-Gen., **including the restrictions given in the Notes therein**;
- welding consumables shall produce deposited weld metal with the following restrictions on chemical composition:

  $$\frac{(10\ P + 5\ Sb + 4\ Sn + As)}{100} \leq 15$$

  in which the constituents are expressed in mg/kg;

  and:

  $Mn + Si \leq 1.10$

  in which the constituents are expressed in wt%.

- formed heads shall be inspected in the same way as the base plate material and shall be delivered in the quenched and tempered condition;
- in the quotation the Manufacturer shall provide complete information on temperatures and soaking periods for austenitizing, quenching and tempering and for both intermediate and final heat treatments envisaged and how he intends to guarantee the as-built properties, taking these heat treatments into account.

NOTE: Equipment built according to the above requirements will provide maximum operational flexibility with respect to starting up and shutting down provided the materials' properties are monitored by the use of test blocks placed in the equipment (see Appendix 5).

For 1.25Cr-0.5Mo hydroprocessing equipment with a maximum operating temperature above 450° C and with a primary membrane design stress less than 50 MPa, the following requirements shall apply:

- phosphorus content shall be less than 0.005%;
- carbon content shall be less than 0.14%;
- for plate, forgings and fittings ASTM/ASME Class 1 materials should be specified;
- materials should be supplied in the normalised and tempered condition;
- a minimum preheat for welding of 150°C should be used; and
- final PWHT should be in the range 700-720°C.

Bolting materials shall be selected from DEP 30.10.02.11-Gen. or DEP 30.10.02.31-Gen. (as applicable), otherwise approval of the Principal is required.

Bolts coated with zinc or cadmium shall not be used. Aluminium coatings or suitable non-metallic coatings are permitted. Carbon steel and low-alloy steel bolting for aluminium vessels shall be aluminized or the bolting shall be made from stainless steel, selected from DEP 30.10.02.11-Gen.

Aluminium grades having a magnesium content of 3% or higher shall not be used for design temperatures above 65 °C.

Flange facing finish shall comply with ASME B16.5.

See for further requirements AD-940.

Add to AG-301.1 (a):
The Principal shall specify on the data/requisition sheets if a fatigue detail analysis is required to be performed by the Manufacturer. (To decide whether such an analysis is required, the Principal may use the provisions of article AD-160 of this Division). If a fatigue detail analysis is specified, the Principal shall specify the required fatigue service lifetime and the Principal shall provide all operating data necessary for the Manufacturer to perform the analysis. If a vessel is intended to be used in a service where more than one set of operating parameters (pressure and temperature) is envisaged (e.g. catalyst regeneration, batch processes, etc.) the data shall include this information and shall state the duration of each envisaged operating mode.

Add to AG-301.1 (b):
The corrosion allowance for carbon steel and low alloy steel in general process service shall be 3 mm unless otherwise specified by the Principal.

For non-corrosive or very mildly corrosive conditions (e.g. steam, dry compressed air, LPG, LNG and dry natural gas service) the corrosion allowance shall be 1 mm.

Corrosion allowances for equipment in services where the operating temperature is always below zero °C shall be as follows:

- killed carbon steel, 3.5% Ni steel and 9% Ni steel: 1 mm
- aluminium and stainless steel: no corrosion allowance

Prevention of corrosion by application of cladding or liners:
The effective thickness of a cladding will depend on the corrosion rate expected, and shall be subject to the approval of the Principal. Generally, no additional corrosion allowance is needed unless specified. Reference is made to part UCL, which has been amended by Appendix 1 of this DEP, for the required clad thickness.

The following corrosion allowances shall be applied to removable internals in pressure vessels:
- No corrosion allowance on stainless steel internals, unless specified.
- Heavily-loaded components (catalyst grids, etc.) in non-clad equipment made from carbon or low-alloy steel shall have a corrosion allowance on each surface equal to half the required corrosion allowance for the equipment.

Add to AG-301(c):
See 1.3.2.

Add to AG-301(d):
The data/requisition sheets shall at least contain the items as specified in this DEP.

AG-302 MANUFACTURER'S RESPONSIBILITY

Add new clause:
AG-302.1 (e)

For the despatch of drawings and documents, approval drawing specification form DEP 05.00.54.81-Gen. and final drawing specification form DEP 05.00.54.82-Gen. shall be used, except that the Contractor's own despatch standard forms may be used if approved by the Principal.

The Manufacturer shall submit approved drawings to the Inspecting Authority.

NOTE: Certified drawings shall be understood to mean drawing(s) bearing an approval stamp of the approval

office and, where applicable, an official stamp of the authorities concerned, signed and dated.

PART AM MATERIAL REQUIREMENTS

ARTICLE M-1 GENERAL REQUIREMENTS

AM-100 MATERIALS PERMITTED

Add to this clause:
(e) See the amendments to AG-301 for restrictions in the selection and use of materials.

(f) Electric-resistance-welded or induction-welded tubes may be used only within the restrictions of DEP 30.10.02.11-Gen.

AM-101 CERTIFICATION BY MATERIALS MANUFACTURER

Add to this clause:
The fabricator shall indicate in his order to the mill how many heat treatments he is likely to carry out during fabrication (including repairs) plus one for the user (in case a later field repair is necessary). The fabricator shall ensure that he receives a written guarantee from the mill that the steel supplied can be heat treated as proposed without detrimental effect on the minimum guaranteed mechanical properties.

Amended per Circular 38/99

Material inspection certificates shall be in accordance with ISO 10474 type 3.1.B.

AM-105.1 CAST, FORGED, ROLLED, OR DIE FORMED STANDARD PRESSURE PARTS

Add to this clause:
All requirements, including the amendments made by this DEP, shall be met. Certification and identification of all parts shall be the same whether manufacturered from base material by the vessel manufacturer or obtained as pre-fabricated parts.

ARTICLE M-2 SPECIAL REQUIREMENTS FOR FERROUS MATERIALS

AM-201.1 PLATES

Add to this clause:
Plates for equipment in hydrofluoric acid service shall in addition comply with ASTM A 770 S3 (with a minimum area reduction of 35%) or with EN 10164 (Quality Class Z 35).

Replace AM-201.1 (d) by:
Flat heads, tube sheets and flanges shall not be machined from plate, but shall be forgings.

AM-201.5 CASTINGS

Add to this clause:
Castings shall not be used for pressure-containing parts.

AM-203 ULTRASONIC EXAMINATION

AM-203.1 PLATE MATERIAL

Add to AM-203.1 (a):
Plates for equipment in hydrogen service shall be ultrasonically examined in accordance with BS 5996 B4E2.

Plates for equipment in hydrofluoric acid service shall be ultrasonically examined in accordance with BS 5996 B4E2.

Add to AM-203.1 (b):
For ultrasonic examination of clad plates see Appendix 2.

Ultrasonic examination shall be employed instead of radiography wherever the plate thickness exceeds 50 mm (or 25 mm if the double-wall technique is being used).

AM-205 LIQUID PENETRANT EXAMINATION

Remove: "which exceed 3/4 in."

Add new clause:

AM-206 HARDNESS REQUIREMENTS

For hardness requirements and extent of hardness check for carbon and ferritic alloy vessels, see Appendix 1 of this DEP.

AM-220 FOR INTEGRAL AND WELD METAL OVERLAY CLAD STEEL BASE MATERIAL

Delete AM-220.1

ARTICLE M-3 SPECIAL REQUIREMENTS FOR FERRITIC STEELS WITH TENSILE PROPERTIES ENHANCED BY QUENCHING AND TEMPERING

Add to this Article:
These steels shall not be used without the approval of the Principal.

ARTICLE M-4 SPECIAL REQUIREMENTS FOR NONFERROUS MATERIALS

Add to this Article:
Additional requirements for a non-ferrous material used for a pressure vessel shall be agreed with the Principal and shall be stated on the data/requisition sheets.

PART AD DESIGN REQUIREMENTS

ARTICLE D-1 GENERAL

AD-110 LOADINGS

Add to AD-110 (c):
External nozzle loadings shall be specified on the data/requisition sheets.

Add to AD-110 (d):
Wind loads shall be determined in accordance with Appendix 1 of DEP 34.00.01.30-Gen., unless deviation is necessary to comply with national and/or local regulations. The contractor shall state on the data/requisition sheets the wind pressure either at the top of the equipment or, for equipment with an overall height over 30 metres and/or having a length to diameter ratio larger than 10, at different specific elevations. The calculation of the stated wind pressure shall take into account the applicable correction factor for the aspect ratio (K) of the equipment and assume the shape factor (Cf) to be 1.

The Manufacturer shall check the static deflection and the stresses due to the wind pressure during operation and the stress during shutdown. The deflection at the top of the equipment is restricted to 1/500 of the overall height for brick-lined equipment and to 1/200 for all other equipment. The calculation of the deflection during operational conditions shall take into account insulation, steel structures and piping that are guided or supported by the equipment.

The shape factors (Cf) shall be as follows:

ITEM		SHAPE FACTOR, Cf
equipment (if cylindrical)		0.7
steel structures (platforms, ladders etc)		1.0
piping supported or guided by the equipment	if the distance between the pipe and the equipment is more than 20 percent of the average diameter*	0.7
	if the distance between the pipe and the equipment is not more than 20 percent of the average diameter*	1.5

NOTE: Average diameter = (diameter of equipment + diameter of pipe) / 2

The area to be taken into account for steel structures shall be:
1.1 m^2 for a full, round platform
1.7 m^2 for a full, square platform
0.33 m^2 per metre for a cage ladder
0.11 m^2 per metre for a flush ladder

Equipment having an overall height to diameter ratio larger than 10 may be prone to vortex shedding, and the following shall be considered:

- piping and platforms shall be distributed around the circumference of the equipment, especially within the top part (one third of overall height) to prevent vortices being formed.
- if the above is not possible (e.g. only one overhead line and only rest platforms every 6 metres), and if the frequency of shedding of eddies is within 70% of the natural frequency of the equipment, three wind deflectors shall be installed with a width of $^1/_{10}$ of the equipment diameter, evenly spaced in circumference and having a pitch of 5 times the diameter of the equipment within the top third part of the equipment.

Add AD-110 (h):
All vertical vessels shall be provided with lifting trunnions, attached by full penetration welds, or lifting lugs as specified on the data/requisition sheets. The tail end of vertical vessels that have a mass greater than 20 tonnes shall be provided with a tailing lug (or lugs).

Amended per Circular 38/99

Lifting lugs and trunnions shall be designed for a total load of 1.5 times the lifted weight of the equipment to allow for dynamic effects, etc., except lifting lugs and trunnions on vessels liable to be lifted from an offshore barge, etc., which shall be designed for a total load of 3 times the lifted weight. See for lifting trunnions for vertical vessels over 50 tonnes Standard Drawing S 10.115. To avoid corrosion, heat loss and thermal stress, on insulated pressure vessels the protruding part of lifting trunnions should be removed after erection.

If davits are to be provided for servicing components having a mass greater than 25 kg, mounted at the top or attached to the sides of columns higher than 20 m, this shall be specified on the data/requisition sheets. If required davits shall be provided in accordance with Standard Drawing S 28.015.

AD-104 MINIMUM THICKNESS OF SHELL OR HEAD

Replace AD-104 by:
Unless other precautions are taken to prevent deformation or damage during transport and handling, no vessel shall have a wall thickness less than:

- 3 mm for high-alloy steel vessels;
- t_{min} (including the corrosion allowance) for carbon and low-alloy steel vessels transported as one unit or in cylindrical parts. t_{min} shall be derived from the following equation, with a minimum of 6 mm:

$$t_{min} = \frac{D}{650} + 1.8 \qquad \text{(mm)}$$

where D = mean vessel diameter in mm.

AD-115 CORROSION

Add to this clause:
For corrosion allowances see AG-301.1 (b)

AD-116 CLADDING

Replace this clause by:
Thickness of cladding shall not be taken into account when determining the required thickness of various parts. See also Appendix 2 of this DEP.

AD-117 LININGS

Add to this clause:
For the requirements for process equipment with internal chemical-resistant brick lining, see DEP 30.48.60.23-Gen.

AD-121.1 DESIGN PRESSURE

Add to this clause:
DEP 01.00.01.30-Gen. shall apply.

If a fatigue detail analysis is required to be performed by the Manufacturer the Principal shall specify the required fatigue service lifetime. The Principal shall provide all operating data necessary to perform the analysis.

If a vessel is intended to be used in a service where more than one set of operating parameters (pressure and temperature) is envisaged (e.g. catalyst regeneration, batch

processes, etc.) the data shall include this information and shall state the duration of each envisaged operating mode.

For insulated flanges the design temperature shall be equal to the design temperature of the vessel. For uninsulated flanges the design temperature may be 85% of the design temperature of the vessel for lap-joint flanges, and 90% of the design temperature of the vessel for all other types of flanges, in accordance with ASME B31.3.

For insulated flanges, the design temperature of the bolting shall be taken as equal to the design temperature of the vessel, for uninsulated flanges the design temperature of the bolting may be taken as equal to 80% of the design temperature of the vessel.

AD-121.2 DESIGN PRESSURE

Add to this clause:
See also AD-121.1 of this DEP.

ARTICLE D-4 WELDED JOINTS

AD-410 TYPES OF JOINTS PERMITTED

Add to AD-410:

Amended per Circular 38/99

The minimum distance between two longitudinal seams in one course shall be 200 mm or five times the wall thickness, whichever is the larger.

However, where this cannot be achieved, the last 30 cm of the adjacent longitudinal seams shall be subjected to 100% NDE in accordance with AF-220.

The minimum distance between the edge of any attachment weld of a pressure part (e.g. a nozzle) to the edge of a another pressure weld of the vessel shall be 50 mm or twice the thickness of the pressure part, whichever is the greater.

Similarly, the minimum distance between the edge of a non-pressure attachment weld to the edge of a pressure weld of the vessel shall also be 50 mm or twice the thickness of the pressure part, whichever is the greater. However, if this is not possible the attachment weld shall cross the pressure weld completely by a length of at least 50 mm or twice the wall thickness (whichever is the greater) in order to avoid stress concentration. Prior to making the attachment weld, 100% NDE in accordance with AF-220 shall be performed on the adjacent pressure weld in the area where the attachment weld will cross.

AD-412 CATEGORY B LOCATIONS

Delete all after " Type No.1 butt joints"

Delete clause AD-412.1

AD-413 CATEGORY C LOCATIONS

Delete all after "full penetration corner joints (see AF-223)"

AD-414 CATEGORY D LOCATIONS

Delete clause AD-414.1

Delete clause AD-414.2

AD-416 SPECIAL LIMITATIONS FOR JOINTS IN LETHAL SERVICE

Add to AD-416:
Type No.2 joints shall not be used.

AD-417 JOINTS ATTACHING NONPRESSURE PARTS AND STIFFENERS

Add to AD-417:
Stud welds shall not be used.

ARTICLE D-5 OPENINGS AND THEIR REINFORCEMENT

Amended per Circular 08/97

AD-502 LOCATION OF OPENINGS IN WELDED JOINTS

Add to AD-502:
Requirements added to AD-410 shall apply.

AD-540 LIMITS OF REINFORCEMENT

Add to AD-540:
The required thickness of an integrally reinforced branch shall not be greater than twice the vessel wall thickness at the location of the attachment.

AD-570 REQUIREMENTS FOR NOZZLES WITH SEPARATE REINFORCING PLATES

Replace AD-570 (a) and (b) with:
The material of the reinforcing plate should be the same material as used for the shell.

Replace AD-570 (d) with:
Reinforcing pad thickness shall not exceed 40 mm or the as-built shell thickness, whichever is the lesser.

Add to AD-570:
(f) Reinforcing pads shall not be used in hydrogen service above 230 °C (Part I, 1.3.2).

ARTICLE D-6 NOZZLES AND OTHER CONNECTIONS

AD-601 PERMITTED TYPE OF NOZZLES AND OTHER CONNECTIONS

Add to AD-601 (b):
For nozzles, Standard Drawing S 10.101 shall apply.

Nozzle types shall be as follows:

Type of service	vessel wall thickness, t (mm)		Nozzle type
all	t < 50		set-in
	t ≥ 100		forged saddle type
cyclic	t ≥ 50		forged saddle type
non-cyclic	50 ≥ t < 100	nozzle thickness ≥ t/2	set-in
		nozzle thickness <t/2	set-on (Notes 1 and 2) or set-in

NOTES: 1. For set-on nozzles, the following conditions shall apply to the plate material of the shell:

- The plate material shall meet ASTM A 770 S3 (with a minimum area reduction of 35%) or EN 10164 (Quality Class Z35); and
- 100% ultrasonic examination shall be performed on a 100 mm wide band around the nozzle opening before attachment of the nozzle. Acceptance criteria shall be BS 5996 B4E2.

2. Set-on nozzles shall not be used in hydrogen service above 230 °C (Part I, 1.3.2).

For both set-in and set-on nozzles, the fillet of the attachment weld shall blend smoothly with both vessel and nozzle wall without any notch, sharp corner or undercut.

All inside edges of nozzles and connections, whether flush or extended, shall be rounded off to a radius of at least 3 mm.

Modify AD-601 (e):
replace 'when the openings are in shells 2 1/2 in. and more in thickness' **with** ' for all openings, except for studded connections'

add: 'Socket-welded, single fillet-welded, expanded, brazed or screwed connections shall not be used.'

delete: AD-601 (h)

AD-610 NOZZLE NECKS ABUTTING THE VESSEL WALL

Refer to AD-601 (b)

AD-612 INSERTED NOZZLE NECKS WITH ADDED REINFORCEMENT

Modify AD-612-1:

Replace in 1st sentence '(maximum size NPS 1/4 tap) that may be tapped' **with** 'per closed compartment, tapped 1/4 inch NPT,'

Delete 2nd and 3rd sentence and replace with 'Tell-tale holes shall not be plugged, but shall be filled with a non-corrosive compound (e.g. Ensis) or grease to prevent the ingress of water after the test for tightness of the welds and, if applicable, PWHT.

AD-620 FITTINGS WITH INTERNAL THREADS

Delete AD-620

AD-621 WELDED CONNECTIONS NOT SUBJECT TO EXTERNAL LOADING

Delete this clause; partial penetration welds shall not be used.

FIG AD-612.1

Details (c), (e), (f), (g) and (h) shall not be used. Detail (d) may be used only if approved by the Principal.

FIG AD-613.1

Detail (f) shall not be used.

FIG AD-621.1

Details (a), (b) and (c) shall not be used.

AD-635 STUDDED PAD TYPE CONNECTIONS NOT SUBJECT TO EXTERNAL LOADING

Add to AD-635:
Only if approved by the Principal.

AD-640 THREADED CONNECTIONS

Delete this clause

AD-641 RESTRICTIONS ON THE USE

Delete this clause

Article D-7 FLAT HEADS, BOLTED, AND STUDDED CONNECTIONS

AD-710 BOLTED FLANGED CONNECTIONS

Add to AD-710 and AD-720
All bolt holes shall straddle the normal centre lines of the vessel.

NOTE: The Principal may specify the use of DIN flanges (e.g. if the site is standardized on the use of DIN flanges), in which case the ratings and the design requirements specified by the applicable DIN standard shall apply. All further requirements stated below are applicable only to ANSI B16.5 and ANSI B16.47 flanges. The additional requirements for DIN flanges, if any, shall be specified on the data/requisition sheets.

Unless otherwise approved by the Principal, only raised-face (narrow-faced) flanges shall be used.

Unless otherwise approved by the Principal, welding neck flanges shall be used for all equipment.

For austenitic stainless steel and non-ferrous vessels, lap-joint flanges may be used, subject to approval by the Principal.

Modify AD-711.1, first sentence:
Slip-on flanges conforming to ASME/ANSI B16.5 may only be used if approved by the Principal, and provided all the following conditions are met.

ARTICLE D-9 ATTACHMENTS AND SUPPORTS

AD-900 GENERAL REQUIREMENTS

Add to AD-900 (a):
Continuous liquid outlets on columns and vessels shall be provided with a vortex breaker, see Standard Drawing S 10.010, and in the following cases internally extended vortex breakers shall be used:
- in fouling service;
- for hydrocarbon liquid outlet of separators where the liquid is separated from water or aqueous solutions, except where this would give rise to corrosion problems in the bottom.

Delete AD-900 (b)

Replace AD-900 (c) (1) with:
Continuous fillet welds shall be used for all internal structures, supports and fittings to be welded to the vessel wall.

Delete AD-900 (c) (2)

Delete AD-900 (c) (3)

AD-901 MATERIALS FOR ATTACHMENTS TO PRESSURE PARTS

Replace AD-901 with:
Materials for supporting lugs, skirts, baffles and similar non-pressure parts welded to the vessel shall be of established identity and shall at least be compatible with the material to which they are attached.

Delete AD-901.1

AD-910 TYPES OF ATTACHMENT WELDS

Add to AD-911 (a):
Where applicable double fillet welds shall be used.

FIG AD-912.1

Detail (i) is not permitted.

AD-940 DESIGN OF SUPPORTS

Add to 940 (a):
Equipment supports shall be provided with at least 2 earthing bosses per piece of equipment in accordance with Standard Drawing S 68 004.

The design of supports shall be such that the metal temperature of the part of the support resting on concrete will not exceed 100 °C. For vessels with operating temperatures below ambient, this temperature shall be such that no condensation will occur under normal operating conditions. The mechanical design should provide for insulation sealing, adequate surface protection and prevention of condensate collecting areas.

If full skirts are specified they shall be constructed in accordance with Standard Drawing S 20.001. There shall not be any flanged connections inside full skirts.

If half skirts are specified they shall be constructed in accordance with Standard Drawing S 22.005. Half skirts shall not be used for vessels with fire proofing or for vessels connected to piping that is prone to vibration.

If saddles are specified they shall be constructed in accordance with Standard Drawings S 22.001 or S 22.002.

Legs are permissible as supporting structures in proven applications.

ARTICLE D-10 ACCESS AND INSPECTION OPENINGS

AD-1000 GENERAL REQUIREMENTS

Add AD-1000 (d):
Threaded inspection openings shall not be used.

AD-1020 SIZE AND TYPE OF ACCESS AND INSPECTION OPENINGS

Replace AD-1020.1 with:
Manholes (access openings) shall have a minimum clear inside diameter of 460 mm; however, nominal pipe sizes DN 500 (20"), DN 600 (24") and DN 750 (30") are preferred.

For the required sizes and the number of access openings required in columns with removable trays, see DEP 31.20.20.31-Gen.

Davits shall be provided for all openings DN 300 mm (12") nominal up to and including DN 750 mm (30"). Typical details are shown in Standard Drawing S 10.070, except for vessels

in low-temperature service, for which the covers shall be hinged.

Replace AD-1020.2 with:
The nominal minimum diameter for inspection openings (handholes) is DN 150 (6").

Hand hole covers shall be provided with a grip, see Standard Drawings S 10.039, S 10.053 and S 10.054.

AD-1025 THREADED OPENINGS

Delete AD-1025

ARTICLE D-11 SPECIAL REQUIREMENTS FOR LAYERED VESSELS

Add to D-11:
Layered vessels shall not be used unless approved by the Principal. Additional requirements, if any, shall be specified on the data/requisition sheets.

PART AF FABRICATION REQUIREMENTS

ARTICLE F-1 GENERAL FABRICATION REQUIREMENTS

AF-100 MATERIALS

Add to AF-100:
A pre-manufacturing meeting shall be held if considered necessary by the Manufacturer or the Purchaser.

Add to AF-102:
The Manufacturer shall prove that in the as-built condition material grades actually used for the construction of low-alloy vessels comply with the requirements of the purchase order. A non-destructive positive alloy material identification (such as an X-ray fluorescence analysis) shall be carried out if specified on the data/requisition sheets.

AF-104 REPAIR OF DEFECTIVE MATERIALS

Replace in AF-104.3 "3/8 in." **by** "1/8 in."

AF-110 FORMING

Add to AF-111:
All ferritic steel plates which have been cold deformed by dishing, flanging or rolling to an internal radius less than 10 times the plate thickness (more than 5% deformation) shall be given a normalizing treatment and, if necessary, a tempering treatment afterwards. Similarly, this rule applies to ferritic steel pipe which has been locally bent (with or without local heating) to an internal radius less than 10 times the outside diameter of the pipe.

Normalizing of CS components and base materials shall be performed separately, not as part of the hot-forming operation, unless the finishing hot-forming temperature is in the normalising temperature range of 850 °C to 960 °C. In both cases, the temperature shall be recorded and documented by a temperature recording chart.

All hot formed stainless steel heads shall be separately solution annealed after hot forming operation.

AF-112 BASE METAL PREPARATION

Add to AF-112.1 (b):
For Cr-Mo equipment with a maximum operating temperature above 350 °C all the cut edges shall be given 100% magnetic particle examination and there shall be no indications.

Add to AF-112.1 (c) 4:
No linear indications are allowed.

Add to AF-112.5:
For low alloy steels irrespective of thickness.

AF-130 TOLERANCES FOR SHELLS

Add to this clause:
For tolerances not covered by code requirements, see Appendix 3 of this DEP.

AF-135 TOLERANCE FOR FORMED HEADS

Add to this clause:
For tolerances not covered by code requirements, see Appendix 3 of this DEP.

AF-140 FITTING AND ALIGNMENT

Add to this clause:
For tolerances not covered by code requirements, see Appendix 3 of this DEP.

ARTICLE F-2 WELDING FABRICATION REQUIREMENTS

AF-220 SPECIFIC REQUIREMENTS FOR WELDED JOINTS

Add to AF-220:
In addition to the requirements for all the weld categories and types :

For Cr-Mo equipment with a maximum operating temperature above 350 °C all cut edges shall be given 100% magnetic particle examination and there shall be no indications.

Examination for internal flaws:
The full length of all categories of welds (A, B, C and D) shall be examined 100% by radiographic or ultrasonic methods.

NOTE: If radiography is not feasible, ultrasonic examination shall apply. This is valid for category C and D welds on nozzles where radiography is not possible (in such cases, ultrasonic examination of the welds shall be performed before the reinforcing pad is installed).

Examination for surface flaws:
The full length of all categories of welds (A, B, C and D) shall be examined by the wet magnetic particle or liquid penetrant method, with the exception of carbon and carbon manganese steels with a specified minimum tensile strength below 460 N/mm^2.

All categories of welds and attachment welds shall be 100% visually examined.

Full penetration tee or corner-type joints including nozzle attachement welds shall be non-destructively examined by either radiography (preferred) or ultrasonics, to the degree of the applicable construction category.

Non-full penetration tee or corner-type joints shall not be used.

The final non-destructive examination of welds for acceptance purposes shall be carried out after completion of PWHT, if any. At the Manufacturer's option, radiography may be performed before PWHT, in which case an ultrasonic examination shall be performed after PWHT for acceptance purposes.

AF-221.1 WELD PENETRATION AND REINFORCEMENT

Add new clause:
AF-221.1 (b) (3) On equipment operating below 0 °C, there shall not be any undercut.

AF-221.2 EXAMINATION REQUIREMENTS

Delete the first sentence and the word "Otherwise," in the second sentence.

AF-222 TYPE NO.2 BUTT JOINTS

Delete AF-222

AF-223.1 PENETRATION AND FUSION

Delete reference to fig. AD-612.1 (c), (e), (f) and (g).

AF-224 PARTIAL PENETRATION JOINTS FOR NOZZLE ATTACHMENTS

Delete this clause

AF-225 FILLET WELDED JOINTS

Add to this clause:
These joints may be used only for non-pressure parts such as attachments.

AF-226 WELDS ATTACHING NOZZLES AND OTHER CONNECTIONS

Add to this clause:
In table AF-226.1 reference is made to the amendments made to the applicable Sections and figures mentioned.

AF-227 WELDS ATTACHING NONPRESSURE PARTS AND STIFFENERS

Add to this clause:
Reference is made to restrictions on AG-301.1.

Add to AF-227.1:
See AF-221.2.

AF-228 LIQUID PENETRANT EXAMINATION

Replace 1st sentence by:
All welds (both butt and fillet) in austenitic and austenitic/ferritic steels shall be examined by the liquid penetrant method (see Article 9.2).

AF-230 MISCELLANEOUS WELDING REQUIREMENTS

AF-231 PREPARATION OF REVERSE SIDE OF DOUBLE WELDED JOINTS

Delete the last sentence of this clause

AF-234 PEENING

Delete this clause

AF-236 FRICTION WELDING VISUAL EXAMINATION

Delete this clause

AF-237 CAPACITOR DISCHARGE WELDING

Add to this clause:
This method of welding may be used only for the attachment of skin thermocouples.

AF-240 WELDS ATTACHING NOZZLES AND OTHER CONNECTIONS

Add to this clause:
In table AF-241.1 reference is made to the amendments made to the applicable Sections and figures mentioned.

AF-260 WELDING TEST PLATES

Add to this clause:
Production control test plates are not required for materials P1 groups 1, 2 and 3, unless the specified minimum tensile strength exceeds 460 N/mm^2. In all other cases, production control test plates shall be provided at the rate of two test plates per 100 m of butt weld or part thereof (circumferential plus longitudinal) and shall represent the welding on the vessel or on a group of similar vessels made of the same material, ordered to the same specification and with the same welding procedure/welder/welding operator qualification. Production control test plates are also required in those cases where the chemical composition of the weld deposit of welds in alloy materials has to be checked, i.e. where a minimum alloy content is required to meet the service conditions (creep, corrosion, hydrogen service). Production control test plates are also required for weld-deposited

cladding.

The test plates shall be made at an early stage of production welding with a thickness equal to the thickness of the shell.

In the case of spherical vessels, the test plates shall be welded separately and they shall represent each type of seam and welding position. For site-constructed vessels, the test plates shall be welded at the construction site.

One plate (or, if more than two plates were required, half the total number of plates) shall be selected and tested at an early stage. The required tests shall be in accordance with those required for Welding Procedure Qualification as described in ASME IX. If the vessel will be post-weld heat treated, then this test plate(s) shall be given a simulated heat treatment before testing, and a permanent time/temperature record shall be retained by the Manufacturer. This test plate(s) result shall be considered valid if the eventual vessel post-weld heat treatment is within the specified time/temperature range. The other test plate(s) shall be placed inside the vessel during its post-weld heat treatment, and shall be retained in case later testing may be required.

NOTE: As an alternative to the above, unless otherwise specified by the Principal, the Manufacturer may choose to post weld heat treat all the production control test plates inside the vessel, rather than performing a simulated post weld heat treatment.

A post-weld heat treatment certificate stating actual temperature/time parameters shall be included in the Manufacturer's report. The original temperature/time indicator recorder charts shall be retained by the Manufacturer.

For Cr-Mo equipment with a maximum operating temperature above 350 °C and with a primary membrane design stress greater than 50 MPa, two of the untested welding production control test plates shall be used to prepare four test blocks for installation in the equipment. For the details of preparation and installation of test blocks, see Appendix 5.

ARTICLE F-4 HEAT TREATMENT OF WELDMENTS

AF-400 HEAT TREATMENT OF WELDMENTS

Add to AF-401:
For Cr-Mo equipment with a maximum operating temperature above 350 °C the following requirements shall apply in addition to the other requirements of this DEP:

- the preheat temperature shall be maintained during flame cutting, welding (i.e. interpass), arc gouging, welding of temporary attachments and other thermal applications;
- if, for fabrication reasons, the final required heat treatment is not performed directly after welding, a post-weld soaking heat treatment shall be performed at a temperature of 350 °C for 3 hours, without cooling down below the preheat temperature, prior to cooling down to ambient temperature. However, nozzle welds shall receive an intermediate PWHT.
- The final PWHT temperature shall be at least 20 °C below the tempering temperature, with a minimum holding time of 1 hour per 25 mm of thickness (with a minimum of 1 hour). Soaking periods shall be based on the heaviest welded section, including the total thickness of the vessel wall.

Add to AF-402:
See also the amendment to AF-401.

The PWHT procedure shall clearly indicate the type and location of calibrated thermocouples to be used. This procedure shall form part of the heat treatment procedure to be submitted for approval. A PWHT certificate, stating actual temperature/time parameters, shall be included in the Manufacturer's report. The original temperature/time indicator recorder charts shall be retained by the Manufacturer.

ARTICLE F-5 SPECIAL REQUIREMENTS FOR WELDING CORROSION RESISTANT INTEGRAL OR WELD METAL OVERLAY CLAD OR LINED PARTS AND FOR COMPOSITE WELDS

Add the following introduction:

Pressure vessels constructed of material with corrosion resistant integral cladding, weld metal overlay cladding, or with applied linings shall comply with Article F-5 of this Division and with the requirements as specified of Appendix 2 of this DEP.

Loose linings shall not be applied.

AF-503 INSERTED STRIPS IN CLAD MATERIALS

Delete this clause

AF-540 METHODS TO BE USED IN APPLIED LININGS

Delete this clause

ARTICLE F-6 SPECIAL REQUIREMENTS FOR FERRITIC STEELS WITH TENSILE PROPERTIES ENHANCED BY QUENCHING AND TEMPERING

Add to this Article:
These steels shall not be used without the approval of the Principal.

ARTICLE F-8 SPECIAL FABRICATION REQUIREMENTS FOR LAYERED VESSELS

Add to this Article:
Layered pressure vessels shall not be used unless specified by the Principal.

PART AI INSPECTION AND RADIOGRAPHY

AI-102 INSPECTOR'S DUTY

Add to AI-102 (a):
The Principal shall specify if he (or his nominee) will perform shop surveillance, and if so the Principal shall specify the scope.

The Principal should tailor the scope of the Principal's inspection to avoid duplication with the Inspecting Authority.

AI-110 THE INSPECTOR

Add AI-110 (c):
See the amendment to AI-102 (a).

AI-500 TECHNIQUE FOR RADIOGRAPHIC EXAMINATION OF WELDED JOINTS

Add to this clause:
Radiography may be used for a plate thickness up to 50 mm (or 25 mm if the double-wall technique is being used). For a plate thickness greater than 50 mm, a mechanized ultrasonic inspection technique shall be used which is capable of producing hard copy inspection results.

If the time of flight defraction technique is applied, operators and acceptance criteria shall be subject to the approval of the Principal.

PART AT TESTING

AT-352 FLUID MEDIA AND TEMPERATURES FOR HYDROSTATIC TESTS

Add to this clause:
For test water quality, see DEP 61.10.08.11-Gen

AT-400 PNEUMATIC TESTS

Add to this clause:
Pneumatic testing shall not be performed without the approval of the Principal.

PART AS MARKING, STAMPING, REPORTS, AND RECORDS

AS-130 NAMEPLATE

Add to AS-130 (a):
Nameplate standard drawing S 10.114 shall be used. Bronze nameplates shall not be used on stainless steel equipment. For vessels required for low-temperature service (0 °C or lower) and for equipment containing liquefied gas or very toxic substances, the nameplates shall include the upper design temperature and pressure and the lower design temperature and pressure.

AS-300 MANUFACTURER'S DATA REPORTS

Add to this clause:
The manufacturer's data report for ASME VIII, Div. 2 vessels shall be made and forwarded in accordance with the applicable sections of Appendix I, regardless of whether code stamping is required. The manufacturer shall also list all agreed and authorized technical deviations and concessions from the original purchase order requirements in the form A-1 (supplementary sheet) and include it in the data report. Form A-1 shall also be used for certifying the results of positive alloy material identification (PAMI) when specified by the purchaser.

In exceptional cases, when statutory requirements such as national or local regulations demand more information and evidence in terms of certification to be supplied as compared to that provided by the ASME data report, the Purchaser may specify DEP 31.22.10.35-Gen. as the basis of the manufacturer's data report. In such cases, the Manufacturer shall follow the conditions of the purchase order for making the report.

PART V REFERENCES

In this DEP reference is made to the following publications:

NOTE: Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments/supplements/revisions thereto.

SHELL STANDARDS

Index to DEP publications and standard specifications	DEP 00.00.05.05-Gen.
Index to standard drawings	DEP 00.00.06.06-Gen.
Definition and determination of temperature and pressure levels	DEP 01.00.01.30-Gen
Approval drawing specification	DEP 05.00.54.81-Gen.
Final drawing specification	DEP 05.00.54.82-Gen.
Metallic materials - Selected standards	DEP 30.10.02.11-Gen.
Metallic materials - Prevention of brittle fracture	DEP 30.10.02.31-Gen.
Painting and coating of new equipment	DEP 30.48.00.31-Gen.
Design and installation of chemical-resistant brick lining for process equipment	DEP 30.48.60.13-Gen.
Trays for columns	DEP 31.20.20.31-Gen.
Manufacturing report for pressure vessels	DEP 31.22.10.35-Gen.
Piping - general requirements	DEP 31.38.01.11-Gen.
Minimum requirements for structural design and engineering	DEP 34.00.01.30-Gen.
Field inspection prior to commissioning of mechanical equipment	DEP 61.10.08.11-Gen.
Equipment and tools for maintenance and inspection. Part 2: - Mechanical maintenance - Equipment, tools and bolt tensioning	DEP 70.08.10.11-Gen.

STANDARD DRAWINGS

NOTE: The latest issue of standard drawings is identified in DEP 00.00.06.06-Gen.

Vortex breakers for nozzles	S 10.010
Bolting with ISO inch (unified) screw thread for non-standard flanges	S 10.035
Pad-type hand holes with cover flange ANS class 150 and 300 for unfired carbon steel, low alloy steel and stainless steel pressure vessels	S 10.039
Pad-type hand holes - carbon steel. Nom.diameter 6" and 8"; design pressure 10.3 and 20.6 bar ga; design temperature 343 °C	S 10.053
Pad-type hand holes - lined carbon steel. Nom.diameter 6" and 8"; design pressure 10.3 and 20.6 bar ga; design temperature 343 °C	S 10.054
Davit for ANS or BS flanges nom. size 12 - 24 inch incl., classes 150-600 incl.	S 10.070
Flanged nozzles to apparatus	S 10.101

Details of bush-lined and overlay clad nozzles	S 10.103
Nameplate with bracket for vessels and heat-exchange equipment	S 10.114
Typical details of lifting trunnion for vertical vessels	S 10.115
Bolting with ISO metric screw thread for non-standard flanges	S 10.116
Skirts, cylindrical and conical	S 20.001
Saddles for horizontal apparatus. Shell dia. 150 mm OD up to and incl. 1000 mm OD	S 22.001
Saddles for horizontal apparatus. Shell dia. 1050 mm OD up to and incl. 3600 mm OD	S 22.002
Supports for vertical vessels (half skirts) - Dia. 350-1500	S 22.005
Davit to columns; General arrangement and details	S 28.015
Earthing boss for steel structures, tanks, vessels, etc.	S 68.004

AMERICAN STANDARDS

Pipe flanges and flanged fittings	ANSI/ASME B16.5
Large diameter steel flanges	ANSI/ASME B16.47
Chemical plant and refinery piping	ANSI/ASME B31.3

Issued by:
American National Standards Institute, Inc.
1430 Broadway, New York
NY 10018, USA.

Steels for Hydrogen Service at Elevated Temperatures and Pressures in Petroleum Refineries and Petrochemical Plants	API 941

Issued by:
American Petroleum Institute
Publications and Distribution Section
2101 L Street Northwest
Washington, DC 20037, USA.

Amended per Circular 38/99

ASME Boiler and Pressure Vessel Code:

Rules for construction of pressure vessels	ASME VIII, Div. 1 (July 1995, plus addenda A95)
Alternative rules for construction of pressure vessels	ASME VIII, Div. 2 (July 1995, plus addenda A95)
Qualification standard for welding and brazing procedures, welders, brazers, and welding and brazing operators	ASME IX

Issued by:
American Society of Mechanical Engineers
345 East 47th Street
New York, NY 10017, USA.

Specification for general requirements for steel plates for pressure vessels	ASTM A 20
Specification for forgings, carbon steel, for piping components	ASTM A 105
Standard specification for seamless carbon steel pipe for high temperature service	ASTM A 106
Standard specification for piping fittings of wrought carbon steel and alloy steel for moderate and elevated temperatures	ASTM A 234
Standard practice for detecting susceptibility to intergranular attack in austenitic stainless steels	ASTM A 262
Standard specification for corrosion-resisting chromium steel-clad plate, sheet, and strip	ASTM A 263
Standard specification for stainless chromium-nickel steel-clad plate, sheet, and strip	ASTM A 264
Standard specification for nickel and nickel-based alloy-clad steel plate	ASTM A 265
Standard specification for seamless and welded steel pipe for low temperature service	ASTM A 333
Standard specification for forgings, carbon and low alloy steel, requiring notch toughness testing for piping components	ASTM A 350
Specification for bolting materials, high-temperature, 50 to 120 ksi yield strength, with expansion coefficients comparable to autenitic steels	ASTM A 453
Standard specification for pressure vessel plates, carbon steel, for moderate and lower temperature service	ASTM A 516
Straight-beam ultrasonic examination of plain and clad steel plates for special applications	ASTM A 578
Through-thickness tension testing of steel plates for special applications	ASTM A 770
Standard specification for steel plates for pressure vessels, produced by Thermo-Mechanical Control Process (TMCP)	ASTM A 841
Standard test method for indentation hardness of metallic materials by portable hardness testers	ASTM E 110
Test method for hydrophobic surface films by the atomizer test	ASTM F 21

Issued by:
American Society for Testing and Materials
1916 Race Street Philadelphia
Pa 19103, USA.

Sulfide Stress Cracking Resistant Material for Oil Field Equipment	NACE MR0175
Laboratory Testing of Metals for Resistance to Sulfide Stress Cracking in H_2S Environments	NACE TM0177

Issued by:
The National Association of Corrosion Engineers
P.O.Box 218340

Houston, Texas 77218, USA.

BRITISH STANDARDS

Specification for acceptance levels for internal imperfections in steel plate, strip and wide flats, based on ultrasonic testing — BS 5996

Issued by:
British Standards Institution
389 Chiswick High Road
London W4 4AL
UK.

EUROPEAN STANDARDS

Destructive tests on welds in metallic materials. Hardness testing. Hardness test on arc welded joints — EN 1043-1

Steel products with improved deformation properties perpendicular to the surface of the product; technical delivery conditions — EN 10164

Issued by:
Comité Européen de Normalisation
Secrétariat Central
Rue de Stassart 36
B-1050 Brussels
Belgium.

Copies can also be obtained from national standards organizations

GERMAN STANDARDS

Clad Steel — AD Merkblatt W 8

Issued by:
Beuth Verlag GmbH
Burggrafenstrasse 4-10
D-1000 Berlin 30
Germany.

INTERNATIONAL STANDARDS

Steel and Steel Products, Inspection documents — ISO 10474

Issued by:
International Organization for Standardization
1, rue de Varembé
CH-1211 Genève 20
Switzerland.

Copies can also be obtained from national standards organizations.

APPENDIX 1 HARDNESS REQUIREMENTS FOR CARBON AND FERRITIC ALLOY STEEL PRESSURE VESSELS

1. WELDING PROCEDURE QUALIFICATION

In addition to the standard mechanical tests, each welding procedure qualification test (WPQT) shall include a macro section and hardness traverses in accordance with EN 1043-1. The series of readings shall extend from unaffected base material on one side, across the weld to unaffected base metal on the other side. Three traverses shall be made: one 2 mm below the outer surface, one 2 mm below the inner surface and one across the centre. The distance between measurements across the weld shall not exceed 2 mm. No part of the weld, HAZ or base metal shall exceed 248 HV 10, except for utility (steam, water and air) services, for which the maximum hardness shall be 290 HV 10.

WPQT hardness testing shall be performed by the Vickers method.

2. PRODUCTION WELDS

2.1 TEST PROCEDURE

Transverse weld hardness testing of production welds shall be carried out using a portable Vickers or Rockwell tester in accordance with ASTM E 110 or by another method capable of detecting a hard HAZ in a reliable and repeatable manner (e.g., Equotip, Microdur or other equivalent if approved by the Principal).

Whenever possible, tests shall be made on the inside (process-contacted side) of the vessel.

Tests shall be made on properly ground surfaces.

On heat-treated vessels, hardness measurements shall be carried out after PWHT.

2.2 GENERAL AND UTILITY SERVICE

Spot checks shall be carried out on the production welds with at least one set of hardness measurements carried out for each welding procedure applied.

For each set of hardness measurements required, the average of three measurements on the weld and on each HAZ shall be reported.

No part of the weld, HAZ or base metal shall exceed 248 HV 10.

2.3 HYDROGEN, HF AND VERY TOXIC SERVICES

One set of hardness measurements shall be carried out for each welding procedure qualification applied and for each 10 metres of finished weld (with a minimum of one test).

For each set of hardness measurements required, the average of three measurements on the weld and on each HAZ shall be reported.

No part of the weld, HAZ or base metal shall exceed 248 HV 10.

3. WET H_2S SERVICE/SOUR SERVICE

See Appendix 4, Section 3.7.

APPENDIX 2 REQUIREMENTS FOR WELDED PRESSURE VESSELS CONSTRUCTED OF MATERIAL WITH CORROSION RESISTANT INTEGRAL CLADDING, WELD METAL OVERLAY CLADDING OR APPLIED LININGS

Pressure vessels or vessel parts constructed of base material with corrosion resistant integral or weld metal overlay cladding and vessels and vessel parts that are fully or partially lined inside or outside with corrosion resistant plate, sheet, or strip, attached by welding to the base plate before or after forming or to the shell, heads, and other parts during or after assembly into the completed vessel, shall satisfy the requirements of ASME VIII, Div. 2, Article F-5, except as modified in this Appendix.

MODIFICATIONS TO ARTICLE F-5 OF ASME VIII, DIV. 2.

1. Linings other than those obtained by using integrally clad plate or overlay weld deposits shall not be used without the approval of the Principal. For linings in hydroprocessing equipment, only weld overlay deposits shall be used; the use of integrally clad plate shall be subject to the approval of the Principal.
2. Integrally clad plate shall be of the homogeneously clad type as obtained by roll cladding or explosive cladding. The clad plates shall conform to ASTM A 263, A 264 or A 265, as applicable, irrespective of the design calculation method used. Integrally clad plate in accordance with AD Merkblatt W 8 may be used.
3. Integrally clad plate and linings applied by overlay weld depositing, and products formed from these materials, shall be ultrasonically examined to check the quality of the bond in accordance with the requirements of ASTM A 578, acceptance level S6.

   In addition the following requirements shall be fulfilled:

   - Any unbonded area shall be smaller than 10 cm^2;
   - The total of the unbonded areas shall not exceed 100 cm^2 per 1 m^2 area of plate (areas less than 1.0 cm^2 shall be ignored).

   This also applies to clad restoring of welds in clad plate where a band of 50 mm wide on each side of the weld shall be examined.
4. Only overlay-welded nozzles or nozzles made of integrally clad plate shall be used.
5. The design of nozzles shall be in accordance with Standard Drawing S 10.103.
6. The thickness of the material used for cladding or lining shall not be included in the computation of the required wall thickness.
7. The welding procedure shall be qualified in accordance with ASME IX, which is referred to in ASME VIII, Div. 2, Article F-5.
   1. Chemical analysis of weld overlay of the production welds shall be performed at a depth of 2 mm with the following extent:
      - one analysis per course;
      - one analysis per head;
      - one analysis per nozzle.

      The material composition shall comply with the specification of chemical requirements for the original clad material.
   2. The ferrite content of weld overlay of the production welds shall be performed at a depth of 2 mm with the following extent:
      - one analysis per course;
      - one analysis per head;
      - one analysis per nozzle.
        The ferrite content shall be between 3% and 8%.

      Calibration records of the ferrite scope to be submitted to the Principal for approval.
   3. Liquid penetrant examination shall be performed on the entire clad surface. The acceptance criterion shall be zero indications of cracks.
   4. For linings in hydroprocessing equipment, the cladding shall be in a non-sensitized condition. This shall be demonstrated by passing the intergranular corrosion test in

accordance with ASTM A 262, practice E.

8. The grade of stainless steel overlay shall be specified by the Principal in the data/requisition sheets.

   For a maximum operating temperature not higher than 425 °C, the weld overlay thickness shall be a minimum of 3 mm. For a maximum operating temperature higher than 425 °C, the weld overlay thickness shall be a minimum of 5 mm.

9. The Manufacturer shall demonstrate that he is able to control the chemical composition of the weld overlay within agreed values, either by using a normal two-layer technique in which the first layer is applied with a low heat input, or by a proven single-layer mechanised welding process. The latter is subject to approval by the Principal.

10. Welds in the base materials shall be non-destructively examined in accordance with the construction category before any overlay weld is deposited. Ultrasonic examination for final acceptance purposes shall be on finished welds (including weld overlay, clad restoring and PWHT).

APPENDIX 3 VESSEL TOLERANCES

1. GENERAL

Amended per Circular 38/99

Tolerances for vessels subject to internal and/or external pressure shall be as stated in UG-80 and UG-81. The maximum deviation of the shell from a straight line shall not exceed 0.3%, either of the total cylindrical length or of any individual 5 m length of the vessel.

2. VESSELS WITH INTERNALS

For dimensions of tray support rings see section 4.5 of this Appendix.

If vessels are to be fitted with special screens or filters which require a more precise fitting the tolerances shall be in accordance with the screen/filter manufacturer's recommendation and be specified on the data/requisition sheets.

3. LENGTH

Tolerance on overall length measured between the tangent lines shall be in accordance with the following table:

Length L (mm)	Tolerance (mm)
L ≤ 100	± 2.0
1 000 < L ≤ 4000	± 4.0
4 000 < L ≤ 10 000	± 8.0
L > 10 000 and all vessels having a wall thickness over 70 mm	± 13.0

NOTE: Tangent lines shall be punch-marked on the dished heads, both externally and internally at the intersection of knuckle with the cylindrical section.

4. ATTACHMENTS

Tolerances for attachments are given below. The alphabetic coding is given in Figure 1 at the end of this Appendix.

4.1 NOZZLES IN SHELLS AND DOMED ENDS (EXCEPT FOR NOZZLES FOR LEVEL INSTRUMENTS, INSPECTION OPENINGS/MANHOLES)

a. Position
Measured from tangent line, ± 6 mm

b. Projection
For nozzles on shell measured from shell curvature, and for nozzles on domes measured from tangent line, ± 6 mm

c. Alignment
Of nozzle flange face with the indicated plane, maximum 0.5 degree in any direction.

d. Radial orientation
Measured from reference centre line to centre line of nozzle, ± 1 degree with a maximum circumferential tolerance of 15 mm.

e. Bolt hole orientation
Maximum rotation 1.5 mm measured at bolt circle.
NOTE: Bolt holes to straddle centre lines, unless otherwise indicated

f. Deviation of nozzle centre line in head
Not to exceed 3 mm
NOTE: Nozzles and supports for stacked heat exchangers shall be checked for correct alignment during

fabrication, and due allowance shall be made for the gaskets specified.

4.2 NOZZLES FOR LEVEL INSTRUMENTS

g. Distance
Measured from centre to centre: ± 1.5 mm

h. Projection difference
For each pair of flanges, measured from shell curvature: 1.0 mm.

i. Alignment
Of nozzle flange face with the indicated plane: maximum 0.25 degree in any direction.
Further tolerances for level instrument nozzles shall be in accordance with 4.1 a, b and e.

4.3 INSPECTION OPENINGS/MANHOLES

j. Position
Measured from bottom tangent line: ± 12 mm.
Further tolerances for manholes shall be in accordance with 3.1 d and e.

k. Height
Measured from shell curvature: ± 12 mm.

l. Alignment
Of flange face: maximum 1 degree in any direction.

4.4 VESSEL SUPPORTS

m. Support height

Distance H from lower tangent line to base or support (mm)	Tolerance (mm)
H ≤ 1000	± 2.0
1000 < H ≤ 4000	± 4.0
4000 < H ≤ 10000	± 8.0

n. Base ring or support out of levelness
0.2% of nominal diameter with a maximum of 12 mm.

p. Foundation bolt pitch circle
For vessel with ID ≤ 2100 mm: ± 3 mm.
For vessel with ID > 2100 mm: ± 6 mm.

q. Distance between legs (horizontal vessel)
± 3 mm.

r. Height of leg (horizontal vessel)
± 5 mm.

4.5 TRAY SUPPORTS

Amended per Circular 62/97

s. Tray support ring levelness
Measured as greatest difference all around: ± 0.15% of the outside tray diameter, with a maximum of 4 mm.

t. Tray support ring position
Distance of tray support ring to lower tangent line: ± 6 mm.

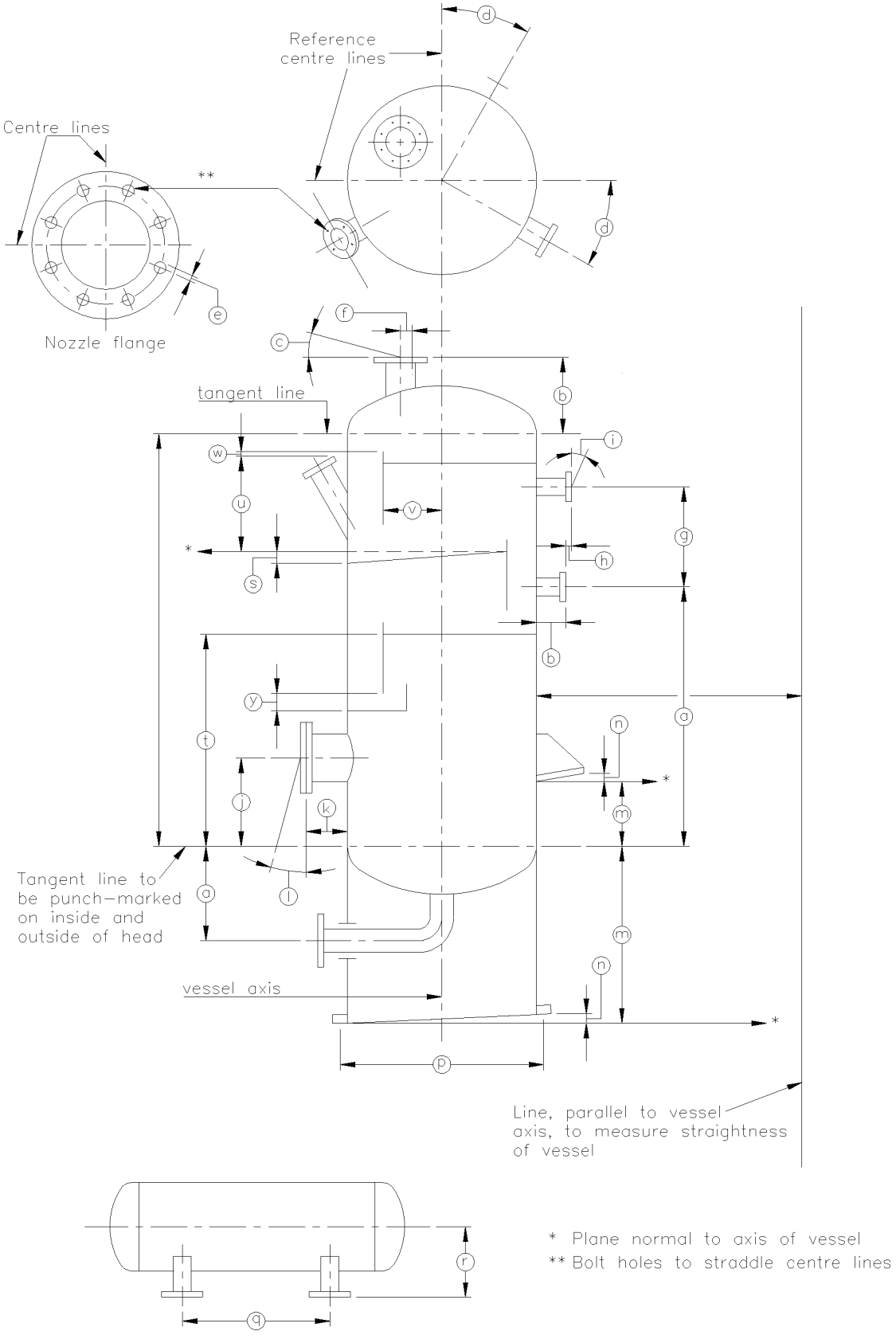
u. Distance between two adjacent tray support rings (and from tray support ring to centre of adjacent nozzle or instrument connection): ± 3 mm, except for the distance of a draw-off tray support ring to the centre of the corresponding nozzle, for which the tolerance is ± 2 mm.

v. Distance of vertical downcomer plate to vessel axis
± 3 mm

w. Height of fixed weir above tray support ring
± 3 mm.

y. Distance from downcomer bottom to tray support
± 3 mm.

Figure 1 Alphabetic coding



APPENDIX 4 CARBON STEEL PRESSURE VESSELS IN WET H_2S SERVICE/SOUR SERVICE

1. INTRODUCTION

This Appendix shall be applied for the specification and fabrication of carbon steel pressure vessels in order to mitigate or avoid the effects of aqueous hydrogen charging in "Wet H S" or "Sour" process environments (see their definitions below). Types of material damage that can occur as a result of aqueous hydrogen charging include sulphide stress corrosion (SSC) cracking of hard weldments and microstructures, hydrogen blistering, hydrogen induced cracking (HIC) and stress-oriented hydrogen induced cracking (SOHIC).

SSC is the occurrence of brittle fracture under the combined action of stress and H S dissolved in water. Hydrogen blistering, HIC and SOHIC are lamellar cracking phenomena, often connected or (in the case of HIC and SOHIC) propagating in a stepwise manner. Hydrogen blistering, HIC and SOHIC are most commonly associated with plate or strip product forms and are much less common in seamless pipe or wrought products (although HIC has been experienced in seamless products which have a poor microstructure due to incorrect chemistry or heat treatment). Furthermore, in some high pH refinery process streams a form of alkaline stress corrosion cracking (ASCC) is a concern. ASCC is normally mitigated by applying PWHT to welds and cold formed products.

2. DEFINITION OF WET H S/SOUR SERVICE

"Wet H S" service is the term commonly used for refinery and gas plant (SIOP) environments containing water and H S (plus other corrosives or contaminants), whereas "Sour" service is the term traditionally used for similar environments in exploration and production (SIEP) services.

However, the chemical composition of the environments is often quite different, and these differences are described in this Section.

Although the definitions of these services differ between SIOP and SIEP, the approach to materials selection and testing has been standardised and is described in Sections 3, 4 and 5 of this Appendix.

2.1 SIEP - "SOUR" SERVICE

General requirements (Section 3) shall apply to prevent the occurrence of SSC if:

- Sour conditions, as defined in NACE MR0175, prevail; **and**
- the temperature at any time during operation is between 0 °C and 65 °C.

Additionally, special requirements (Sections 4 and 5) shall apply to prevent the occurrence of hydrogen blistering, HIC and SOHIC if:

- In gas-containing systems, the partial pressure of H S exceeds 0.0035 bar (abs); **or**
- In liquid containing systems, the concentration of H S is higher than that occurring in a liquid equilibrium with a gas containing H S at a partial pressure of 0.0035 bar (abs).

and:

- the temperature has to be between 0 °C and 65 °C; **and**
- the pH of the liquid has to be lower than 7; **and**
- an electrolyte (typically an aqueous phase) is normally in contact with the steel.

2.2 SIOP - “WET H S” SERVICE

All carbon steel vessels in refineries exposed to process streams shall be designed and manufactured to resist the potential cracking mechanisms caused by the generation of free hydrogen in an aqueous corrosion reaction in Wet H S process environments.

In refinery streams containing free water and H S, the pH is often around 6 or higher due to the presence of ammonia. Trace quantities of contaminants such as chloride or fluoride may also be present, which form ammonium salts (ammonium chloride and ammonium fluoride). Cyanides can also play an important role in refinery streams as they affect iron sulphide scale persistence and possibly hydrogen pick-up. In high pH streams containing

significant levels of sulphide and carbonate ions, measures shall be taken to prevent carbonate cracking, which is a form of alkaline stress corrosion cracking (ASCC).

The materials selection, testing and PWHT requirements should be based upon on the potential damage mechanism(s) anticipated or experienced in the service and the severity of the process environment (potential level of hydrogen flux and/or ASCC).

Tables 1A, 1B and 1C should be used to assess the severity of the process environment as applicable to the type of damage mechanism being considered

NOTE: When using Tables 1A, 1B and 1C the environment being considered should be present during normal operations. Short term upsets should only be considered if the damage mechanism anticipated or experienced is also likely to occur in the short term. If in doubt, the materials engineer of the Principal shall be consulted.

Table 2 summarises these materials selection and PWHT requirements for the potential damage mechanisms in the different severity categories.

TABLE 1A SUSCEPTIBILITY TO SSC

If there is no free water likely to be present then the material is **not** considered susceptible to SSC.

If water is likely to be present, the pH is greater than 4.0 and the cyanide level is low, then the following table should be used to estimate the severity category with respect to SSC. Process conditions outside these ranges should be further assessed for hydrogen blistering, HIC and SOHIC severity using Table 1B.

pH of water	**Cyanide content (mg/kg)** (Note 1)	**H_2S CONTENT OF WATER (mg/kg)**		
		< 50	**50 to 1000**	**> 1000**
		SEVERITY CATEGORY		
4.0 to 5.4	(Note 2)	Low	Moderate	High
5.5 to 7.5	(Note 2)	Low	Low	Moderate
7.6 to 7.9	**< 50**	Low	Moderate	High
≥ 8.0	**< 20**	Low	Moderate	High

NOTES:
1. If the cyanide level cannot be established during design or from experience, the materials engineer of the Principal shall be consulted for an assessment based upon the type of process unit, feed, water wash practices, etc.
2. The level of cyanide is not significant at pH 7.5 and below.

TABLE 1B SUSCEPTIBILITY TO HYDROGEN BLISTERING, HIC AND SOHIC

If there is no free water likely to be present then the material is **not** considered susceptible to hydrogen blistering, HIC or SOHIC. If water is likely to be present and conditions are outside the range of Table 1A with respect to pH or cyanide, the following table should be used to determine the severity category for hydrogen blistering, HIC and SOHIC.

pH of water	Cyanide content (mg/kg) (Note 1)	H_2S CONTENT OF WATER (mg/kg)		
		< 50	50 to 1000	> 1000
		SEVERITY CATEGORY		
< 4.0	(Note 2)	Moderate	Moderate	Moderate
7.6 to 7.9	≥ 50	Moderate	Moderate	High
≥ 8.0	≥ 20	Moderate	High	High

NOTES:
1. If the level of HCN cannot be established during design or from experience, the materials engineer of the Principal shall be consulted for an assessment based upon the type of process unit, feed, water wash practices etc.
2. The level of HCN is not significant at pH 7.5 and below.

TABLE 1C SUSCEPTIBILITY TO CARBONATE CRACKING

If there is no free water likely to be present or the water phase contains less than 50 mg/kg H_2S then the material is **not** considered susceptible to carbonate cracking. If there is free water likely to be present with more than 50 mg/kg H S at a pH of 7.6 or greater, then the following table should be used to determine the severity category for carbonate stress corrosion cracking.

pH of Water	$CO_3^=$ CONTENT (mg/kg) of WATER			
	< 100	100 to 500	501 to 1000	> 1000
	SEVERITY CATEGORY			
7.6 to 8.3	Low	Low	Low	Moderate
8.4 to 8.9	Low	Low	Moderate	High
≥ 9.0	Low	Moderate	High	High

TABLE 2 SUMMARY OF SIOP "WET H S" MATERIALS AND PWHT REQUIREMENTS

POTENTIAL MECHANISM(S) (Note 1)	SEVERITY CATEGORY		
	LOW	MODERATE	HIGH
	MATERIALS AND PWHT REQUIREMENTS		
SSC	General Refinery Service	Section 3	Section 3 + PWHT (Note 4)
Hydrogen blistering, HIC and SOHIC (Note 2)	Not Applicable	Sections 3, 4 and 5	Clad, or Sections 3, 4, 5 and 6 (Note 3)
Carbonate Cracking	Section 3	Section 3 + PWHT (Note 4)	Section 3 + PWHT (Note 4)

NOTES:
1. Potential mechanisms are not exclusive, i.e. if there is more than one mechanism active, the materials and PWHT requirements may have to be combined to address the severity of more than one environment. For example, the fractionator overheads in a Fluidised Catalytic Cracking Unit (FCCU) may have a high severity for hydrogen blistering, HIC, SOHIC and carbonate cracking and in such a case the requirements for materials and PWHT shall be combined.

2. Any in-service vessel (or vessel in a directly comparable service) that requires replacement because it has been damaged by significant hydrogen blistering and/or HIC should be assessed as a "Moderate Severity" environment. A vessel that has experienced SOHIC should be assessed as a "High Severity" environment. In such cases the materials engineer of the Principal shall be consulted.

3. For carbon steel vessels, additional mitigation measures, such as injection of polysulphide or inhibitors may be required; the materials engineer of the Principal shall be consulted.

4. PWHT indicates a requirement for postweld heat treatment of all shop and field welds.

3. GENERAL MATERIALS, WELDING AND HARDNESS REQUIREMENTS FOR VESSELS IN WET H S/SOUR SERVICE

3.1 GENERAL

All materials shall be in accordance with the materials property and heat treatment requirements of NACE MR0175 as supplemented or modified by this Appendix. Certification to NACE MR0175 is only required if specified by the Principal.

3.2 HEAT TREATMENT CONDITION

All materials shall be supplied in the normalised condition. Normalising shall be carried out as a separate heat treatment. The acceptability of hot-finished material shall be subject to the approval of the Principal.

3.3 PLATE

Plate shall comply with ASTM A 516, as modified below.

3.3.1 Chemical composition

In order to ensure effective resistance to SSC in the as-welded condition, the chemical composition (product analysis) shall be restricted as follows, except where the standard material specification is more restrictive:

Single Elements	**Maximum wt.%**
Carbon (C)	0.20
Sulphur (S)	0.01
Multiple Elements	
Vanadium (V) + Niobium (Nb)	0.02
Carbon Equivalent (Note 1)	0.43

NOTES: 1. Carbon Equivalent (CE) shall be calculated using the following formula:

$$CE = C + \frac{Mn}{6} + \frac{(Ni + Cu)}{15} + \frac{(Cr + Mo + V)}{5}$$

2. The micro-alloying elements Boron (B), Titanium (Ti), Niobium (Nb) and Vanadium (V) shall not be intentionally added to the steel unless this has been given the prior approval of the Principal.

3.3.2 Through-thickness testing

All plates shall meet the through-thickness testing requirements of ASTM A 770 S3 (with a minimum area reduction of 35%). HIC-tested plate in accordance with Sections 4 and 5 of this appendix is an acceptable alternative.

3.4 FORGINGS (Flanges, etc.)

Forgings shall be in accordance with ASTM A 105N or ASTM A 350-LF2, with the following restrictions:
Carbon: 0.25 wt.% max.
CE: 0.43 max.

3.5 SEAMLESS PIPE (e.g. for nozzles)

Seamless pipe shall be in accordance with ASTM A 106 Grade B or ASTM A 333 Grade 6, with the following restrictions:
Carbon: 0.23 wt.% max.
CE: 0.43 max.

3.6 WELDED PIPE AND FITTINGS

Fittings shall be in accordance with ASTM A 234 WPB or WPC. Generally, only seamless pipe and fittings should be used for vessel nozzles. Base materials shall be in accordance with the above specifications for forging or pipe, as applicable. Where this is impractical, welded pipe and fittings may be used and shall be manufactured from plate complying with Section 3.3 of this Appendix. Welding of such fittings shall be done using welding procedures qualified in accordance with Section 3.7 of this Appendix.

3.7 WELDING AND HARDNESS REQUIREMENTS

3.7.1 Welding Procedure Qualification

Material purchased for the contract, or equivalent material (i.e., specification, grade, CE and chemistry controls), shall be used for all welding procedure qualification tests (WPQTs).

In addition to the standard mechanical tests, each WPQT shall include a macro section and hardness traverses in accordance with EN 1043-1. The series of readings shall extend from

unaffected base material on one side, across the weld to unaffected base metal on the other side. Three traverses shall be made: one 2 mm below the outer surface, one 2 mm below the inner surface and one across the centre. The distance between measurements across the weld shall not exceed 2 mm. No part of the weld, HAZ or base metal shall exceed 248 HV 10.

WPQT hardness testing shall be performed by the Vickers method.

NOTE: The weld metal deposit shall not contain more than 1.00% nickel.

3.7.2 Production Welds

Transverse weld hardness testing of production welds shall be carried out using a portable Vickers or Rockwell tester in accordance with ASTM E 110 or by another method capable of detecting a hard HAZ in a reliable and repeatable manner (e.g., Equotip, Microdur or other equivalent if approved by the Principal).

Whenever possible, hardness tests shall be made on the inside (process-contacted side) of the vessel.

Hardness tests shall be made on properly ground surfaces.

On heat-treated vessels, hardness testing shall be carried out after PWHT.

One set of hardness measurements shall be carried out for each welding procedure qualification applied and for each 10 metres of finished weld (with a minimum of one test).

For each set of hardness measurements required, the average of three measurements on the weld and on each HAZ shall be reported.

No part of the weld, HAZ or base metal shall exceed 248 HV 10.

4. HIC RESISTANT MATERIALS REQUIREMENTS

The requirements of this Section are additional to the general requirements of Section 3 of this Appendix.

4.1 HEAT TREATMENT CONDITION

Heat treatments other than normalising (such as quench and tempering (Q+T) or thermal/mechanical controlled process (TCMP)), used to improve microstructure homogeneity and enhance HIC resistance, may be applied only with the approval of the Principal.

Vessels shall be given PWHT unless otherwise specified by the Principal. The minimum PWHT time and temperature shall be 1 hour at 610 °C. The maximum PWHT time and temperature shall be governed by the design code requirements and the material properties as guaranteed by the material supplier.

4.2 PLATE

4.2.1 General

Plate complying with ASTM A 516, as modified below, shall be used for all pressure boundary plate components in contact with the process environment. All other plate materials (e.g. reinforcing pads, clips, skirts) shall be made from material complying with Section 3.4 of this Appendix.

ASTM 841 TMCP steel may be considered but shall only be used with the approval of the Principal.

Plate material shall be HIC-tested in accordance with Section 5 of this Appendix. Plate shall be tested in a simulated PWHT condition (see Section 4.1 of this Appendix).

4.2.2 Manufacturing process

The steel shall be vacuum-treated, fully deoxidised, desulphurised and dephosphorised.

The manufacturing/rolling process shall be such that a homogeneous microstructure is obtained, i.e. the structure shall be free of any significant ferrite/pearlite banding (see Section 5.6 of this Appendix). Calcium treatment shall be applied for inclusion shape control, except that it need not be applied to plate with very low sulphur levels (below 0.001%). The calcium content should not exceed 3 times the sulphur content. Alternative methods of inclusion shape control shall be subject to the approval of the Principal.

4.2.3 Chemical composition

In order to ensure effective resistance to both HIC and SSC, the chemical composition (product analysis) shall be restricted as follows, except where the standard material specification is more restrictive:

Single Elements	**Maximum wt.%**
Carbon (C)	0.20
Manganese (Mn)	1.30
Phosphorous (P)	0.01
Sulphur	0.002
Silicon (Si)	0.40
Copper (Cu)	0.4
Nickel (Ni)	0.4
Chromium (Cr)	0.3
Molybdenum (Mo)	0.12
Vanadium (V)	0.015
Niobium (Nb)	0.015
Titanium (Ti)	0.02
Boron (B)	0.0005
Multiple Elements	
Cr + Mo	0.3
Ni + Cu + Cr + Mo	0.7
V + Nb	0.02
Carbon Equivalent (Note 1)	0.43

NOTES: 1. Carbon Equivalent (CE) shall be calculated using the following formula:

$$CE = C + \frac{Mn}{6} + \frac{(Ni + Cu)}{15} + \frac{(Cr + Mo + V)}{5}$$

2. The micro-alloying elements Boron (B), Titanium (Ti), Niobium (Nb) and Vanadium (V) shall not be intentionally added to the steel unless this has been given the prior approval of the Principal.

4.2.4 Lamination check

Plate shall be subjected to an ultrasonic lamination check in accordance with BS 5996 B4E2.

4.3 WELDED PIPE AND FITTINGS

Generally, only seamless pipe and fittings should be used for vessel nozzles. Where this is impractical, welded pipe and fittings manufactured from plate complying with Section 4.2 of this Appendix shall be used. Welding of such fittings shall be done using welding procedures complying with Section 3.7 of this Appendix.

5. HIC TESTING

5.1.1 Responsibility

HIC testing is the responsibility of the vessel manufacturer but the testing may be performed by the steel manufacturer. Material inspection certificates shall be in accordance with ISO 10474, type 3.1.C (for which the vessel manufacturer or steel manufacturer shall appoint the witnessing party, which shall be subject to the approval of the Principal).

5.1.2 Frequency of Testing

The vessel Manufacturer shall perform HIC sensitivity tests in the solution prescribed in Section 5.4 of this Appendix.

Plate materials shall be subjected to HIC testing at a frequency of one test per heat. For pressure vessel plate where more than one thickness may be rolled from the same heat, tests shall be performed on both the thickest and the thinnest plates produced from each heat.

5.2 QUALIFICATION OF TEST METHOD

Before commencement of the work, the vessel Manufacturer shall provide the Purchaser with a detailed procedure for the testing, metallographic preparation and evaluation of HIC specimens. The Manufacturer shall qualify the test method using samples from a steel of known crack sensitivity. The Principal shall indicate if any of these tests are to be witnessed.

5.3 SAMPLING

5.3.1 Removal of Test Specimens

Three adjacent specimens shall be removed cold, by machining from the test plate. The dimensions shall be 100 mm x 20 mm x t, where t is the plate thickness. The long dimension of the specimen shall be parallel to the plate rolling direction. For plates or pipe greater than 20 mm in thickness but less than 50 mm, specimens shall be extracted from the middle of the plate such that the specimen thickness is not greater than 20 mm. For plate thickness equal to or greater than 50 mm, an additional set of specimens shall be removed from the surface.

5.3.2 Specimen Preparation

The specimens shall first be rough ground on a belt grinder or by surface grinding. This shall be followed by final grinding to a 320 grit finish using silicon carbide papers. They shall then be degreased in acetone. The effectiveness of degreasing shall be demonstrated by using the atomiser test of ASTM F 21. Thereafter, extreme care shall be taken not to contaminate the coupons, which should only be handled with tongs or clean gloves.

5.4 TEST SOLUTION

The test shall be performed in the NACE TM0177 (low pH) test solution, i.e. 0.5% acetic acid + 5% NaCl + H S in water, with a pH of 2.9 to 3.3. The test shall be performed in glass vessels only.

The solution shall be de-aerated by bubbling nitrogen through it at a rate of 100 cm^3/l/min for 1 hour. The specimens shall be immersed in the solution with the face of 100 mm x 20 mm in the vertical position and the lower face raised from the cell bottom on Teflon or glass rods. When stacked, the specimens shall also be separated by similar rods, see Figure 1.

Nitrogen bubbling shall be continued for a further 1 hour, after which the solution shall be saturated by bubbling H S at the rate of 2 to 5 l/min for one hour through an open-ended tube with a 5 mm internal diameter. Upon reaching saturation, the H S flow rate may be reduced to 100 cm^3/min. for a 10 litre solution, or pro rata, and maintained at this rate for the test period. The H S purity shall be 99.5 vol.% or higher, and oxygen-free.

A small positive pressure of H S should be maintained in the test cell by the use of an outlet trap to prevent oxygen contamination from the air. If at any time during the test a white haze clouds the solution, the test shall be stopped and repeated with new specimens and fresh solution.

Conditions for the test shall be as follows:

Temperature		25 ± 3 °C
H S concentration		2300 to 3500 ppm, saturated condition
pH value	initial	2.9 to 3.3
	final	3.5 to 4.0
Test period		96 hours

The pH value of the solution shall be measured at the beginning and the end of the test and the H_2S concentration in the solution shall be determined at the end by iodometric titration.

5.5 EVALUATION OF BLISTERING AND HYDROGEN INDUCED CRACKING

5.5.1 Blistering

The tendency to blistering shall be reported after visual examination, and photographs shall be taken of the two wide faces of each coupon to show any blistering.

5.5.2 Hydrogen Induced Cracking

Specimens, taken with their long axis (100 mm) parallel to the rolling direction, shall be sectioned transversely at three points as shown in Figure 2. The intention of this sectioning procedure is to examine for cracks, in each case on a plane transverse to the rolling direction.

Cracking shall be estimated by micrographic examination at magnifications of X30 and X100.

5.5.3 Evaluation

For each crack observed, the length and extent of stepwise propagation shall be measured. For each section containing cracks, one photograph shall be taken showing the complete transverse sections.

HIC is defined in terms of crack length ratio (CLR), crack thickness ratio (CTR) and crack sensitivity ratio (CSR).

These values shall be reported for each section examined, and as the average of three (3) sections per specimen. In this evaluation, cracks which have no part more than 1 mm from the surface associated with surface blistering shall be disregarded. Refer to Figure 3.

5.5.4 Acceptance Criteria

The following acceptance criteria shall be met:

TABLE 5

	% (maximum)		
	CLR	CTR	CSR
Average	5	1.5	0.5
Single	7	2	0.7

The maximum individual crack length on any section shall not exceed 5 mm.

If any specimen fails to meet the above acceptance criteria, the heat of steel represented by the test shall be rejected.

5.6 EVALUATION OF PLATE MICROSTRUCTURE FOR BANDING

One specimen from each plate shall be polished and etched (in thicker plates, multiple specimens representing the full thickness shall be prepared) and the microstructure evaluated for the degree of banding according to ASTM E 1268. Microindentation hardness tests are not required. Results shall be reported, for information only, using ASTM E 1268 reporting nomenclature.

5.7 REPORTING

a) Results of cracking evaluation indicating individual CLR, CTR and CSR for each section and also averaged over 3 sections, and pass/fail.

b) Photomicrographs of the specimens showing cracking, together with photomicrographs of adjacent material structures and photomicrographs of the bulk material structure (samples) used to assess microstructure banding:

   i) Unetched, showing the type of inclusions in the steel
   ii) Etched, showing the parent material microstructure.
   iii) Assessment of microstructure banding per ASTM E 1268.

c) pH of the H_2S saturated solution at the beginning and at the end of the test, the H_2S content and confirmation of the type of solution.

d) Photographs of specimens, showing any blisters.

e) Location and dimensions of specimens.

f) Full chemical analysis of material tested including analysis for micro-alloying elements.

g) Mechanical properties of materials tested after a simulated PWHT cycle.

6. TESTING FOR SOHIC

In high severity SOHIC environments, HIC-resistant steels may be susceptible to SOHIC in areas of local stress concentrations such as welds.

If HIC-resistant carbon steel is specified for a high severity SOHIC environment then testing for SOHIC resistance shall be performed in addition to the HIC testing requirements of Section 5 of this Appendix.

The materials engineer of the Principal shall be consulted for specific testing requirements and acceptance criteria. Unless otherwise specified, the testing shall be as follows:

a) A stressed Double Beam (DB) specimen shall be used. Both beams shall be from the same section of plate to be tested. Sampling shall be in accordance with the requirements for HIC testing (Section 5 of this Appendix). Sufficient specimens shall be removed from the plate(s) to be tested to cover the full plate thickness. The beam axis

(i.e. the stressing orientation) shall be perpendicular to the material rolling direction and perpendicular to the intended welding direction.

b) The DB specimen(s) shall be coated on all sides except the tension surface to produce one-sided exposure conditions. A polymeric coating resistant to deterioration in the test environment should be used to mask the protected surfaces.

c) The stress concentration in the beams shall be created by machining a standard notch into the tension side of each beam.

Figure 1 Specimen arrangement in cell

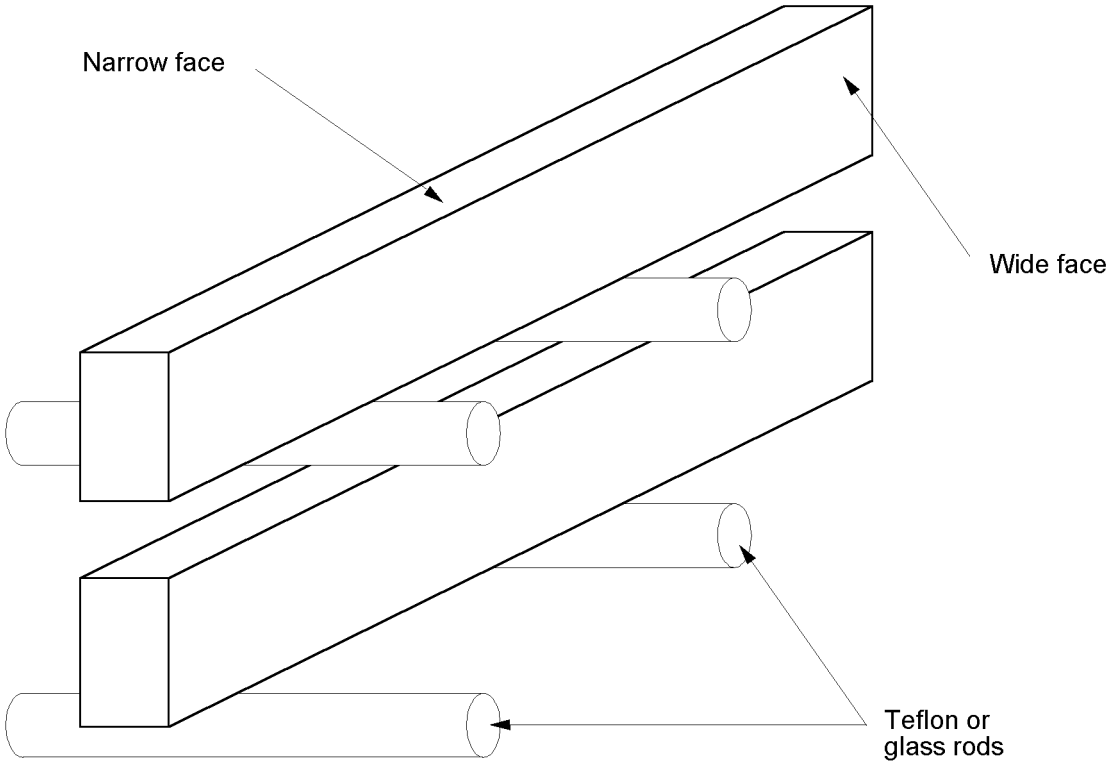


Figure 2 Sectioning of specimens

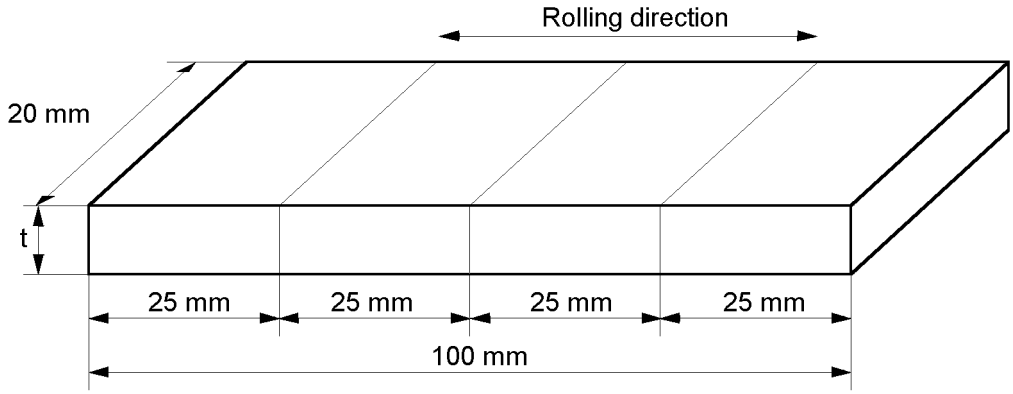
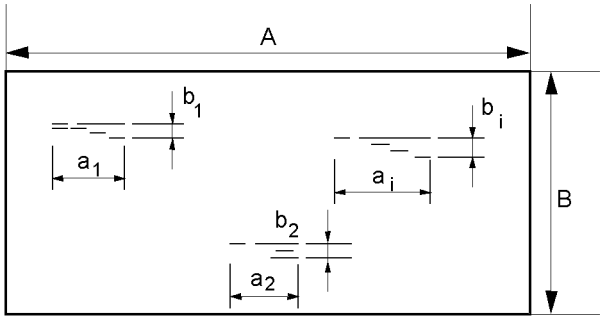


Figure 3 Evaluation of HIC

Cracks are evaluated according to crack length ratio (CLR), crack thickness ratio (CTR) or crack sensitivity ratio (CSR) by measuring the total crack length, extent of stepwise cracks or stepwise crack area respectively.

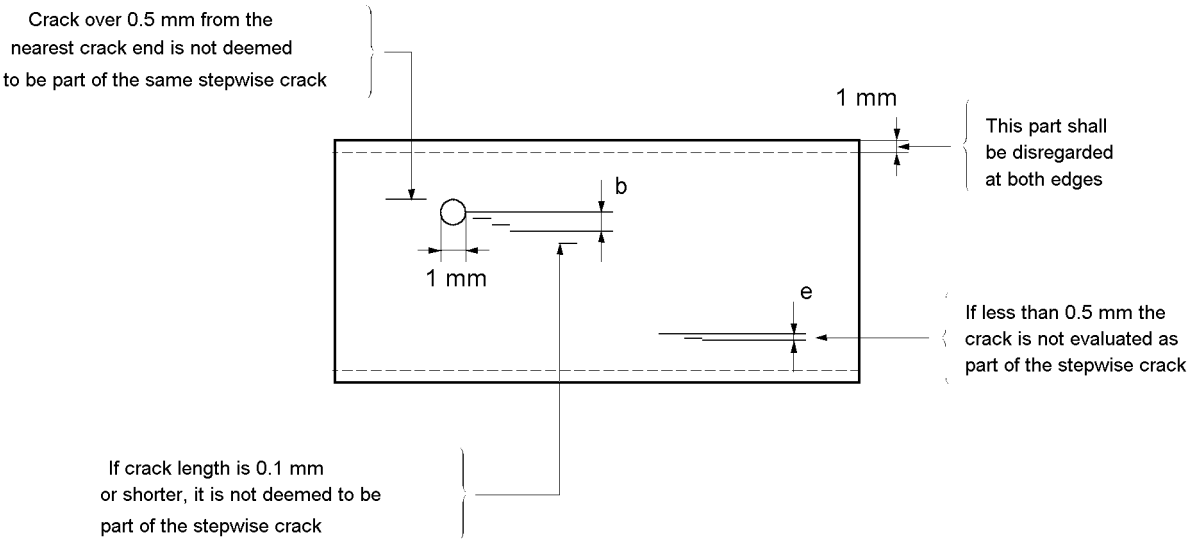


Length of stepwise crack = $\sum a_i$

Extent of stepwise crack = $\sum b_i$

CLR, CTR and CSR values can be calculated with the following equations.

$$CLR = \frac{\sum_{i=1}^{n} a_i}{A} \times 100\ (\%) \qquad CTR = \frac{\sum_{i=1}^{n} b_i}{B} \times 100\ (\%) \qquad CSR = \frac{\sum_{i=1}^{n} a_i \cdot b_i}{A.B} \times 100\ (\%)$$



Definition of stepwise crack

APPENDIX 5 PREPARATION AND INSTALLATION OF TEST BLOCKS

The test blocks shall be made by welding a block from the heat with the lowest J-factor to a block from the heat with the highest J-factor, as shown in Figure 4.

J-factor = (%Si + %Mn) x (%P + %Sn) x 10^4

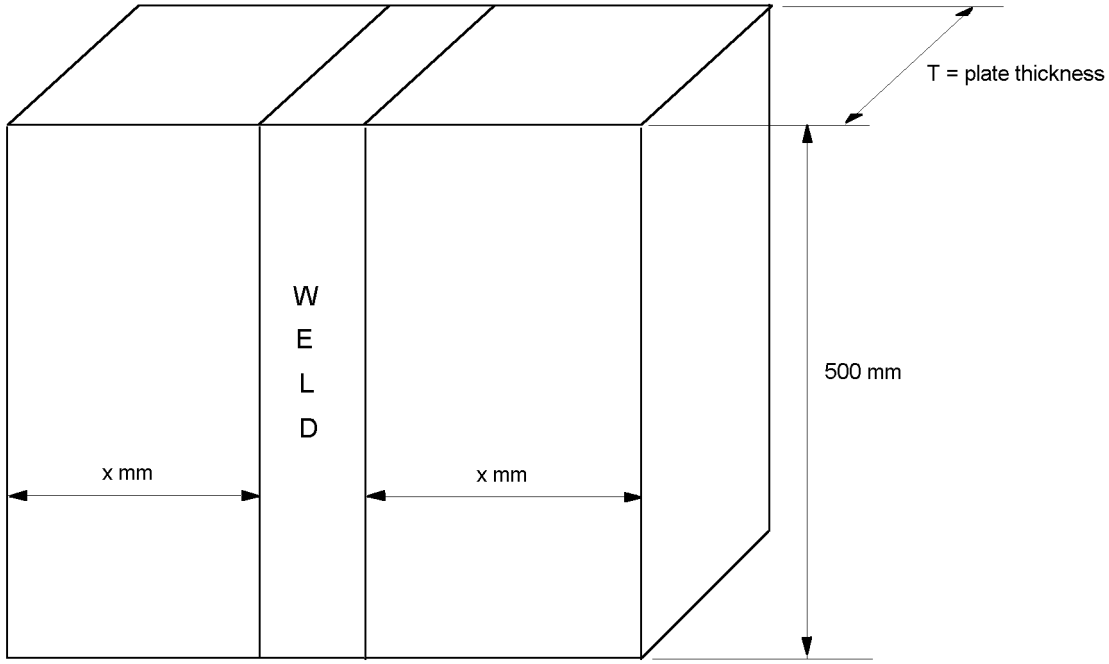
The outside surface shall be clad or weld overlayed in accordance with the same procedures used for the vessel. The heat number and J-factor shall be stamped in the cladding or weld overlay of the respective piece.

A total of four test blocks shall be installed as follows:

- 2 blocks, 180 degrees apart, in the bottom area of the catalyst bed at the top of the reactor; and
- 2 blocks, 180 degrees apart, in the bottom area of the catalyst bed at the bottom of the reactor.

Each block shall be installed loose, in a cage attached to supports on the vessel wall. The design of this cage shall be subject to the approval of the Principal.

Figure 4 Test block for installation in a Cr-Mo vessel



x = 100 mm if T is greater than 150 mm

x = 200 mm if T is not greater than 150 mm