



TECHNICAL REQUIREMENTS

MECHANICAL

Document No. OL-TR-MR-000

UNFIRED PRESSURE VESSELS

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1. SCOPE

- 1.1 This specification covers general requirements for design and fabrication unfired pressure vessels.
- 1.2 This specification is supplemental to design drawings, standard details and instructions in the Requisition. In the case of conflict between any of the documents, the vendor must get written clarification from OL before proceeding.
- 1.3 All codes, standards and specifications (local and national) referred to herein are the latest edition and include the latest addenda issued prior to the purchase order date, unless otherwise specified in the Requisition documents.
- 1.4 All pressure vessels, as a minimum, are to be designed, fabricated, inspected, tested and stamped in accordance with the ASME Unfired Pressure Vessel Code, Section VIII, Division 1 or EN 13445 as noted in OL requisition or data sheet. The vessel fabricator is responsible for conformity to Pressure Equipment Directive (P.E.D) 97/23/CE essential safety requirements and ASME Code or EN 13445 requirements.
- 1.5 The vessel fabricator is to furnish and install the following in accordance with OL design data unless designated to be furnished by others:
- a) Vessel internals (see paragraph 5.4).
 - b) Bolts.
 - c) Gaskets and spares as required.
 - d) Ladder and platform clips (bolting is by others).
 - e) Pipe support and guide clips (bolting is by others).
 - f) Column davit, including brackets and sleeve.
 - g) Manway davits and hinges.
 - h) Insulation rings and stiffening rings.
 - i) Insulation and fireproofing studs and nuts.
 - j) Lifting and tailing attachments.
 - k) Attachments welded to vessel for removable internals, trays, downcomers, support beams, etc.
 - l) All surface preparation and painting shown on OL drawings and in specifications.

2. REFERENCES

2.1 European Standards

EN 13445 (all parts) *Unfired pressure vessels*

2.2 American Society of Mechanical Engineers (ASME) Standards

ASME SEC VIII D1 *BPVC Section VIII - Rules for Construction of Pressure Vessels - Division 1*

ASME SEC VIII D2 *BPVC Section VIII - Rules for Construction of Pressure Vessels - Division 2 Alternative Rules*

ASME SEC IX *BPVC Section IX - Welding, Brazing, and Fusing Qualifications*

ASME SEC II A *BPVC Section II A - Ferrous Material Specification*

ASME SEC II B *BPVC Section II B - Non-Ferrous Material Specifications*

ASME SEC II D *BPVC Section II D - Material Properties*

2.3 OL Specifications

OL-TR-GR-000 *General Requirements*

OL-TR-CR-002 *Civil. Heat Insulation*

OL-TR-CR-011 *Civil. Corrosion Protection and Lining. Painting*

OL-TR-CR-012 *Civil. Corrosion Protection and Lining. Lining for Piping and Pressure Vessels*

OL-TR-MR-000 *Mechanical. General*

OL-TR-MR-001 *Mechanical. General Welding, Fabrication and Inspection*

OL-TR-MR-002 *Mechanical. Positive Material Identification*

OL-TR-MPR-001 *Mechanical. Piping*

2.4 Local, State, National Codes and Legislations

Legislation of the Republic of Lithuanian *Law on the Supervision of Potentially Dangerous Equipment No. I-1324 („Lietuvos Respublikos Potencialiai pavojingų įrenginių priežiūros įstatymas Nr. I-1324 (aktuali redakcija nuo 2011-07-19)“)*

Legislation of the Republic of Lithuanian *Law on Assessment of Conformity VIII-870 („Atitikties įvertinimo įstatymas VIII-870“)*

Legislation of the Republic of Lithuanian *Technical Regulation on Pressure Equipment (Slėginių įrenginių techninis reglamentas)*

Legislation of the Republic of Lithuanian *Technical Regulations for Equipment and Protection Systems Used in Potentially Explosive Atmosphere („Įrangos ir apsaugos sistemų, naudojamų potencialiai sprogioje aplinkoje, techninis reglamentas“)*

Legislation of the Republic of Lithuanian *Fire protection safety rules („Bendrosios gaisrinės saugos taisyklės“)*

STR 1, 2 (Legislation of the Republic of Lithuanian) *Technical regalement's of construction*

2.5 Others

Equipment shall comply also with the following:

2.5.1 Process Equipment Design by L.F. Brownell and E.H. Young.

2.5.2 Pressure equipment, as defined in Pressure Equipment Directive (P.E.D.) 97/23/CE article 1, shall fully satisfy the P.E.D. essential safety requirements;

- 2.5.3** In particular, design and construction shall be carried out by Manufacturer according to ASME or EN code, as amended under the supervision and approval of the nominated Notified Body, to fulfill P.E.D. requirements;
- 2.5.4** Equipment and Protection Systems intended for use in Potentially Explosive Atmospheres shall be in full compliance with Directive 94/9/CE (ATEX) requirements.

NOTES:

- (1) *Detailed information relevant to Area Classification, Group, Ignition Temperature etc., shall be as indicated on individual Material Requisition or Data Sheet.*
- (2) *Manufacturer shall affix the CE marking and shall prepare a declaration of conformity for the Equipment. Nomination of a Notified Body shall be made as needed; U stamp not required unless noted otherwise.*

- 2.5.5** Compliance with European Directives includes all needed/requested CE nameplates, marking, declaration of conformity, operating instruction manuals etc.

3. TERMS AND DEFINITIONS

For general terms and definitions see:

- Section 3 of EN 13445-1.

- 3.1** **MAWP:** Maximum Allowable Working Pressure (MAWP) is the maximum allowable pressure at the design temperature in the corroded condition. MAWP is determined by calculation, using the actual thickness less the corrosion allowance, in accordance with ASME SEC VIII D1, Paragraph UG-98.

- 3.2** **Vessel Thickness:** Vessel thickness is defined as the thickness required for strength of the pressure vessel shell, including corrosion allowance but excluding weld overlay, lining, integral cladding or non-integral parts.

4. DOCUMENTATION

4.1 Drawings

- 4.1.1** An outline drawing shall be furnished for each vessel, and shall contain the data shown in the appropriate **Data Sheet** (doc. no OL-TR-MVR-DS1). The location of the vessel marking or nameplate, the size and orientation of all nozzles and connections, and the anchor bolt layout shall also be shown on this drawing.

- 4.1.2** A separate outline drawing for each vessel shall be furnished with appropriate markings to cross-reference each component (shell plates, heads, nozzles, flanges, forgings, skirt plates, etc.) to the applicable mill test certificates for the steels used in the construction.

- 4.1.3** Fabrication drawings shall show weld details and shall reference applicable welding procedures. The drawings shall also include impact test requirements, showing (as applicable):
- a) Component;
 - b) Thickness for impact purposes;
 - c) Material specification;
 - d) Critical Exposure Temperature or Minimum Design Metal Temperature;
 - e) Appropriate Charpy impact requirements (average/minimum values).

- 4.1.4** Two copies of all required drawings made by the Fabricator shall be submitted for approval prior to the start of fabrication.

4.2 Fabrication data

- 4.2.1** A Manufacturer's data report shall be furnished and shall contain the same information as required by form U-1 of ASME SEC VIII D1 or EN 13445. Certified material test reports shall be furnished, and they shall represent the properties in the as-fabricated condition. The data report shall be signed by the Manufacturer, by an Authorized Inspector as defined in Par. UG-91 of the ASME Code / EN 13445 - 5, or as otherwise required by the applicable code. Other documentation (code papers, etc.) covering the construction of vessels built to the code of another nation shall be signed by the Manufacturer and, where applicable, by others having authority to sign such documentation.
- 4.2.2** Signed copies of data reports and other required documentation shall be submitted to the Inspector prior to shipment of the vessel.
- 4.2.3** Welding, PWHT, and weld repair procedures shall be submitted to the Purchaser for review prior to the start of fabrication.
- 4.2.4** Two copies of design calculations (including lifting attachments and supports) made by the Fabricator shall be furnished prior to or along with submission of drawings for approval. When calculations are made using a computer, all input data, assumptions, computer program version used, and a summary of the results shall be furnished.
- 4.2.5** Fabrication-Upon completion of fabrication, the Fabricator shall supply the Purchaser with:
- Passport of the form established by AB "ORLEN Lietuva" (see OL-TR-MVR-TP1);
 - A copy of certification issued by the State Energy Inspectorate to operate (repair) crude oil and petroleum products units. In case erection on site;
 - Erection, Installation quality certificate. In case erection on site;
 - Declaration and certificate(s) of compliance with design/manufacturing code and Pressure Equipment Directive PED 97/23;
 - Design documentation (Detail Drawings, calculations, flanged joints tightening torque values);
 - List of materials used in the pressure vessel (tabulated: position number acc. to dwg., quantity, no. of tech. specification or standard, certificate No.);
 - Results of new elements wall thickness measuring. In case reconstruction on site;
 - Positive materials identification (PMI) log and reports;
 - Welding logbook;
 - Approved welding procedure specifications and list of WPQR;
 - List of approved welders and/or welding operators, copies of welders' certificates;
 - PWHT logbook, procedures and time/temperature charts;
 - Non-destructive test (NDT) reports;
 - Results of production test coupons (if applicable);
 - Reconstruction technology. In case reconstruction on site;
 - Quality and testing plan;
 - Copies of non-conformity reports, repair procedures;
 - Pressure test (Hydrostatic or pneumatic) chart and report;
 - Report of final examination and dimensional report (as built condition);
 - Insulation, anticorrosive coating (painting), fireproofing (if applicable) acceptance statement;
 - Leveling (geodesic measurement) report (if required according to Design);
 - Grounding report. In case erection on site;
 - Materials certificates including welding consumables;
 - Safety equipment inspection reports (if presented);
 - Manufacturers analysis of hazard;

- z) Record of marking and nameplate details;
- aa) Operating instruction.

NOTE: When weld production test plates are required, the test results shall be forwarded to the Owner no later than 10 working days after the test plates are welded.

- 4.2.6 When specified by the Owner's Engineer, the Vendor shall register all ASME Code stamped vessels with the National Board.

5. DESIGN

5.1 General

- 5.1.1 The Maximum Allowable Working Pressure (MAWP) shall be based on total actual metal thickness, less corrosion allowance. PED requirements too are to be met.
- 5.1.2 All vessels shall be hydrotested according to P.E.D. (EN 13445-5).
- 5.1.3 The MAWP shall be limited only by the shell, heads, or flanges. Minor components such as reinforcing shall not limit the MAWP.
- 5.1.4 Unless noted otherwise, all vessels shall be designed to permit full hydrostatic testing, fully corroded condition, in the final erected position with all dead loads at operating condition (includes vessel, insulation, internals, platforms, ladders, external piping, etc., but excludes operating liquid, catalyst, packing, etc.) and 25% of design winds. To compensate for the test medium static head resulting in higher test pressure in the lower area of vessels while maintaining minimum test pressure at the top, allowable stress in the lower area may be increased to a maximum of 90% of the code yield stress at 20°C (100°F) times applicable joint efficiency of the material. The Fabricator shall furnish calculations verifying adherence to this criteria.
- 5.1.5 Detail calculations, for approval and record, are required for the design of all components, and appurtenances of the vessel. This shall include:
 - a) Weight calculation; including fabricated, erection, operating, test and shipping weights;
 - b) Thickness calculations for pressure envelope;
 - c) Reinforcement requirements for all openings;
 - d) Analysis of vessel support; including base and anchor bolt calculations and Zick analysis for horizontal vessels supported on saddles;
 - e) Wind and earthquake analysis;
 - f) Local stress analysis for external loads on nozzles and attachments;
 - g) Calculations for lifting and tailing devices, including local stress effects on the vessel, and analysis of shell buckling stresses for tall vertical vessels;
 - h) Shop support system to be used during hydrotest of large vessels.
- 5.1.6 Calculations are to be submitted with the first approval issue of fabricator's detail drawings.
- 5.1.7 Where design calculations are computer generated, input data shall be included along with necessary explanatory notes for interpretation. Output data shall include the applicable formulas with the proper values shown as a part of those formulas along with the results. The vessel fabricator is responsible for the accuracy of all computer programs used for the analysis.
- 5.1.8 It is the vessel fabricator's responsibility to design lifting and tailing devices for the vessel. The design shall be based on full weight of the vessel plus 50% impact loading.

The vessel shell, head and skirt shall be checked for added reinforcement and bracing requirements.

5.1.9 External loads due to wind and earthquake shall be determined in accordance with the procedures of the governing code and/or the data specified on the design drawings.

5.1.10 Vertical vessels with a length over diameter (L/D) ratio greater than or equal to 15 shall be checked for aerodynamic vibration due to vortex shedding from wind to ensure their structural safety. All the vessels with a ratio W/LD2 lower than 4000 shall be examined for wind induced vibrations as well, where:

W= operating weight (N)

L= total vessel height (m)

D= average inside diameter of top half of vessel (m)

5.1.11 The effective vessel diameter for wind shall include the thickness of the shell and insulation, plus the insulated OD of the largest process line on the top of the vessel. Platform area shall be added to the vessel projected area, and shall be calculated as the projected width of the platform times one-third the handrail height. The platform area shall include the appropriate force coefficient. When the platform area is unknown, a minimum wind multiplication factor shall be applied to the vessel diameter as per the Table 1.

Table 1. Minimum Wind Multiplication Factor

Vessel Diameter mm / inch.	Factor
≤ 914 / 36	1.50
≤ 1372 / 54	1.37
≤ 1981 / 78	1.28
≥ 2006 / 79	1.18

5.1.12 The maximum vertical vessel deflection based on corroded thicknesses shall not exceed 152mm (6") per 30,5m (100ft) of height.

5.1.13 For design temperatures of 425°C (800°F) and higher the design details for nozzles, supports, and other attachments to the vessel shell shall be free of high local stress concentrations. Design details using fillet welds shall be avoided unless ground to a smooth radius.

5.1.14 Corrosion allowance as specified in design drawings shall be provided on all internal surfaces of shells, heads, nozzles, and manways. All internals welded to the shell, tray support rings and downcomer bolting bars shall have 3/4 the specified corrosion allowance on each side exposed to the process fluid.

5.1.15 Corrosion allowance of alloy clad vessels shall be considered equal to alloy clad thickness of shells and heads or as specified in the Data Sheet.

5.1.16 Strip lining shall not be used for corrosion protection without prior approval from OL.

5.1.17 Unless otherwise noted, the minimum corroded thickness of internal attachments welded to shell, such as tray support rings and downcomer bolting bars, shall be 5mm (3/16").

5.1.18 In hydrogen service, all spaces fully closed by welds, (for example, continuous fillet weld attachments) shall be vented or shall be full penetration welds.

- 5.1.19** Specified thicknesses are minimum, unless otherwise noted.
- 5.1.20** Load bearing welds attaching non-pressure retaining parts to pressure retaining parts shall be designed according to the same allowable stress basis for primary membrane tensile (compressive) and shear stresses as required for pressure retaining components of like material.
- 5.1.21** Minimum design Metal Temperature shall be defined by Vendor taking into account the minimum ambient temperature and considering the shop hydrotest temperature.
- 5.1.22** When a vessel is specified in the Material Requisition as operating in Hydrogen Service the following must be taken into account:
- a) Materials having yield strength greater than 480 MPa shall not be employed;
 - b) All attachments and pads welded on vessel wall shall have a vent hole.
- 5.2 Shells and Heads**
- 5.2.1** The minimum design thickness excluding corrosion allowance shall not be less than 5mm (3/16") or (I.D. + 2540 mm (100"))/1000.
- 5.2.2** On vertical vessels with varying wall thicknesses the plate thicknesses indicated on design drawings must be maintained except that the thicker sections may be increased in length in order to use standard length plates. As an example, the lower course of plate may be called out as 20mm (3/4") plate for 5400mm (18'-0") up from the tangent line. This could be 5700mm (19'-0") or 6000mm (20'-0") if the fabricator chooses to use a standard length plate.
- 5.2.3** The vessel fabricator is to locate all welded joints on shop drawings submitted for approval. No longitudinal welded joints will be allowed within the downcomer area or behind any other obstruction which may prevent inspection. Circumferential welded joints are to be located so that proper internal inspection can be made. The minimum straight flange on heads shall be 40mm (1-1/2").
- 5.2.4** Unless otherwise noted on design drawings, heads are to be ellipsoidal with a ratio of the inside major axis to the inside minor axis of 2 to 1.
- 5.2.5** For large diameter, low pressure vessels, the maximum compressive stresses in the knuckle region of toriconical heads, torispherical heads, and conical reducers with a transition knuckle shall be evaluated for the adequacy of the knuckle radius and thickness for the prevention of buckling of the knuckle under internal pressure and external loads, and hydrotest.
- 5.3 Supports**
- 5.3.1** Vertical drums 900mm (36") in diameter and smaller shall be supported on legs.
- 5.3.2** All towers and vertical drums over 900mm (36") in diameter are to be skirt-supported.
- 5.3.3** Drums supported on steel saddles shall be as per detailed design drawing. Saddles shall not be placed over vessel girth seams and are to be continuously welded to the shell.
- 5.3.4** Vertical vessel skirts shall be provided with 100mm, 6mm thick (4" STD.) pipe vents. Two vents for vessels under 900mm (36") in diameter. Four vents for vessels 900mm (36") in diameter and larger.

- 5.3.5** Skirt access openings shall be provided. One access opening is required for vessels 1200mm (48") in diameter and smaller. Two access openings are required for vessels over 1200mm (48") in diameter.
- 5.3.6** Anchor bolting shall be designed to an allowable stress of 100MPa (15,000psi) based on tensile stress area unless otherwise specifically noted on OL design drawings. The minimum anchor bolt size shall be M24 (1") in diameter. 3 mm on diameter corrosion allowance has to be taken into account.
- 5.3.7** Unless otherwise noted design of vertical vessel base ring shall be based on Brownell and Young method, outlined in "Process Equipment Design" by L.F. Brownell and E.H. Young.
- 5.3.8** Allowable concrete bearing stresses for base design may be taken as 7MPa (1050psi) if the Shifted Neutral Axis method of base design is used.
- 5.3.9** Minimum skirt thickness shall be 6mm (1/4") excluding corrosion allowance.
- 5.3.10** The attachment of a supporting skirt to a vessel subject to cyclic temperature change (e.g., coker drums) shall be adequately designed to accommodate flexing at the skirt to vessel joint.
- 5.4 Internals**
- For addition requirements see doc. no. *M1004-TR-MVR-002* "Internals for Towers, Drums and Fixed Bed Reactors".
- 5.4.1** Unless otherwise noted on design drawings, the vessel fabricator is to furnish all vessel internals except trays, catalyst and packed beds. The vessel fabricator will furnish the tray support rings, downcomer bolting bars, temporary tray support clips and beams and all other vessel attachments necessary for tray and other internals installation. The vessel fabricator will install the trays unless specifically instructed otherwise.
- 5.4.2** All internal piping which can be flanged to pass through manways shall be flanged near the vessel wall. All removable internals are to be fabricated to pass through vessel manways. All internal piping shall be self-venting and draining.
- 5.4.3** Unless otherwise specified on design drawings, all carbon steel internal piping is to be extra strong or heavier. Low alloy internal piping is to be standard weight or heavier. Use of mitered joints requires prior approval of OL.
- 5.4.4** Internal flanges may be either forged slip-on or fabricated from suitable plate and machined flat. They shall be in the same quality material as specified for the internal pipe. Bolt heads and nuts shall be semi-finished heavy hex type. Stud-bolts with two hex nuts each may be substituted in place of hex head bolts. Carbon steel internal flanges are to have carbon steel bolts. Alloy internals are to have alloy bolts of the same material.
- 5.4.5** Unless otherwise noted all internal flange bolting is to be securely tightened and the bolt heads and nuts are to be tack welded.
- 5.4.6** All pipe or tubing for heating or cooling coils shall be seamless.
- 5.4.7** Internal piping shall be supported, as required, by chairs or other supports welded to the vessel shell or heads. Distributors shall not be supported from trays.

5.5 Connections, Nozzles

5.5.1 Unless noted on design drawings or data sheet:

- a) All connections to the vessel shall be flanged.
- b) The minimum nozzle size shall be DN25 (1").
- c) The minimum nozzle size for process connections shall be DN50 (2").
- d) Nozzle sizes DN50 (2") and under shall be long welding necks.
- e) Flange ratings are to be as specified on design drawings.
- f) Minimum flange rating for DN40 (1-1/2") and smaller shall be 300# (PN40).

5.5.2 Lap-joint flanges require OL approval. If allowed, the stub end shall be equipped with stops to prevent the flange ring from falling when the bolting is loosened.

5.5.3 Slip-on flanges are limited to 150# (PN16), design temperatures up to and including 150°C (300°F), and non-cyclic service. Slip-on flanges shall not be used in hydrogen service. (Hydrogen service is defined as H₂ partial pressure greater than 3.4bar(a) (50psi(a)).

5.5.4 Bolting on flanges shall clear vessel insulation by not less than the distance required to insert and operate a box wrench.

5.5.5 The inner edge of all manways and nozzles shall be rounded to 3mm (1/8") radius.

5.5.6 Nozzle necks larger than DN250 (10") may be made of built-up construction using formed plate when seamless pipe is not readily available and construction is approved by OL. Nozzle necks DN250 (10") and smaller are to be made with seamless pipe.

5.5.7 The corrosion allowance for nozzles and manways is to be at least equal to the corrosion allowance specified for the vessel section in which they are located.

5.5.8 The minimum neck thickness for all nozzles including manholes (unless design conditions dictate a heavier wall) is to be Schedule 80 (or EN equivalent) up to and including DN200 (8") size, and 12mm (1/2") wall for DN250 (10") and larger.

5.5.9 Process nozzles in the corroded condition shall be capable of withstanding the moments and forces in Table 2 below. The forces act as shown in Figure 1. Calculations are to be made in accordance with WRC-107 at the nozzle to shell intersection (pipe O.D.). Other methods require OL approval. None of the individual stresses (circumferential, longitudinal, shear or combined) may exceed 2.5S_a at pipe O.D. for nozzle without pad or 1S_a at pipe O.D. for nozzle with pad. Stresses shall be checked at nozzle O.D. and pad O.D. In some cases, added shell thickness may be required.

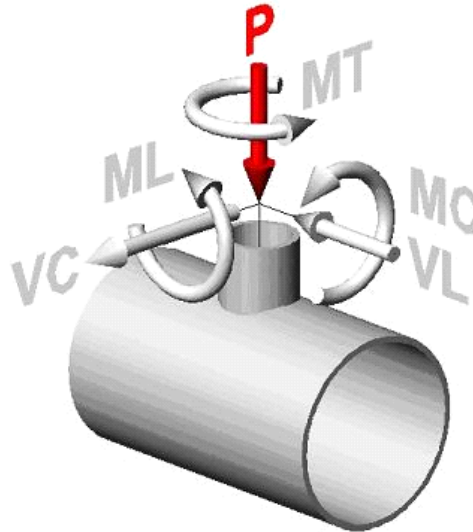


Figure 1. Nozzle Forces and Moments

Table 2. Nozzle Loads

Nozzle Size DN (Inch.)	Force N			Moments N-m		
	P	V _L	V _c	M _T	M _L	M _c
50 (2")	2750	1600	1600	210	320	510
80 (3")	4000	3500	3500	660	990	1570
100 (4")	5500	5000	5000	1230	1840	2940
150 (6")	8000	8800	8800	2680	4030	6430
200 (8")	11000	13300	13300	5730	8600	13740
250 (10")	13500	19000	19000	7670	11500	18380
300 (12")	16000	23200	23200	8430	12650	20180
350 (14")	19000	25600	25600	10200	15300	24470
400 (16")	22000	29500	29500	11200	16800	26820
450 (18")	25000	33300	33300	11500	17250	27470
500 (20")	27000	37200	37200	14260	21400	34220
600 (24")	32000	44900	44900	20700	31080	49770
>600 >(24")	36500	48100	48100	23000	34500	55300

- 5.5.10** Actual loads on nozzles will be communicated after order placement, if greater than specified in the table. Vendor has to check nozzles under actual loads too without extra cost.
- 5.5.11** Each reinforcing pad or section thereof is to have at least one test hole tapped M8. The weld of each pad is to be given an air and soap solution test 0.34bar(g) (5psi(g) minimum) before post weld heat treatment in the presence of the OL inspector. After the test, the hole is to be filled with corrosion inhibiting grease and the hole not welded or plugged. If the pad is fabricated in two parts the weld is to be oriented in the circumferential direction.
- 5.5.12** All bolt holes are to straddle the North, South, East, West, Vertical or Horizontal centerlines.

- 5.5.13** Flange facings are to be standard machine finish for spiral-wound gaskets, and a fine serrated finish for smooth metal gaskets. The vessel fabricator is to specify the type of finish to be furnished. Welding neck flanges are to have the same bore as the nozzle necks to which they are attached.
- 5.5.14** Where spiral wound gaskets are specified, the flange surface finish range for acceptance shall be 125 Ra minimum to 250 Ra maximum. Finishes shall be judged by visual comparison with surface finish roughness standards conforming to ANSI B46.1. It is the vendor's responsibility both to comply with the above finish requirements and to assure that the flange is protected from damage during shipping, storage, and installation.
- 5.5.15** External bolting is to be supplied by the vessel fabricator and will be minimum of ASTM A-193 Gr. B7 stud bolts, complete with two ASTM A-194 Gr. 2H heavy hex nuts each. For bolt metal temperatures over 480°C (900°F), bolting will conform to ASTM A-193 Gr. B16 stud bolts with ASTM A-194 Gr.4 nuts.
- 5.5.16** Gaskets are to be furnished as specified on the design drawings or data sheets. Dimensions of raised face gaskets are to be in accordance with ANSI B16.5 or EN 1092, Appendix E. Flexitallic Type "CG" or equal is to be used for all hydrocarbon services. All gasketing and packing shall be commercial quality, fabricated from asbestos-free material, and suitable for the process environment. The fabricator is to ship one gasket, new and unused, for each nozzle having a cover. This gasket is to be shipped separately with proper protection and identifications.
- 5.5.17** For hot taps requirements refer to ANNEX A of *OL-TR-MPR-001*
- 5.6 Manways**
- 5.6.1** Access and inspection openings, closing mechanisms and special locking elements shall be according to EN 13445 – 4 Annex C except as modified hereinafter.
- 5.6.2** All trayed towers shall have DN500 (20") nom. (DN450 (18") minimum I.D.) manways.
- 5.6.3** All drums over DN1200 (4ft) in diameter with removable internals shall have DN500 (20") nom. (DN450 (18") minimum I.D.) manway.
- 5.6.4** All drums over DN1200 (4ft) in diameter without removable internals shall have an DN450 (18") (nominal) manway.
- 5.6.5** All drums under DN1200 (4ft) in diameter shall have an DN450 (18") (nominal) manway.
- 5.6.6** With the exception of hinged side mounted manways on horizontal vessels, all manways are to be provided with davits.
- 5.6.7** Trayed towers shall be provided with top and bottom manways and with intermediate manways at approximately 20 tray intervals. However, consideration shall be given for providing access to internal pipe distributors in determining the number and location of intermediate manways.
- 5.7 Insulation and Fireproofing Supports**
- 5.7.1** Insulation and fireproofing supports are to be shown on the fabricator's outline drawings per design drawings and the applicable OL specifications (*OL-TR-CR-003*).

- 5.7.2** When vacuum stiffeners are used as insulation support rings, sizes must be shown on the vessel fabricator's drawings and be welded in accordance with the ASME or EN Code. Vacuum stiffeners may be used as insulation supports as long as the maximum distance between them is less than or equal to OL standard insulation ring spacing.

6. MATERIALS

- 6.1** Materials are to be as specified on design drawings and data sheets.
- 6.2** Requirements for materials shall be according to EN 13445-2 except as modified hereinafter.
- 6.3** In order to avoid additional cost during the installation of new equipment and when repairing the old one, the materials of all welded elements and items have to have good weldability. Good weldability of steel is assured by limiting carbon, phosphorus or sulphur content Table 3.

Table 3. Maximum Welded Steel Carbon, Phosphorus or Sulphur Content

Material group (Group as per CR ISO 15608)	Maximum element content %, during alloy analysis		
	C	P	S
Non-alloy and alloy steels Cr-Mo, Cr-Mo-V, Ni(<10) of group 1÷6 and 9	0,23	0,035	0,025
Ferritic stainless steels of group 7.1	0,08	0,040	0,015
Martensitic stainless steels of group 7.2	0,06	0,040	0,015
Austenitic stainless steels (Cr≤19) of group 8.1	0,08	0,045	0,015
Austenitic stainless steels (Cr>19) of group 8.2	0,10	0,035	0,015
Austenitic-ferritic (Duplex) stainless steels (Cr>19) of group 10	0,03	0,035	0,015

- 6.4** Substitution of material used for pressure and non-pressure parts of a strength grade higher than that specified shall not be made without OL approval.
- 6.5** Each plate or forging shall be legibly stamped or stenciled showing grade number and plate or forging number. When metal stamping is done it shall preferably be on the long edge of each component as it leaves the mill. Metal stamping on rolled surfaces shall be done with a "low stress" stamp.
- 6.6** Materials subject to post weld heat treatment (PWHT) shall be purchased with mill test reports indicating heat treating time sufficient to allow at least one full PWHT cycle in addition to all planned PWHT.
- 6.7** Alloy materials shall be verified in accordance with OL Engineering Specification No. *OL-TR-MR-002*, "Positive Material Identification".

7. SHOP DRAWINGS AND DATA

- 7.1** The vessel fabricator is to submit checked drawings and other data in accordance with requirements stated in OL's Requisition.

- 7.2 Fabrication is to be in accordance with certified final drawings approved by OL.
- 7.3 Shop drawings are to have the same numbers and letters to identify trays and nozzles as shown on design drawings or data sheet.
- 7.4 Shop drawings detailing tray support rings and downcomer bolting bars are to be furnished by the tray fabricator. After approval by OL they will be forwarded to the vessel fabricator. The vessel fabricator need not duplicate these drawings.
- 7.5 The vessel fabricator's shop drawings for vertical vessels will specify that the base and first foot of skirt will show by painted line and letter the North, South, East, and West coordinates.
- 7.6 The fabricator's final certified drawings shall indicate as-built dimensions, weights and details.
- 7.7 Net fabricated weight, shipping weight and weight full of water shall be indicated on the fabricator's drawings. In addition, the weight of all removable internals and the weight of the largest internal piece shall be indicated separately.

8. FABRICATION AND WELDING

- 8.1 Unless otherwise stated on design drawings, all welding shall conform to ASME or EN Code requirements regardless of whether or not the vessel carries a Code Stamp.
- 8.2 All shell and head joints and skirt seams are to be full penetration, double-welded butt joints. Connections between skirts and vessel head are to be made with a smooth flat faced fillet weld. The skirt attachment weld shall be equal to the skirt thickness and the height shall be at least twice the width.
- 8.3 All welds for nozzles and manways attaching to shell or heads are to be full penetration through the vessel wall. In certain cases involving very heavy walls, the fabricator may submit an alternate method for approval. Strength calculations of the attachment are to be submitted for OL approval.
- 8.4 Except in H₂ service, tray support rings are to be welded to the vessel shell with continuous welds, both top and bottom. In H₂ service, the bottom weld shall have a 12mm (1/2") skip every 200mm (8"). The top weld is to be designed as the strength weld and the bottom weld is to be a seal weld. All welding must have sufficient metal to provide for the specified corrosion allowance.
- 8.5 Openings in a vessel shall be located to clear both the circumferential and longitudinal seams. Min distance between circumferential and longitudinal welds of vessel and welds of nozzles or other attachments shall not be less than wall thickness of shell/heads but not less than 20mm.
- 8.6 Reference marks shall not be center-punched on the inside or outside of any vessel constructed of materials requiring an impact test. Corrosion resistant lining or cladding shall not be centerpunched.
- 8.7 Fabrication involving welding shall not be sublet or subcontracted to any other party without prior approval of OL.
- 8.8 External attachments for structural elements, manhole davits, etc., shall be welded in place before vessel is post weld heat treated.

- 8.9 OL Engineering Specification No. OL-TR-MR-001, "General Welding, Fabrication and Inspection" requirements shall be followed.

9. INSPECTION AND TESTING

- 9.1 In addition to any inspection required by local authorities having jurisdiction, all materials, workmanship, welding procedures, results of operator's qualification tests, as well as any required Code examination shall be subject to witness and/or inspection in the vendor's shop by an OL-authorized inspector. Records of radiographic examination, certificates of magnetic particle, liquid dye penetrant, or other examination shall also be made available, when applicable. Waiver of inspection(s) must be obtained in writing from OL's Project Manager. The OL inspector shall be furnished with documentation proving the vendor's quality control personnel have the required level of competence for non-destructive examination provided by the shop.
- 9.2 Prior to final inspection, all slag, scale, dirt, weld, spatter, paint, oil and other foreign matter are to be removed in order that the inspection can be conducted.
- 9.3 Inspection by OL shall in no way relieve the Vendor of his responsibility to meet the requirements of the Purchase documents.
- 9.4 OL's inspectors shall have free entry to the vendor's shop at all times when the work is being performed. The vendor shall afford the inspectors all reasonable facilities to satisfy them that the vessels are being furnished in accordance with the specifications.
- 9.5 100% radiography or ultrasonic tests are required, regardless of material, thickness or service, for all welds of pressure-bearing parts. Tests shall be done after post weld heat treatment.
- 9.6 Vessels having a design pressure of 34bar(a) (500psi(a)) or greater shall have all external attachment welds to pressure containing parts examined by the magnetic particle (DC prod contact) or liquid penetrant method. This type examination shall be performed after any required post weld heat treatment and hydrostatic testing.
- 9.7 Clean fresh water shall be the primary hydrostatic test medium unless use of a different medium is approved by the client or his representative. Hydrostatic testing of vessels with austenitic stainless steel internals shall be done with potable quality water having a chloride content of not more than 50 ppm (parts per million). If chloride content is greater than 50 ppm, up to a maximum of 250 ppm, a sufficient quantity of sodium nitrate shall be added to provide a test medium of 0.5% by weight sodium nitrate solution. Water with a chloride content of greater than 250 ppm shall not be used for hydrotest. Vessel(s) shall be dried thoroughly, immediately after draining, to prevent the possibility of evaporation and concentration of chlorides.
- 9.8 Temperature of vessels and testing medium during hydrostatic tests shall be in accordance with EN 13445.
- 9.9 The test pressure shall be maintained for a period of at least one-half hour per 25mm (1") of thickness but not less than one hour. The thickness of the head or shell, whichever is greater, shall be used to determine the length of the test period.
- 9.10 A pressure of not less than 2/3 of the test pressure (100% of design) shall be maintained for sufficient time to determine if there are any leaks, but not less than 1 hour following the application of the hydrostatic test pressure per UG-99.

- 9.11** The pneumatic test shall be used only when the hydrostatic test is impractical, such as for vessels so designed and/or supported that filling with water is unsafe, or for vessels in services where a testing liquid cannot be tolerated. Pneumatic testing shall not be permitted without prior written approval by OL.
- 9.12** Requirements of OL Engineering Specification No. *OL-TR-MR-001*, "General Welding, Fabrication and Inspection", shall be followed.
- 9.13** All welds of pressurized parts of vessel for fluids group 1 acc. P.E.D. shall be tested by volumetric methods (radiographic or ultrasonic testing).
- 9.14** If the vessel working in creep range - lifetime monitoring actions should be described in operation instruction.
- 9.15** The requirements of ISO 15156 apply to vessels which intended for use in H₂S containing environments.
- 9.16** Hardness testing of welding joints shall be performed for materials group 5 and 6 acc. ISO/TR 15608.

10. DIMENSIONAL TOLERANCES

- 10.1** Tolerances are to be held as indicated in manufacturing Code and design drawings or data sheet.

11. CLEANING AND PAINTING

- 11.1** All internal and external parts are to be cleaned thoroughly and free from grease, scale, weld spatter, slag, rust and any other foreign matter.
- 11.2** The preparation and painting of exterior surfaces, when required, will be specified on design drawings.
- 11.3** OL Engineering Specification No. *OL-TR-CR-001*, requirements shall be followed.

12. NAMEPLATE

- 12.1** Each complete vessel shall be provided with an approved corrosion resistant nameplate seal welded to the nameplate bracket. The bracket shall be per OL requisition and so located that it is easily accessible from grade or a platform after installation.
- 12.2** The nameplate shall contain as a minimum, the following data:
- a) Code symbols showing if vessel is radiographed and/or stress relieved.
 - b) Manufacturer's name.
 - c) Manufacturer's serial number and National Board number.
 - d) Date tested.
 - e) Maximum allowable working pressure at design temperature with specified corrosion allowance.
 - f) Shell and head thickness.
 - g) Corrosion allowance.
 - h) Purchaser's item number and description.
 - i) Purchase Order number.
 - j) Test pressure.

13. PREPARATION FOR SHIPMENT

- 13.1 The vessel fabricator is to prepare each vessel for shipment.
- 13.2 All internal parts that may become damaged in shipment are to be suitably supported and made fast. Signs indicating that "VESSEL CONTAINS SHIPPING BRACING WHICH MUST BE REMOVED" shall be conspicuously located.
- 13.3 Suitable temporary supports, marked and tagged for removal after vessel installation, shall be provided to prevent damage during shipment.
- 13.4 All flanged openings shall be protected with one piece plywood covers. Plywood covers shall be 10mm (3/8") thick for flange sizes DN150 (6") or smaller, 12mm (1/2") thick for DN200 (8") through DN300 (12"), and 20mm (3/4") thick for larger sizes.
- 13.5 A minimum of four M10 (3/8") bolts shall be used for flange sizes DN300 (12") and smaller and eight M10 (3/8") bolts for larger flange sizes.
- 13.6 Machined surfaces and flange faces are to be covered with acceptable rust preventive.
- 13.7 Vessels are to be clearly identified by painting or stenciling the OL contract and item number in a conspicuous location on the shell, head or support.
- 13.8 The following shall be applied to vessels prepared for water shipment:
- a) All vessel openings shall be made watertight;
 - b) All flanged connections which are not furnished with permanent blinds shall be covered with 6mm (1/4") minimum thickness, full diameter, steel plate covers. The covers shall be installed with 3mm (1/8") thick cloth inserted neoprene gasket, and secured with full bolting. Covers need not be drilled for bolting larger than 20mm (3/4") diameter bolts and suitable cut washers if a seal can be maintained;
 - c) Special vessel openings shall be provided with suitable closures designed by the fabricator and approved by OL;
 - d) Loose items shipped apart from the vessels shall be crated for protection against physical damage and sealed in sheet plastic against water damage;
 - e) Protective measures shall be subject to inspection and rejection. All costs occasioned by any rejection shall be for the account of fabricator;
 - f) When the vessel has internals or vessel surfaces of austenitic materials, the vessel fabricator shall provide a positive nitrogen pressure of 3 psig (20 kPA(g)) minimum on the vessels to provide protection against possible chloride attack by the sea water. Manufacturer is invited to submit alternate methods for consideration. Vessels shall be assumed to be deck cargo. Manway blinds shall be marked "NITROGEN PURGED - DO NOT OPEN";
 - g) The vessel internals not installed in the vessel by the Vendor shall be crated, boxed, and loaded in a manner such as to protect all parts from damage or loss in transit and shall be shipped so that they arrive at the erection site prior to or with the vessel;
 - h) Details of shipping supports, saddles, bracing, tiedowns, loading and unloading methods, etc., are required for OL approval;
 - i) Vendor shall locate and identify the center of gravity of the vessel.

ANNEX A. (INFORMATIVE) ALLOY LINED PRESSURE VESSELS

A.1. Scope

- A.1.1** This ANNEX covers additional requirements for Alloy Lined Pressure Vessels and is supplemental to OL Engineering specification NO. OL-TR-MVR-001 "Unfired Pressure Vessels".
- A.1.2** This ANNEX covers general requirements for the design and fabrication of pressure vessels made from integrally-clad alloy bonded to carbon steel or low alloy steel base metal and corrosion resistant alloy linings applied to carbon or low alloy steel.
- A.1.3** The term "alloy lining" as used herein refers to the type of alloy cladding, alloy weld overlay (for shells and heads) and alloy sleeve liners (for nozzles) specified for the vessel under consideration.

A.2. Design

A.2.1 General

- A.2.1.1** Maximum allowable working pressure (MAWP) shall be based on total metal thickness less corrosion allowance.
- A.2.1.2** Strip lining for shells and heads shall not be used for corrosion protection without prior approval from OL.
- A.2.1.3** All integrally clad plate material shall satisfy the requirements ASME or EN Code as though cladding was included in the pressure thickness. However, the thickness of the cladding shall not be included in the design calculations.

A.2.2 Corrosion Allowance

- A.2.2.1** When nozzles are lined with sleeve liner, a corrosion allowance of 1.6mm (1/16") minimum shall be provided on backing material.

A.2.3 Internals

- A.2.3.1** Unless otherwise noted on design drawings internal piping is to be the same alloy as specified for the vessel cladding or lining.
- A.2.3.2** Ferritic or martensitic alloy steel internal piping will be schedule 10 (or EN equivalent) or heavier.
- A.2.3.3** Austenitic alloy steel, nickel or high nickel alloy internal piping will be schedule 10S (or EN equivalent) or heavier.
- A.2.3.4** Carbon steel internal piping will only be used when specifically called for on design drawings in which case the schedule of pipe will be specified.
- A.2.3.5** Internal flanges may be either ANSI 150# (PN16) forged slip-on welding type or fabricated from suitable plate and machine faced. They are to be of the same quality material as specified for the internal pipe. Bolt heads and nuts are to be the semi-finished heavy hex type. Studs with two hex nuts each may be substituted in place of hex head bolts.

- A.2.3.6** Ferritic alloy steel internal flanges are to have ASME SA-193-B6 bolting with ASTM SA-194-6 nuts.
- A.2.3.7** Austenitic alloy steel internal flanges are to have austenitic alloy steel bolts conforming to ASME SA-193-B8 with ASME SA-194-8 nuts for vessel design temperatures 260°C (500°F) and under. For temperatures over 260°C (500°F), ASME SA-193-B8C bolting is to be used with ASME SA-194-8C nuts.
- A.2.3.8** Nickel and high nickel alloy internal flanges are to have bolts and nuts of the same material as specified for the flanges.
- A.2.3.9** Carbon steel internal flanges, if specified on design drawings, are to have carbon steel bolts and nuts.
- A.2.4 Connections**
- A.2.4.1** For vessel design temperatures exceeding 399°C (750°F), all external connections are to be flanged and DN50 (2") minimum size.
- A.2.4.2** Lined or sleeved connections are to be trimmed flush with the inside surface of the vessel and have the inside edge of the base material rounded or chamfered before installing the sleeve and alloy weld deposit.
- A.2.4.3** Use of solid alloy nozzle requires prior approval from OL. For vessel design temperatures above 232°C (450°F) and vessels requiring PWHT, solid alloy nozzles shall not be used.
- A.2.4.4** Austenitic stainless steel nozzles are not permitted in vessels with carbon steel shells and heads.
- A.2.4.5** The alloy lining is to be rigidly welded at the flange facing and at the juncture of the nozzle neck with the shell or head. Nozzle necks made from rolled plate may be fabricated from integrally clad plate if the size is large enough to produce satisfactory weld joints. These are joints where the inside surface can be backchipped and welded after the carbon or low alloy steel weld is completed.
- A.2.4.6** Nozzles lined with a sleeve such as tubing, pipe or rolled plate (this does not pertain to strip lining) are to have the sleeve and its attaching welds designed for all of the following:
- A.2.4.6.1** Air and soap solution leak detection pressure.
- A.2.4.6.2** Difference in thermal expansion between nozzle and sleeve at operating, design and postweld heat treating (if applicable) temperatures.
- A.2.4.6.3** The outer nozzle wall is to be furnished with a minimum size 3mm (1/8") nominal pipe threaded test hole for the purpose of testing, and a forged steel pipe plug for installation after the test.
- A.2.5 Minimum Neck Thickness**
- A.2.5.1.1** Seamless alloy pipe, or formed alloy plate necks for use with forged alloy welding neck of slip-on flanges: schedule 40S (or EN equivalent) pipe up to and including DN200 (8") diameter and 8mm (5/16") wall for larger nozzles.

- A.2.5.1.2** Upon OL approval, seamless alloy lap joint stubend (welded to seamless alloy pipe neck if required to meet specified nozzle projection) for use with forged carbon steel lap flange: schedule 40S (or EN equivalent) up to and including DN200 8" diameter and 8mm (5/16") wall for larger nozzles.
- A.2.5.1.3** Seamless carbon or low alloy steel pipe or formed plate used in combination with alloy sleeve or lining: schedule 40 (or EN equivalent) and up to and including DN250 (10") diameter and 10mm (3/8") wall for larger nozzles. If integrally clad plate is used for nozzle necks and if the cladding is stipulated as the corrosion allowance, the minimum thickness requirement applies to the carbon or low alloy base metal.
- A.2.5.1.4** Nozzle neck thickness shown on design drawings may be used for sizes up to and including DN600 (24") providing no conflict occurs between the thicknesses and code requirements. For sizes above DN600 (24") special consideration is to be given to both pressures and thermal expansion.

A.3. Fabrication and Welding

- A.3.1** All shell and head joints are to be full penetration double-welded butt joints. The joint design and alloy filler metal for integrally-clad construction must be such that the resulting weld on the alloy clad side of the plate will be equal in corrosion resistance to the alloy cladding.
- A.3.2** When integrally bonded clad plate is the alloy lining used, the lining shall be cut back at all seams to permit backwelding of the base metal. Weld metal shall be ground smooth and fully covered with the weld deposit overlay. The weld deposit overlay shall be at least as thick as the lining but no greater than twice its thickness.
- A.3.3** When integrally bonded clad vessels are used, a minimum, of 10% of the clad surface shall be ultrasonic examined for lack of bond after forming. Unbonded areas that cannot be encompassed by a 76mm (3") diameter circle shall be repaired by weld deposit overlay. When repairs in excess of 5 percent of the total examined area are required, the vessel shall be 100 percent ultrasonic examined. Repaired areas and weld deposit overlay at weld seams shall be 100% liquid dye penetrant examined in accordance with ASTM E165 or ISO 3452. Ultrasonic examination shall be in accordance with ASTM A578 S6 for spot examination or S7 for 100% examination or EN 10160.
- A.3.4** The weld overlay shall be applied circumferentially to the vessel and shall be relatively smooth with no notches and undercuts that would act as stress intensifiers. Flaws on the surface of the base metal that would interfere with bonding of the overlay shall be removed by grinding.
- A.3.5** All cracks and fissures and circular defects greater than 1.6mm (1/16") diameter in weld deposit overlay shall be removed. Repaired areas shall be 100% reinspected by liquid dye penetrant.
- A.3.6** Nozzles and manways in alloy lined portions of vessels shall be lined and faced. The facing shall be made with weld deposit which is at least as thick as the lining when properly machined and or the same alloy as the lining.
- A.3.7** OL Specification No. OL-TR-MR-001, "General Welding, Fabrication and Inspection Specification" requirements shall be followed.
- A.3.8** Tray support rings are to be made from the same alloy as the cladding or lining. They are to be attached directly to the alloy- cladding in vessels constructed from

integrally-clad material. Carbon steel vessels with applied alloy linings are to have the alloy support rings welded to the carbon steel shell, and the lining is to be attached to the ring in a manner which will assure adequate corrosion protection. The tray support rings are to be welded to the vessel shell with continuous welds, both top and bottom. The top weld is to be designed as a strength weld, and the weld on the underside is to be a seal weld and be made before welding the lining to the ring, in the case of applied linings. An excessive amount of welding should be avoided. Applied linings of the multiple spot and seam welded type are to have the lining removed at the tray support ring to permit welding it to the vessel shell. The resulting gap is to be closed by strip lining as previously described. Tray support gussets when required are to be alloy and be attached directly to the vessel shell. Complete details of design and welding procedures shall be submitted for OL's approval.

A.4. Inspection and Testing

- A.4.1** Sleeve-lined nozzles are to be tested and witnessed by the OL inspector. The test pressure shall be a minimum of 172 kPa(g) (25 psig) and a maximum of 482 kPa(g) (70 psig). This test will be conducted after all postweld heat treating and hydrotesting operations have been performed.
- A.4.2** All sleeves are to be tested by air and soap solution or other suitable liquid. All test holes are to be left open until after the vessel is pressure tested. After the pressure test is complete the liquid between the liner and vessel wall shall be completely removed by drying before closing the test holes in the liner sections by welding. The welded up test holes will be inspected by the dye penetrant method to detect cracks.
- A.4.3** Clean fresh water shall be the primary hydrostatic test medium unless use of a different medium is approved by the owner or his representative. Hydrostatic testing of austenitic stainless steel lined vessels shall be done with potable quality water having a chloride content or not more than 10 ppm (parts per million). If chloride content is greater than 10 ppm, up to a maximum of 250 ppm, a sufficient quantity of sodium nitrate shall be added to provide a test medium of 0.5% by weight sodium nitrate solution. Water with a chloride content of greater than 250 ppm shall not be used for hydrotest. Vessel(s) shall be dried thoroughly, immediately after draining, to prevent the possibility of evaporation and concentration of chlorides.
- A.4.4** OL Specification No. OL-TR-MR-001, "General Welding, Fabrication and Inspection Specification" requirements shall be followed.

ANNEX B. (INFORMATIVE) HEAVY WALL PRESSURE VESSELS

B.1. Scope

This ANNEX covers additional requirements for Heavy Wall Pressure Vessels, over 51mm (2") thickness and is supplemental to OL Engineering specification NO. OL-TR-MVR-001 "Unfired Pressure Vessels".

B.2. Design

B.2.1 Shell and Heads Requirements

B.2.1.1 Formed heads shall be 2:1 elliptical or hemispherical. The head skirt thickness shall not be less than the required thickness of the connecting cylinder. (Reference figure AD.420.2 of the ASME Code Section VIII, Division 2)

B.2.1.2 The apex angle of conical transitions shall not exceed 60 degrees.

B.2.1.3 A knuckle radius shall be provided at all cones to cylinder junctions. The knuckle inside radius shall not be less than 14 percent of the adjacent cylinder outside diameter.

B.2.1.4 No permanent attachments shall be welded to toroidal sections in heads or conical transitions other than support skirts.

B.2.1.5 Layout of circumferential and longitudinal seams shall be such that nozzles, manways and external and internal attachments do not penetrate or interfere with weld seams.

B.2.1.6 Lugs shall not be acceptable for vessels with operating temperatures below 21°C (70°F).

B.2.2 Supports Requirements

B.2.2.1 Leg supports shall not be used.

B.2.2.2 For vessels with design temperatures above 260°C (500°F), excluding internally lined vessels, the skirt-to-shell attachment shall be made by means of a forged head ring with stub, or weld buildup on the head. A support skirt "hot box" shall be provided at the junction between the skirt and the vessel.

B.2.3 Nozzles and Reinforcement Requirements

B.2.3.1 Slip-on flanges shall not be used.

B.2.3.2 Pad type studded or proprietary type construction shall not be used without specific agreement of the Purchaser.

B.2.3.3 Nozzle reinforcement shall be integral. No reinforcing pads shall be allowed on pressure boundary components.

B.2.3.4 Nozzles shall conform to the following requirements of the ASME Code Section VIII, Division 1:

- a) Nozzles DN100 (4") or less - Figures UW-16.1(c), (d), (f-1), (f-2), (f-3), or (f-4).
- b) Nozzles larger than DN100 (4") - Figures UW-16.1 (f-1), (f-2), (f-3), or (f-4).

B.2.3.5 The inside corner radius for all nozzles shall be the smaller of the following:

- a) The thickness of the adjacent vessel shell divided by 4.

- b) The finished inside diameter of the nozzle divided by 4.
- c) 3/4" (19mm).

B.2.3.6 The minimum outside corner radius for all nozzles is 13mm (1/2").

B.2.4 Clad Design Requirements

B.2.4.1 Sleeve lined nozzles and strip lined vessels or nozzles are not permitted;

B.2.4.2 Solid alloy nozzles are not permitted.

B.2.5 Attachments to the Pressure Boundary Requirements

B.2.5.1 Clips or brackets for platforms, ladders, davits and pipe supports shall not be welded to the vessel shell or heads if any of the following conditions are present:

- a) Vessel design temperature of 537°C (1000°F) or more;
- b) Vessel is in cyclic service;
- c) When defined on the Purchaser's drawings.

B.2.5.2 All clips or brackets for platforms, ladders, davits and pipe support clips shall be at least 13mm (1/2") thick. Attachment to the vessel shall utilize a full penetration weld thru the thickness of the clip and must have at least an 8mm (5/16") covering fillet weld.

B.2.5.3 Insulation support clips shall be as detailed on vessel drawing(s).

B.2.5.4 Pads attached to the shell by fillet welds are prohibited.

B.2.5.5 Stitch welded attachments are not permitted. All attachments shall be continuously welded and vented.

B.2.5.6 The use of welded-on erection attachments is prohibited.

B.3. Materials

B.3.1 All ferritic material with a thickness greater than 76mm (3") shall be impact test qualified in accordance with EN 13445 or paragraph UG-84 of Section VIII, Division 1 of the ASME Code.

B.3.1.1 Standard forged flanges per ANSI, API and EN are exempted from this requirement.

B.3.1.2 The test temperature shall be assumed to be no greater than 10°C (50°F).

B.3.2 Test specimens for impact tests shall be given the shortest probable time of post weld heat treatment to be seen by the vessel. Test specimens for tensile tests shall receive the longest possible time of post weld heat treatment.

B.3.3 When the vessel base material is required to be impact test qualified, weld procedure qualifications and production weld test plates shall be impact test qualified in accordance with EN 13445 or paragraph UG-84 of Section VIII, Division 1 of the ASME Code.

B.4. Fabrication

B.4.1 Fabrication shall, in addition to this standard, comply with OL Engineering specifications NO. OL-TR-MVR-001 "Unfired Pressure Vessels" and NO. OL-TR-MR-001 "General Welding, Fabrication and Inspection".

- B.4.2** Full penetration, full fusion welds shall be used for all weld joints except for nonpressure parts.
- B.4.3** Absolutely no welding or arc strikes are permitted on vessel without proper preheat or after final post weld heat treatment.
- B.4.4** Each shell section shall be completely welded longitudinally and corrected for out-of-roundness and peaking of the weld seam prior to assembly.
- B.4.5** All re-rolling and forming of the shell sections shall be completed prior to radiographic examination.
- B.4.6** The location, size and depth of all repair welds shall be recorded. The locations shall be plotted or photographed.
- B.4.7** Vessel vendor must prepare and present to OL for approval a fabrication procedure showing the basic assembly sequence for the vessel and indicating all the proposed heat treatments, including mill treatments, hot rolling, intermediate and final heat treatments to which the vessel and its components will be subjected.
- B.4.8** Nozzles DN100 (4") nominal diameter in vessels 102mm (4") and greater thickness shall be attached to the vessel wall using a butt weld geometry that can be radiographed.
- B.5. Inspection and Testing**
- B.5.1** All pressure boundary plate greater than 51mm (2") thick shall be ultrasonically examined in accordance with EN 10160 or SA578, Level 1, S1.
- B.5.2** Pressure boundary forgings, except standard flanges per ANSI, EN and API shall be ultrasonically examined in accordance with SA388 or EN10228.
- B.5.3** Prior to welding, the cut edges of all plate, including cut openings for nozzles, shall be magnetic particle or liquid penetrant examined. Rejectable indications shall be removed and back welded to provide at least 25mm (1") of sound metal.
- B.5.3.1** All magnetic particle examination shall be performed in accordance with EN ISO 17638 acceptance as per EN ISO 23278 or appendix 6 of Section VIII of the ASME Code. All liquid penetrant shall be performed in accordance with EN ISO 3452-1 acceptance as per EN ISO 23277 or appendix 8 of Section VIII of the ASME Code.
- B.5.3.2** Choice of magnetic particle test method employed shall consider possible adverse effects due to arc striking by prods.
- B.5.3.3** Liquid penetrant examination shall be used for austenitic and non-ferrous materials.
- B.5.4** All pressure retaining butt welds shall be 100 percent examined by radiography in accordance with EN ISO 17636-1 acceptance as per EN 12517-1 or paragraph UW-51 of Section VIII of the ASME Code. Radiography shall be performed after final PWHT but prior to hydrotest.
- B.5.5** All non-butt nozzle to vessel welds shall be ultrasonically examined in accordance with EN ISO 17640 acceptance as per EN ISO 11666 or Appendix 12 of the ASME Code. This examination shall consist of at least two angles - 45 degrees and 60 degrees. This examination shall be done after the final post weld heat treatment.

- B.5.6** For carbon steel vessels greater than 102mm (4") thick and low alloy steel vessels greater than 51mm (2") thick, all pressure retaining welds, all welds of internal and external attachments, all areas where temporary attachments were welded to the shell and any area of the base material showing evidence of arc strikes shall be examined by the magnetic particle or liquid penetrant method after the hydrostatic test. Liquid penetrant examination is allowed only on non-magnetic materials.
- B.5.7** Repair of cracks or other defects shall not be made without a Purchaser-approved repair welding procedure.

ANNEX C. (INFORMATIVE) LOW CHROME ALLOY PRESSURE VESSELS

C.1. Scope

This ANNEX covers additional requirements for Pressure Vessels of Low Chrome Alloy Steel and is supplemental to OL Engineering specification NO. *OL-TR-MVR-001* “Unfired Pressure Vessels”.

C.2. Materials

C.2.1 Shell and head plate shall conform to SA387 Grade 11, Class 2, Normalized and Tempered, with the following additional requirements:

C.2.1.1 Material shall be vacuum degassed with calcium treatment for inclusion shape control.

C.2.1.2 The following maximum levels of trace elements are to be guaranteed in the heat analysis:

a) Sulfur	0.010%;
b) Phosphorus	0.012%;
c) Tin	0.015%;
d) Antimony	0.010%;
e) Arsenic	0.015%.

C.2.1.3 Silicon and Manganese content shall be kept as low as possible while maintaining high temperature tensile and creep properties.

C.2.1.4 Supplemental SA387 requirements S1, S2, S3, S5, S7, S12 and S17 shall be provided.

C.2.1.5 Nozzle forgings shall conform to SA182, Grade F11, Normalized and Tempered.

C.2.1.6 All SA387 steel plate shall meet the requirements of SA578, Level II.

C.2.1.7 The maximum tensile strength of plate, forgings, and weld metal shall be 689,476 Kpa (100,000 psi) at room temperature. In addition, tensile test shall be conducted at design temperature with results reported for information only. NOTE: Accelerated cooling from the normalizing temperature is acceptable, where permitted by applicable product form specification.

C.2.1.8 Maximum hardness of any low chrome pressure containing component or weld after final PWHT shall be 225 Brinell.

C.2.1.9 All pressure retaining components including nozzle forgings and welding consumables shall conform to the following element restrictions in the heat analysis:

a) Max. Phosphorus content	0.012%;
b) Max. Tin content	0.015%.

C.3. Fabrication and Welding

C.3.1 Nozzle Connections

C.3.1.1 All nozzles shall be (per Fig. UW-16.1 (f-1), (f-2), (f-3) or (f-4), insert type with fully radiographable butt welds and radiused contour.

C.3.1.2 Ring joint flanges shall have a flat bottom groove with the intersection between the bottom and the sides of the groove machined to a smooth 3mm (0.125" radius).

C.3.2 Internals

C.3.2.1 Stainless steel support rings shall be welded to reactor I.D. weld metal overlay after final postweld heat treatment. Attachment weld shall be full penetration and shall penetrate into the reactor I.D. overlay no further than required for loading support, using a low heat welding process. Fillet cap welds shall be ground to a smooth concave contour. Overlayed area beneath this attachment weld shall be ultrasonic examined prior to welding.

C.3.2.2 Attachment welds shall be made with Type 308L (E308L or ER308L) electrodes. These welds shall be covered with a thin deposit of Type 347 (E347 or ER347).

C.3.2.3 For clad construction, support ring shall be same material as the vessel shell and welded directly to the base metal with full penetration weld and fillet cap weld ground to a smooth concave contour. Support ring and attachment weld shall be overlayed with two passes of stainless steel per paragraph C.3.7 below. NOTE: This work shall be performed before postweld heat treatment.

C.3.3 Main Vessel Welds

Main vessel welds shall be full penetration double butt (or equivalent) welds free of undercuts and ground for radiographic inspection. They shall be designed to permit 100% radiographic inspection.

C.3.4 Internal Welds

All internal attachment welds shall be in accordance with a welding procedure qualified by ISO 15614 or Section IX of the ASME code.

C.3.5 Non-pressure Welds

Welds attaching non-pressure retaining parts to pressure retaining parts shall be full penetration.

C.3.6 Fillet Welds

Attachment fillet welds shall be ground to a smooth concave contour.

C.3.7 Weld Deposit Overlay

C.3.7.1 A two layer weld deposit overlay to the reactor and nozzle I.D.'s is preferable, however, overlay may be one layer depending on acceptance of fabricator's proposed procedure. The first layer shall be TP309 (E309 with 0.08% maximum carbon or ER309L) and the second layer TP347 (E347 or ER347). A minimum of 3mm (1/8") of uniform composition of TP347 is required at the surface exposed to the environment. In no case shall the thickness of the weld deposit overlay exceed 6mm (1/4"). Weld procedure qualification test shall provide chemical analysis at different depths to confirm this. Acceptance test on vessel shall be performed at a depth of 3mm (1/8").

C.3.7.2 Weld overlay applied to flange face surface shall be minimum two layers and comply with paragraph C.3.7.1 above. The thickness of the TP309 first layer shall be such as to preclude the necessity of postweld heat treatment after the TP347 layer(s) is applied, i.e., the TP347 layer(s) to be applied after final postweld heat treatment following by final machining.

- C.3.7.3** Ferrite content of TP347 weld deposits shall be controlled to a WRC ferrite number (FN) of 10 maximum (4 minimum) as measured by the Severn gauge. FN control of weld deposit(s) shall be by reference to the Schaeffler Diagram for stainless steel weld metals. Limit defined above shall be confirmed by thoroughly checking final deposits prior to final postweld heat treatment with a Severn gauge calibrated in accordance with the standard procedure defined in AWS A4.2 (latest edition). Two test shall be conducted on each shell course, on each head, on each strength weld and one on each nozzle.
- C.3.7.4** The finished weld deposit overlay shall be spot ultrasonically examined (a minimum of 10% of the surface including no less than 0.09 square meter (1 square foot) in each 0.9 square meters (10 square feet) or fraction thereof) before final heat treatment. Unbonded areas that cannot be encompassed by a 25mm (1") diameter circle shall be repaired by removing and re-welding. When repairs in excess of 5 percent of the total examined area are required, the vessel shall be 100 percent ultrasonic examined.
- C.3.7.5** Weld deposit overlay surfaces within 51mm (2") on each side of internal attachment welds shall be 100% ultrasonic examined after final heat treatment and attachment welding. Any unbonded areas shall be repaired and re-examined.
- C.3.7.6** Fabricator shall provide to the Contractor/Purchaser a detailed description of the stainless steel weld overlay procedures to be used plus supporting test and service data showing that the proposed overlay procedure will eliminate or greatly minimize hydrogen induced disbanding in the intended service.
- C.3.8** Postweld Heat Treatment (PWHT)
- Post weld heat treatment shall be at 690°C (1275°F), $\pm 14^\circ\text{C}$ (25°F). Tensile properties shall meet the requirements of the material specification after all the anticipated heat treatments, including one extra final PWHT reserved for future use by the Owner.
- C.4. Inspection and Testing**
- C.4.1** General
- C.4.1.1** CVN impact testing is required for all pressure containing components and welds. Testing shall be per EN 13445 or UG-84 with no exemptions at the specified minimum design metal temperature. In addition, one set of 3 charpy v-notch impact tests shall be run on completely heat treated specimens from each plate, forging and weld sample of each size and heat treated lot. Tests shall be conducted at +10°C (+50°F) with the average value for a set of three specimens being no less than 5.5 kg. meters (40 ft-lbs) but in no case less than 4.8 kg. meters (35 ft-lbs). Lateral expansion in mils and percent shear fracture shall be reported with impact test values. Test coupons shall receive 100 percent of the total heat treatments anticipated for the complete reactor.
- C.4.1.2** All pressure containing welds shall be fully radiographed for their entire length
- C.4.2** Magnetic Particle Examination
- C.4.2.1** Examination shall be in accordance with EN ISO 17638 acceptance as per EN ISO 23278 or Appendix VI of Section VIII, Division 1, of the ASME Code. If prods are used, tips shall be carbon steel, not lead or copper.
- C.4.2.2** All plate edges shall be examined after trimming, but prior to welding, to reveal laminations and injurious segregations. Laminations and injurious segregations shall be

removed by chipping or grinding and shall be re-examined to assure that all defects have been removed.

C.4.2.3 Double-butt welds shall have the initial root passes, including root tack welds, chipped, ground and gouged to sound metal, and the back chipped welds, welding groove and plate edges examined to assure that all cracks, pin holes, porosity or other weld defects are removed before commencing welding on the second side.

C.4.2.4 All weld root areas shall be examined before and after removal of defects.

C.4.2.5 All arc strikes created by MT prods shall be removed by light grinding and examined by liquid penetrant methods prior to post weld heat treatment.

C.4.2.6 All internal and external weld attachments shall be examined after postweld heat treatment using the AC yoke method. All welds shall also be examined after hydrotest.

C.4.3 Ultrasonic Examination

All weld joints in the shell and heads, including all reactor nozzle joints and all repair welds shall be 100% ultrasonically examined in accordance with EN ISO 17640 acceptance as per EN ISO 11666 or ASME code sect.VIII div.1 UW53 app.12 after final heat treatment.

ANNEX D. (INFORMATIVE) VESSEL TECHNICAL PASSPORT

This annex includes technical passport for the Pressure Vessel.

SLĖGINIO INDO PASAS (Pressure vessel passport)

Indo pavadinimas ir technologinis numeris
Equipment description and technological number

Įrenginio pavadinimas, technologinis numeris (Equipment description, technological number)	
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Gamintojas ir jo adresas (Manufacturer, address)	
Tiekėjas ir jo adresas (Supplier, address)	
Savininkas ir jo adresas (Owner, address)	
Projektuotojas ir jo adresas (Designer, address)	

Paso turinys

(Passport content)

Dokumento pavadinimas (Document description)	Skyriaus numeris arba kitos žymės (Chapter number or other notes)	Lapo numeris, skyrius (sheet number)
1	2	3
Bendrieji duomenys (General information)	1	
Techninės charakteristikos ir parametrai (Technical characteristics and parameters)	2	
Registracija (Registration)	3	
Duomenys apie indo pastatymą (Information about vessel installation)	4	
Duomenys apie indo priežiūros meistrą (Information about responsible person for vessel maintenance)	5	
Duomenys apie pakeitimą, remontą (Information about changes, repairs)	6	
Patikrinimo rezultatų įrašymas (Inspection records)	7	
Priedai (Attachments)	8	

1. Bendrieji duomenys

(General information)

Pavadinimas ir paskirtis (Description & service)	
Tipas / Modelis (Type/Model)	
Pagaminimo metai (Data of fabrication)	
Gamyklinis numeris (Serial number)	
Projektinis darbo laikas, metais (Engineered operational duration, in years)	
Pagrindinių elementų plieno markė (Steel of base elements)	Korpusas – (Body) Paskirstymo kamera - (Distribution channel) Vamzdinis pluoštas - (Tube bundle)
Informacija apie terminį apdirbimą (Post weld heat treatment information)	
Suvirinimo siūlių kontrolė (Nondestructive test)	
Forma ir konstrukciniai matmenys, brėžinio numeris (Shape and constructional dimensions, according drawing)	

2. Techninės charakteristikos ir parametrai

(Technical characteristics and parameters)

Darbinės erdvės pavadinimas (Description of the operational conditions)		Korpusas (Shell)	Vamzdeliai (Tubes)
Darbinis slėgis, bar(g) (operation pressure)			
Skaičiuojamasis slėgis, bar (g) (Design pressure)			
Bandomasis slėgis, bar (g) (Test pressure)	Hidraulinis (Hydraulic)		
	Pneumatinis (Pneumatic)		
Bandymo terpė ir trukmė, min. (Testing medium and duration, min.)			
Bandymo terpės temperatūra, °C (Temperature of the test medium)			
Didžiausia leistina indo sienelių darbinė temperatūra, °C (Max allowed vessel shell work temperature)			
Mažiausia leistina sienelių temperatūra, °C (Min allowed shell temperature)			
Darbinės terpės pavadinimas (Name of operation medium)			
Darbinės terpės charakteristika (Characteristic of operation medium)	Nuodingumas (Poisoness)		
	Gailumas (Piteousness)		
	Kenksmingumas ir kt. (Noxiousness)		
	Degumas (Flammability)		
	Sprogumas (Explosiveness)		
	Didžiausia temperatūra, °C (Max temperature)		
	Mažiausia temperatūra, °C (Min temperature)		
Korozijos, erozijos priedas, mm (Corrosion, allowance, mm)			
Vidutinis tūris, l – m³ (Internal volume)			
Talpos svoris kartu su vandeniu, kg (Weight filled up with water)			
Tuščio indo masė kg (Weight of empty vessel)			

3. Registracija (Registration)

Indas užregistruotas (Vessel registered)

Registruojančiosios įstaigos pavadinimas (Name of registering agency)

IDENTIFIKAVIMO KODAS(number)

20md.

Registruojančiojo asmens vardas ir pavardė, pareigos, parašas
(Responsible for registering name, last name, position, signature)

4. Duomenys apie indo pastatymą

(Information about vessel installation)

[illegible]

5. Duomenys apie indo priežiūros meistrą

(Information about responsible person for vessel maintenance)

[illegible]

8. Priedų sąrašas

(Attachments list)

Dokumento pavadinimas (Document description)	Skyriaus numeris arba kitos žymos (Number or other marks)	Lapų (puslapių) numeriai (Page numbers)	Pastabos (Comments)
Atitikties deklaracija (Declaration of conformity)			
Atitikties sertifikatas (Declaration of conformity)			
Gamybiniai ir išpildomieji brėžiniai (Fabrication and „AS BUILT“ drawings)			
Stipruminis skaičiavimas (Strength calculation)			
Medžiagų specifikacija ir sertifikatai (List of materials and certificates)			
Suvirinimo medžiagų specifikacija ir sertifikatai (List of welding materials and certificates)			
Suvirinimo eskizas ir suvirinimo darbų žurnalas (Welding sketch and welding book)			
Suvirintojų sąrašas ir jų kvalifikacija (Welders qualification list)			
Suvirinimo procedūrų aprašai / suvinimo procedūrų patvirtinimai (WPS/PQR)			
Kokybės kontrolės planas (Quality control plan)			
Kontrolės protokolai, ataskaitos (Examinations protocols, reports)			
Neardomos kontrolės personalo pažymėjimai (NDT personnel certificates)			
Terminio apdirbimo žurnalas ir diagramos (PWHT logbook and diagrams)			
Esminiai saugos reikalavimai (Essential safety requirements)			
Taikomos normos (applied regulations)			
Rizikos analizė (Hazard analysis)			
Aparato naudojimo instrukcija (Operating instruction)			
Hidraulinio bandymo ataskaita (Hydro-test certificate)			
Dažymo patikros protokolas (Painting examination report)			
Aparato lentelės nuotrauka (Equipment tag plate photo)			
Montavimo kokybės aktas (Equipment erection conformance declaration)			
Aparato pajungimo schema (Equipment connection scheme)			

ANNEX E. (INFORMATIVE) DATA SHEET

This annex includes data sheet for the following items:

- Pressure Vessels Data Sheet:
doc. no. *OL-TR-MVR-DS1*, 2 pages.