Contents

1. Scope

This section defines the fabrication requirements to be met for ensuring the quality of the product. In addition, the Manufacturer shall respect all tolerances and supplementary requirements specified in engineering drawings.

2. Reference Documents

ITER Vacuum Handbook

RCC-MR 2007: Section 5 Fabrication

3. Marking Procedure

3.1 Surfaces which are to be exposed to vacuum shall only be marked or identified if necessary. Seal faces shall not be marked in any way.

The marking procedure shall be complying with the requirement specified in this annexure and also shall take into consideration the IO official numbering system as defined in clause 2 of Annexure 13.

The bidder shall establish an identification and marking procedure which he shall make mandatory for all subcontractors in order to ensure the traceability of all the plates, parts or welds throughout the manufacturing process. The Same shall be provided for review and approval.

When original marking needs to be removed during the manufacturing process, it shall be transferred before being removed to ensure a permanent identification against relevant material certificates.

All permanent records of inspections shall make reference to the above markings.

The procedure of marking above is not applicable to the filler material. A dedicated procedure shall be prepared by the manufacturer in accordance with Annexure 6 and shall be provided for review and approval.

3.2 Markers shall satisfy the following general requirements:

Sulphur, phosphorus and halogen (fluoride & chloride) content below 200 ppm for each.

Only approved (Appendix_4_Accepted_Fluids_2ELN8N_v1_14) dyes, marker pens, paints, etc. shall be used on surfaces which are exposed to vacuum. Markers other than the approved list, shall be subjected to the acceptance of ITER Vacuum RO.

3.3 Acceptance for the use of any particular marker shall be obtained by submitting the "Acceptance Request Form" to the ITER Vacuum Responsible Officer (RO), through ITER-India.

3.4 General Requirement

3.4.1 The methods used for marking shall not result in contamination of the material, significant strain hardening, or sharp discontinuities.

3.4.2 Items shall be marked in areas which are subjected to minimum loading and shall not be marked in areas where there is stress concentration (particularly in areas where there are discontinuities in shape) or in weld heat affected zones.

3.4.3 Marking must not adversely affect the interpretation of the results of non-destructive examination.

3.4.4 The method used shall suit the quality of marking requested (temporary, final marking, on components whose access will be restricted in the future).

3.5 Methods

3.5.1 Marking shall be by scribing with a clean sharp point, laser scribing or electromagnetic dot peen method.

3.5.1 All methods which meet the requirements Clause 3.4 above may be used, taking into account the following rules:

(i) The use of electric arc marking pencils is forbidden.

(ii) Stamping is permitted on materials more than 6 mm in thickness. Metal stamps shall be round nosed or ball type.

(iii) Chemical etching shall not be used unless accepted by the ITER Vacuum RO.

(iv) A vibrating marking tool may be used for thickness less than 6 mm. The tool shall be carbide tipped and the depth of the indentation shall be approximately 0.25 mm or less.

3.6 Letters or Symbols

3.6.1 The recommended height for characters is 4 to 6 mm for pipes with dia. <=350 mm in diameter and from 8 to 12 mm for pipes with dia. > 350 mm in diameter.

3.6.2 For very small parts, the characters shall be as large as it is possible to make them.

3.7 Temporary Marking

3.7.1 Requirements mentioned in clause 3.1 to 3.3 above shall apply.

3.7.2 Ink stamps, indelible ink, paint and adhesive tapes for temporary marking during manufacture, with the following provisions applying to austenitic stainless steels.

(i) Parts shall only be marked in this way provided that the marking may be removed afterwards. The use of these methods shall be as restricted as possible.

(ii) The inks, paints, etc., used shall not contain any contaminants prohibited in Clause 3.2 above.

(iii) These markings shall be eliminated using a method approved as per "Annexure 7_Cleaning and Cleanliness" prior to any heat treatment, whenever there is a risk of their causing surface contamination.

4. Use of Fluids for various purposes during manufacturing, inspection and testing

4.1 Care must be taken in manufacturing processes so as not to introduce contaminants into surfaces which may be difficult to remove later and which might result in degraded vacuum performance.

4.2 The requirements pertaining to cutting fluids, cleaning fluids, marker pens and US couplants shall apply to all applications where any final surface of the component is exposed or machined.

The requirements pertaining to the use of Liquid Dye Penetrant shall apply at all stages of manufacture.

VQC	Fluid Group Requirements		
	Cutting	**Cleaning**	**Other**
1	Water soluable, sulphur, phosphorus and halogen (fluoride & chloride) content below 200 ppm for each	Solvents or alkaline detergents, rinsed with demineralised water Halogen content below (fluoride & chloride) content below 200 ppm for each	Water based UT couplants, Approved Liquid penetrant product families*.

* The use of Liquid Dye Penetrant (LDP) is strictly regulated by the ITER Vacuum Handbook. A list of accepted LDP is given in Vacuum Handbook-Appendix 4 – Accepted Fluids. If another fluid (not in the list) is required, a "Request for acceptance of fluid"

shall be raised to the IO with the supporting qualification. After qualification, the LDP shall be accepted by the IO.

No baking (because of use of LDP accepted product) is not requested for DNB Vessel and HNB3 Vessel.

4.3 Accepted cutting fluids for use in VQC 1 are listed in "Appendix_4_Accepted_Fluids_2ELN8N_v1_14". The use of other cutting fluids requires prior acceptance.

4.4 Fluids not in the accepted list

Fluids which are not on the accepted list may be proposed for use. If the vacuum related properties of the fluid are not sufficiently well documented for an assessment to be carried out, a programme of measurement of the relevant properties should be agreed between the proposer, ITER-India and the designated ITER Vacuum RO.

Details of fluids to be considered for acceptance should be submitted to the ITER Vacuum RO, through ITER-India, using the "Fluid Acceptance Request Form (ITER_D_48XLVJ)". The proposer shall agree in advance with the ITER-India and ITER Vacuum RO a plan detailing the type and method of testing to qualify the material for use.

The Fluid Acceptance Request Form along with the test data, report and supporting documentation, including any supplier's data (Certificates of Conformity, etc.), is to be submitted for consideration.

Fluids qualified in this way may be added to the accepted list.

4.5 Fluid Selection / Qualification

The properties of interest for usage during the various stages of manufacturing and inspection on the vacuum vessel include:

- Fitness for purpose, i.e. how well it does the job for which it is used
- Easy and complete removal from the vacuum surface
- No induced degradation of the vacuum properties of the surface, e.g. increased
- outgassing
- No significant physical change to the surface
- Health and safety considerations

5. Cutting and Machining

5.1 Use of Cutting Fluids (see clause 4 above)

5.2 General requirements for cutting

All materials shall be cut to shape and sized or prepared for welding by machining, grinding, or thermal cutting. Shearing of plates shall be permitted, subject to the provisions of clause 5.2.1 below.

5.2.1 Shearing

Plates less than 25 mm thick may be cut by shearing, provided that the strain hardened zone is subsequently eliminated by machining or grinding. Weld edges may be prepared by shearing provided that the provision given above is respected.

5.2.2 Plasma Arc and Gas Tungsten Arc Cutting

(i) When plasma arc cutting is used to cut a part to its final shape and size, all residual traces such as metal roll-over and grooves etc. shall be removed from the faces of the cut. Approximately 1 mm of metal shall be removed from the face of the cut by grinding or machining. The same provisions shall be made when gas tungsten arc cutting is utilized for parts of small thickness.

(ii) For austenitic stainless steels, grinding or machining may be replaced by deburring followed by chemical pickling (see "Annexure 8_Pickling and passivation").

(iii) However, when a plasma arc is used to prepare weld edges on austenitic stainless steels, surface preparation after cutting shall be limited to the requirements for examination of weld edges prescribed in "Annexure 6_Welding_Section 5_Production welds"

5.3 The use of abrasive tools previously used with materials different from the ones foreseen for the NB Vessels construction shall be forbidden.

5.4 Machining process shall be developed in order to minimize distortions, leading to the fulfilment of all the tolerances requirements.

5.5 Metallic seals groove machining requirements (Defined by Seal manufacturer / IO)

The performance of the HELICOFLEX® seal is linked to the surface finish of the flanges. The roughness value and the method of production are involved.

Optimum roughness values are given on the 2D drawings provided along with the tender. IO recommend a serration which follows the seal track.

If a flange design requires a manufacturing method other than lathe-turned (circular), additional polishing to create a finish that follows the seal path should be performed.

For milling machining, the 'A' method is preferred. (See picture below)

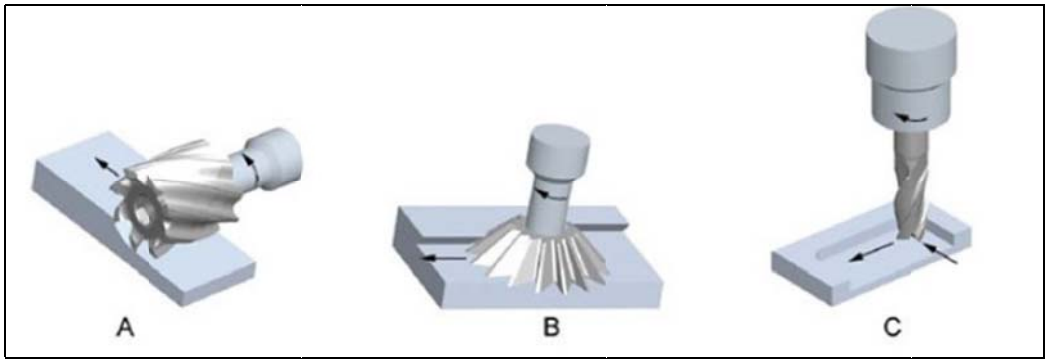


Figure 17: machining method for Metallic seal groove

The roughness of the surfaces dedicated to metallic seals shall be as mentioned in the Build-To-Print drawings as advised by the metallic seal manufacturer (Technetics company).

Initial manufacturing, generally milling, shall remove a very thin layer of material to ease the removal of radial scratches by polishing.

In case the surface presents (visual check) radial scratches it shall be refurbished by polishing.

Polishing shall be done following the seal track.

The sealing surfaces shall be polished with sandpaper using a sanding block made of wood or fibre as follow:

- Use high-grade sandpaper to get rid of the milling traces
- For a final roughness value between Ra0.2 and Ra 0.8µm: use Grade 120 to 240 sandpaper

For non-grooved part, sandpaper guide made of plastic should be mounted on the part as recommended by Technetics company. Details will be provided prior to the contract placement.

The seal gland shall be cleaned after polishing or refurbishing to ensure that sandpaper grit general debris is removed.

The manufacturer shall use guides to follow the pattern of the sealing areas.

The manufacturer shall sand-paper the useful area (around the theoretic axis where will seat the seal).

The manufacturer shall degrease the sealing areas with alcohol.

The seal surface shall be protected to prevent damage by scratching, Impact, machining defects, etc. until the assembly of the gaskets

Bidder shall develop a dedicated procedure / specification to meet the above requirements and in accordance other requirements of this annexure. Any other specific requirements / additional requirements are there from Technitics, the same shall be provided by IO prior to contract placement.

6. Repair without welding

6.1 General

This section covers the repair of defects detected on parts which have already been accepted in accordance with the requirements of all sections of "Annexure 4_Materials" and which are revealed or produced during a manufacturing or installation operation.

If the defect is a surface defects, then these defects shall not be repaired by welding when they meet the following criteria:

6.1.1 The defect shall be removed by grinding, chipping (followed by grinding), or machining. The use of thermal processes is prohibited.

6.1.2 The defect shall be removed or reduced to an acceptable size in accordance with the criteria given in relevant section of "Annexure 4_Materials" for raw material and "Annexure 6_Welding_Section 5_Production welds" for weld edges and surfaces on which weld metal will be deposited.

6.1.3 After removal or reduction of the defect, the remaining thickness of the metal shall be sufficient to meet the design requirements as per the Engineering Drawings. ITER-India may ask for the design justification in such cases and manufacturer has to provide the detailed assessment (e.g calculations, FEA etc) to ensure the design compliance. In addition, the surface condition shall meet the requirements for assembly and non-destructive examination.

6.1.4 Connection with the surrounding area shall be progressively and uniformly blended, taper being 0.25 at most.

7. Forming and Dimensional Tolerances

7.1 Forming

7.1.1 General

(i) The forming procedure comprises all the thermomechanical operations (thermal cycle, deformation and possible heat treatments after forming) applied to a part or a product in order to obtain a given component.

(ii) The use of any forming procedure must not result in the properties of the material of a component falling below the minimum required values. Thus, after forming, heat treatment must be performed, if required as per standard to restore the properties of the material such that they comply with the above mentioned requirements.

(iii) Forming procedure qualification tests are thus intended to demonstrate that the properties obtained, as requested by the product acceptance specification prior to forming, are respected on the finished product.

(iv) Whatever the forming procedure for welded fabricated parts, the welding procedure qualification must take account of the heat treatments associated with forming.

7.1.2 Required Documents

(i) All forming operations must be performed in accordance with the requirements defined in a set of duly identified documents which must comprise the following:

- The forming procedure data sheet used and, for fabrication operations, the corresponding qualification report reference,
- The checks to be performed during and after forming.

(ii) The forming procedure data sheet must:

- List and quantitatively define all variables given in clause 7.2 of this section as determining the validity when qualification of the forming procedure is required.
- Give for information purposes: Either the technological parameters adopted for the forming operation or the reference to an internal procedure containing this information.
- Reference to the forming procedure qualification must appear on the forming procedure data sheet.

7.1.3 Elongation Evaluation Method

$$A\% = \frac{50\,e}{R_f}\left(1 - \frac{R_f}{R_o}\right)$$ for cylinders and cones

$$A\% = \frac{65\,e}{R_f}\left(1 - \frac{R_f}{R_o}\right)$$ for spheres and torispherical parts with deformation < 1%

$$A\% = \frac{75\,e}{R_f}\left(1 - \frac{R_f}{R_o}\right)$$ for spheres and torispherical parts with deformation ≥ 1%

$A\% = 100 \times \ln(Df / Dp)$ for vessel heads

$A\% = 100 \times (r / R)$ for pipes

Where:
e = nominal thickness of the product,
Rf = final radius at the centerline of the part (Rf = knuckle radius for torispherical parts, Rf = minimum radius for truncated parts)
Ro = initial radius at the centerline of the part (equal to infinity for a plate)
R = nominal bend radius in relation to the tube axis
r = nominal radius of the pipe
Df = diameter of the blank
Dp = diameter of the part

7.2 Qualification of the Forming Procedure

7.2.1 Purpose and Necessity of Qualification

(i) The purpose of the procedure qualification is to check, with regard to the main variables, on a test sample, that the forming procedure allows compliance with the quality criteria required. A forming procedure qualification is required in the following cases:

- For one or more operations performed at a temperature of more than 150°C.
- For any operation performed at a temperature of 150°C or less if the maximum calculated elongation (in accordance with the formulae of Clause 7.1.3 above for the various shapes of component) is greater than 10% for austenitic stainless steels.
- In this latter case, the file requested must statistically demonstrate:
  - That the properties demanded by the acceptance specification for the base metal prior to forming are respected, except with regard to the minimum elongation value required,

- That the choice of the new criterion concerning the minimum elongation value is justified and remains compatible with the design requirements.

(ii) The qualification of the forming procedure is not necessary for materials accepted subsequent to forming and associated heat treatments for mechanical properties.

7.2.2 Required Documents

(i) Procedure qualification must be performed according to the requirements specified by a set of duly identified documents comprise the following:

- The forming procedure data sheet for the qualification part (Clause 7.1.2 of this section)
- The area of validity of the qualification
- The checks to be performed and the associated criteria, as a function of the class, adopted for the qualification
- Dimensional sketches showing positions of sampling on test specimens.

7.2.3 Range of Approval of Qualification

The main variables determining the area of validity of the qualification are given below (I to vii). In applying the range of approval of qualification, the manufacturer shall take into account the provisions in Table-1: Range of approval of qualification.

(i) Workshop

- In the case of hot forming: Qualification tests shall be performed in the same workshop, with the same type of machine as the production parts.
- In the case of cold forming: The qualification tests performed in a workshop are valid in all the Manufacturer's workshops producing parts using the same type of machine as that used for qualification.

(ii) Base Metal Grade

Non-stabilized austenitic stainless steels satisfying the intergranular corrosion test defined in RMC 1310, shall be considered as equivalent. Furthermore, products obtained by rolling, drawing or forging shall be considered equivalent.

(iii) Welding

If a weld is subjected to forming, the main variables given as below shall be taken into account.

- Deformation of Weld Joints (Welded Fabricated Parts): This in particular concerns the bending and the dishing of butt welded plates before forming. The weld shall be qualified at the time of forming of the model if deformation exceeds the value of 10% for austenitic steels. High deformation values qualify lower values.
- Welding Processes: Welding processes, and its qualification in accordance with "Annexure 6_Welding_Section 2_Welding Procedure Qualification", are a main variable. In particular, the heat treatment of the weld prior to forming, as defined in ""Annexure 6_Welding_Section 2_Welding Procedure Qualification" is a main variable.

(iv) Geometrical Criteria

- Plates and pipes
  - Deformation: High deformation values, such as defined in clause 7.1.3 of this section qualify lower values.
  - Thicknesses: Qualification of the forming procedure is valid for thicknesses of between 0.75 e and 1.25 e + 3 mm (e being the thickness of the test sample).
- Additional restriction: These rules do not, however, mean that a qualification, obtained without an impact test, can be used for a forming operation on a part whose dimensions allow such test to be performed.

(vi) Forming technique

The qualification is only valid for one forming technique and one given type of machine (press, roller, induction bending machine, sand fill bending, etc.).

(vii) Forming thermal cycle

- Re-qualification is required in the following cases:
  - Any modification to the specified forming temperature ranges
  - Any modification to the specified cooling conditions not followed by heat treatment for mechanical properties after forming
- It should be noted that the Surveillance Agent or Inspector may impose values for these parameters (i.e (i) to (v)) for the production of a qualification test part within the limits given in the documents defining the qualification purpose.

(vi) Heat treatment after forming

- If the heat treatment specified is stress relieving heat treatment the qualification shall be invalidated when one of the following modifications are made to the treatment after forming in production:

- Modification of the specified temperature range
- Modification of the specified ranges of temperature rise and fall rates and the duration of the treatment, taking account of the thickness equivalences defined in clause 7.2.3(iv) of this section and the recommendations defined in RS 1340 and RS 7540 (to be incorporated in the specification)

- If the heat treatment specified is heat treatment for mechanical properties (normalizing, normalizing and tempering, quenching and tempering, solution heat treatment, etc.), the test piece part must then undergo treatment of this type, similar to that specified for the production parts (holding temperature, holding time, cooling rate, etc.).

Table-1: Range of approval of qualification

Table RF 4123 : Range of approval of qualification

Type of production part	Qualification part	Non-destructive examination during qualification	Non-destructive examination during fabrication for parts requiring qualification
Fabricated parts without welds or with welds not taken into consideration in accordance with RF 4123.3.	Fabricated parts with welds not taken into consideration in accordance with RF 4123.3	Before and after qualification test, weld and base metal included	Before or after forming (1). For examination before forming: liquid penetrant examination of the formed zone and hardness testing of the stretched axis of the first five parts of each series of identical parts covered by the same qualification.
	Fabricated parts without welds	Before and after qualification test (1)	Before or after forming(1). For examination before forming: liquid penetrant examination of the formed zone and hardness testing of the stretched axis and where a weld is present, radiographic examination after forming of the first five parts of each series of identical parts covered by the same qualification.
Fabricated parts with welds taken into consideration in accordance with RF 4123.3.	Fabricated parts with welds taken into in consideration in accordance with RF 4123.3	Before and after qualification test, weld and base metal included (1)	After forming and associated heat treatment(1).
Pipe or fitting without welds or with welds taken into consideration in accordance with RF 4123.3.	Pipe or fitting with weld taken into consideration in accordance with RF 4123.3	Before and after qualification test, weld and base metal included (1) (2)	Before or after forming(1). For examination after forming: liquid penetrant and hardness testing on extrados of the first five parts of each series of identical parts covered by the same qualification.
	Pipe or fitting without weld	Before and after qualification test (1) (2)	Before or after forming(1). For examination before forming: liquid penetrant and hardness testing on the extrados and where a weld present, radiographic examination after forming of the first five parts of each series of identical parts covered by the same qualification.
Pipe or fitting with welds taken into consideration in accordance with RF 4123.3.	Pipe or fitting with welds not taken into consideration in accordance with RF 4123.3	Before and after qualification test, weld and base metal included (1) (2)	Before or after forming(1). For examination before forming: liquid penetrant examination and hardness testing on the extrados and radiographic examination after forming of the first five parts of each series of identical parts covered by the same qualification *.

(1) Non-destructive examination stipulated in RS 7000 for welded points and in the procurement specification for the part to be formed. Hardness tests are not required for stainless steel.
(2) Ultrasonic examinations performed before forming will not be repeated after forming.
* For the case of tubes a dimensional check shall be performed, if specified on the inital five bendsof each series of identical bends subjected to the same qualification, in order to check that the criteria definied in RF 4216 are satisfied.

7.2.4 Qualification Tests

(i) Number and Type of Test Piece

The number and the type of forming procedure test piece and the checks to be performed depend on the forming operations to be carried out and are defined by:

- The main variables determining the area of validity of the qualification.
- The type and the criteria of the non-destructive examinations and destructive tests.

(ii) Dimensions

The test piece shall be dimensioned as a function of:

- The forming process
- The test specimen sampling drawing for tests and retests
- The non-destructive examinations to be performed
- Where applicable, the qualification of the calibration procedure.

In any case, for pipes, the angle of each bend shall not be less than 30° and for plates, the width of the part shall not be less than 300 mm or 4e (e=thickness), whichever is greater.

(iii) Production of Test Piece

- Basic materials (base metal and deposited metal)
  - The base metals and possibly the filler materials must be those used in fabrication or representative of them, taking account of the equivalences defined in Clause 7.2.3 of this section.
    - The base metal and the filler material used during the fabrication of the test piece must be accepted and must comply with the criteria of relevant sections of “Annexure 4_Materials” and “Annexure 6_Welding_Section 1_Acc. and Qual. of Filler mat.” with regard to their chemical composition and mechanical properties.

- Forming of the test piece and heat treatment
  - The test piece is formed with the same machine as used in production. During the test, the temperatures of the part shall be recorded or periodical readings shall be taken if recording is not possible. After forming, the heat treatment, which shall be the same as that defined for production, shall be recorded, if necessary.

(iv) Checking the Qualification Test Piece

- General
  - All samples shall be taken after the test piece has undergone all heat treatments and checks stipulated in the documents defining qualification.
  - The test specimens for mechanical properties shall be sampled in areas which proved to be the most sound during the non-destructive examinations. However, sections for macrographic and/or micrographic examination shall be located in zones showing indications which were acceptable during non-destructive examinations.
  - Examinations and tests shall allow characterization of each of the zones having undergone the forming operations:
    - Base metal: on the intrados and extrados or in the stretched and compressed zones
    - Weld (when taken into account as per clause 7.2.3(iii) of this section) deposited metal, heat affected zone of the base metal, cross-checks in the base metal and the welded joint (if not performed elsewhere) not subjected to the thermomechanical forming cycle.
  - In the case of pipe bending, the start of the bend, the bend and the end of the bend shall also be characterized.

(v) Non-Destructive Examination

- The test piece shall, before and after forming, be subjected to all non-destructive examinations as stipulated for fabrication of the parts it qualifies and shall satisfy the requirements of the highest class of these parts.
- The test piece shall be subjected to visual examination and to liquid penetrant examination before and after forming at appropriate locations (in particular in the stretched zone and the welded joint) in compliance with RMC 4000.
- The test piece shall be subjected to a dimensional check to make sure the criteria defined in clause 7.5 of this section and in the equipment specification are satisfied.
- The surfaces of the test piece shall be smooth, free of tears, overlaps, cracks or any other injurious defects.
- The following acceptance criteria shall be apply:
  - Forgings
    - Any indications with one dimension exceeding 1 mm shall be considered a recordable condition.
    - The following indications shall be unacceptable:
      - Linear indications

- Rounded indications with one dimension greater than 3 mm,
- 3 or more grouped indications in a line, separated by less than 3 mm (edge to edge), 5 or more grouped indications within a rectangular area of 100 cm2, whose greatest dimensions shall not exceed 20 cm, taken in the most unfavorable location relative to the indications being evaluated.

- Plates
  - On the faces and edges of plates, the same criteria as outlined above.
  - However, on the edges of stainless steel plates, the following indications are permissible:
    - Linear indications whose length does not exceed 8 mm for plates of thickness less than or equal to 40 mm and 10 mm for plates of thickness greater than 40 mm.
    - Two adjacent indications shall be considered as one if the distance separating them is less than twice the length of the smaller of the two indications. The cumulated length shall be equal to the sum of the lengths of the indications plus the distance separating them.

(vi) Destructive Examination

- Chemical analysis
  - For hot formed stainless steel parts, or those heat treated after forming, the S and C contents shall be measured after finishing to a depth of 1 mm, only if there has been heating by combustion.
  - Criteria: values defined in the procurement specification.

- Mechanical tests
  - Base metal
    - All tests and criteria stipulated for product acceptance (plate, pipe) shall be respected and the corresponding criteria complied with.
    - The test specimen sampling conditions shall be identical to those defined for product acceptance, unless physically impossible. In such a case, the nearest possible choice applies.
    - In the case of pipes, the specimens shall be taken from the intrados and extrados, the test specimen sampling conditions within the thickness being the same as at product acceptance, unless physically impossible.
    - In the case of plates, skin samples shall be removed from the compressed zone and the stressed zone.
  - Welded joints

- The various tests and criteria stipulated for the welding procedure qualification shall be respected and the corresponding criteria complied with.
- In the case of plates, the location of the test samples in the thickness of the product shall be identical to that for the welding procedure qualification, taking account the following requirements:
    - The tests to be performed, at the skin, at a quarter or a third of the skin thickness of the product shall be performed in the extrados part.

- Intergranular corrosion test
    - The corrosion test is not required for all grades which, before forming, satisfy the requirements of RMC 1310, treatment B corrosion test.
- Metallographic examination (Structural examination - Measurement of grain size)
    - An examination using a metallographic replica shall be performed before and after forming for information.

- Hardness measurement
    - Hardness measurement shall be performed, before and after forming, particularly along the stressed axis, for information purposes.

7.2.5 Retest Condition

(i) Unsatisfactory non-destructive examinations:

- If the non-destructive examinations show unacceptable defects, the qualification shall be resumed once the cause of these defects has been found.
- If, during forming of the test piece or during examination, unacceptable defects appear systematically, or are considered as characteristic of the forming procedure, qualification shall be refused.

(ii) Unsatisfactory destructive tests

- If an unsatisfactory result stems from the incorrect performance of the test or the presence of a defect in the test piece, the result concerned may not be taken into account and the test shall be repeated with prior consent of ITER-India and IO.
- In the case of impact tests, the retests may be performed in accordance with the conditions defined in the welding procedure qualification.
- If a test piece does not demonstrate the required properties during destructive tests and after any retests, the cause for the inadequacy shall be determined. In

such a situation another test piece shall be made after appropriate process improvements have been considered. The retest part must meet the requirements.

7.2.6 Test Reports

- The results of the procedure qualification tests shall be kept at the disposal of the Surveillance Agent and transmitted to him at his request.
- They shall be written up in a report which must describe:
  - The main conditions (specified and actual) under which the test part was produced.
  - The non-destructive examinations performed, the associated criteria and their results
  - The destructive tests performed with the values to be respected and the results obtained.
- The test report must give the conclusions of the Manufacturer's inspection service.

7.3 Production Forming Operations

7.3.1 Operational Requirements

- Forming of Fabricated parts comprising Welds:
  - Any welded joint on a part formed after welding is ground flush before forming.
- Bending of cylindrical shells and cones
  - Plates intended for production of cylindrical shells and cones shall be formed by roll or press.
  - If the plates are roll formed, the edges of the longitudinal joints shall be pre-bent by means of a press or roll. The excess straight length shall then be removed before final bending in order to avoid having a flat zone in the joint area. If necessary, the angle of the plates shall be rounded before forming.
  - Precautions shall be taken to avoid marking the parts during forming, in particular in the case of shims being used between the plates and the rollers or platens.
  - During hot bending, for example, the Manufacturer shall take all necessary precautions to remove mill scale from the plates, so as to avoid indentations on their surface.
  - In the case of pre-bending or bending in a press, each pressing sequence covers the entire length of a generatrix.

- Pipe bending

- The choice of the bending process as a function of the diameter and the thickness shall enable the ovalization and thickness reduction tolerances authorized by the design to be respected.
- It is important that the bending tool be exactly adapted to the properties of the pipe (diameter, thickness, mechanical properties, etc.). In particular, when selecting his tool, the Manufacturer shall take account of the pipe tolerances given by the standard to which it is linked, since these vary according to the various standards.
- In the case of rolled, welded pipes, the weld seam is positioned, if possible, in the zone of least deformation.
- When the sand fill hot bending process is used, the material used must be chosen so that it does not stick to the walls of the tube and so that it can be easily removed after bending and avoid hindering subsequent cleaning, as requested in "Annexure 7_Cleaning and Cleanliness"

- Forming of heads
  - Whenever technically possible, heads shall be made from a single piece. When the dimensions of the head do not allow this, dishing and forming of component parts of the head shall be done mechanically.
  - Spinning is authorized on carbon or alloy steel provided that the part is suitably heated over an area extending well beyond that of the worked part.

- Additional precautions for forming austenitic stainless steels
  - Tools intended for forming austenitic stainless materials shall be prepared so that there is no risk of contamination (tools shall be cleaned and degreased) or inclusion of ferritic steel.
  - For hot forming of austenitic stainless steels, heating shall be performed in an inert or slightly oxidizing atmosphere in a low sulfur fuel, electric or gas fired furnace.
  - The use of a coal furnace or carburizing flame furnace is prohibited, whether for local or overall heating of the part.
  - The part must not come into contact with the jet of flames and it shall be degreased prior to heating.
  - Contact between ferritic steel parts and austenitic stainless steel parts is prohibited.

- If lubricants are used for cold forming austenitic stainless steels, they shall comply with the requirements of Clause 4 of this section relating to prohibited contaminants.
- Before hot bending or heat treatment subsequent to bending, the parts shall be degreased in accordance with a procedure and using products complying with the requirements of "Annexure 7_Cleaning and Cleanliness"

7.4 Forming Operation Checks

7.4.1 General case:

On completion of forming operations having required qualification, all parts shall be subjected to:

- A visual examination (supplemented, where doubt exists, by liquid penetrant examination)
- A dimensional check to ensure that the criteria defined in clause 7.5 of this section and the equipment specification are satisfied.
- The checks stipulated in Table-1 of this section with the criteria required for qualification.

7.5 Component forming tolerances

7.5.1 General

(i) During fabrication

In order to satisfy the form requirements for components in their final condition, the Manufacturer shall limit the tolerances of component parts at the procurement stage.

The Manufacturer shall follow the development of the deformation of large shells during fabrication, during which time he can also take additional precautions to ensure that the following requirements concerning the final condition of the apparatus are respected.

Measurement methods concerning the shape of the component before finishing shall be proposed by manufacturer and submitted for approval of ITER-India.

(ii) Final condition

The dimensions of the final component shall be within the tolerances provided in the engineering drawings and as provided in the clause 7.5.2 to 7.5.5 of this section.

(iii) Thickness

At all points of the wall, the thickness must be compatible with Engineering Drawing requirements. 7.5.2 The local out-of-roundness **δ**, either positive or negative, measured on a radius in a plane perpendicular to the axis of the shell, shall not exceed the value given in Figure-1:

- **e** = nominal thickness of the wall (minus corrosion allowance).

(e being the lowest thickness of the wall if the shell comprises parts of differing thicknesses).

- The out-of-roundness, **δ** shall be measured with a circular template of radius equal to the theoretical inside or outside radius, on a length equal to twice the cord subtending the arc determined by Figure-2.
- The value, **L** on Figure-1 and Figure-2shall be determined in the following way:
  - For cylinders, L is either:
    - The straight length between two head bend lines (tangent lines)
      Or
    - the greatest length between two stiffening rings if the equipment comprises reinforcements, or between a head bend line and the first stiffening ring,
  - For cones, L is:
    - The axial height of the conical part
      Or
    - If stiffening rings are used, the axial height between the greatest section of the cone and the first ring, De being in this case the outside diameter of the larger section,
  - For spheres, L is:
    - half the outside diameter De.
- Measurements of form deviations “L” above are not made at the welds.

Figure-1: determination of local out-of-roundness (δ)

Figure RF 4217.a : determination of local out-of-roundness δ

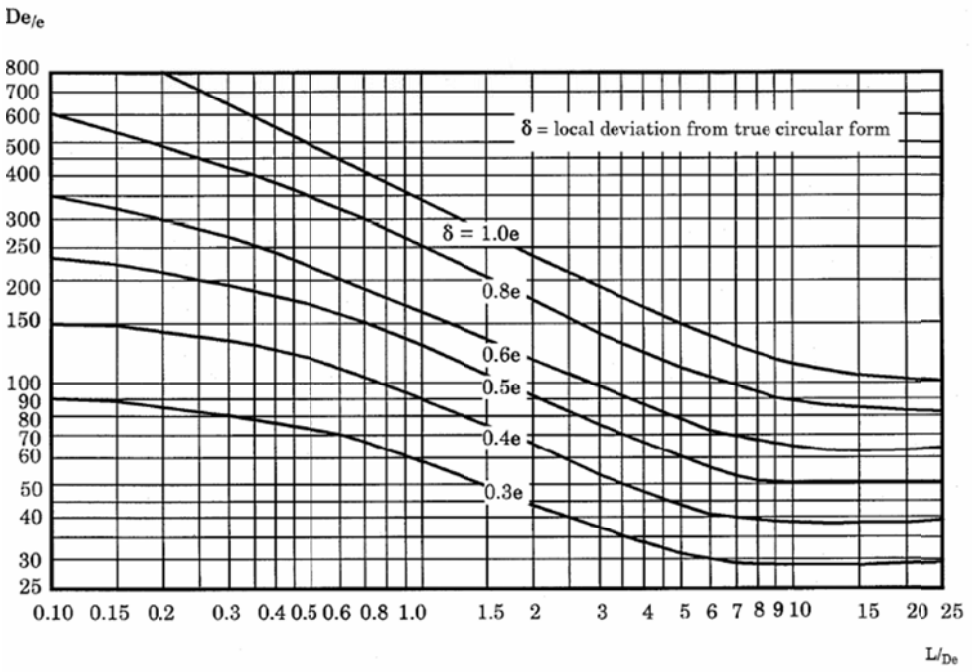
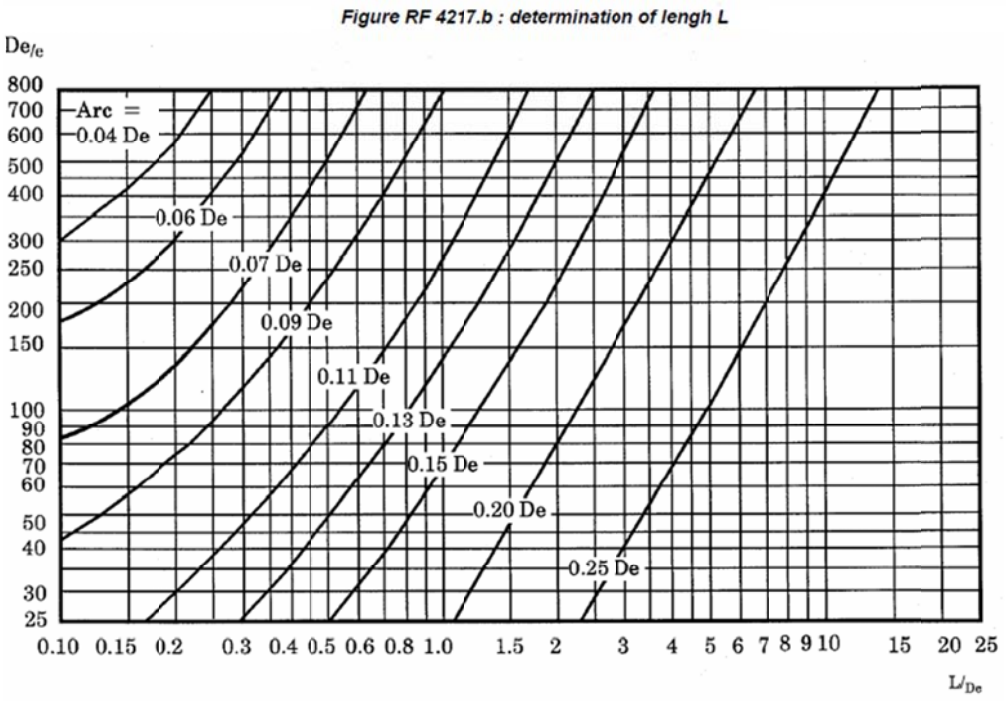


Figure-2: Determination of length 'L'



7.5.3 Deviation from true form of cylinders

(i) Deviations from true theoretical form (measured by means of a segmental circular template of the designed form of the shell whose length is equal to the chord of an angle of 20° at the centreline of the cylinder) shall not exceed 5% of the minimum plate thickness plus 3 mm.

(ii) This value may be increased by 25% when the length of the deviation does not exceed a quarter of the length of the cylindrical shell measured between two circumferential weld seams and does not exceed a maximum of 1 m.

7.5.4 Tolerance devations for vessel parts fabricated from pipes

The parts of components fabricated from pipes shall comply with the form tolerances of the pipe specifications (standard and utilization) and the tolerances, of the equipment specification.

7.5.5 Tolerances for pipe after form

(i) Out-of-roundness

The maximum ovality after forming shall be such that: (Dmax – Dmin)/DN < 8%

DN: the nominal diameter of the pipe,

Dmax: the maximum diameter after forming,

Dmin: the minimum diameter after forming.

(ii) Thickness after bending

The wall thickness after bending shall always be sufficient to meet the Engineering drawing requirements and in no case shall the reduction in pipe wall thickness exceed the following values:

- 10 % for bending radii greater than or equal to 5 D,
- 50.(D/R) % for bending radii less than 5 D. D and Rare pipe nominal diameter and bending radius with respect to the pipe axis respectively.

8. Alignment of Parts Assembled by Welding

8.1 General

8.1.1 Parts assembled by welding are aligned, adjusted and maintained in position during the welding operation, using processes such as jacks, clamps, bridges, tack welds, special jigs, etc. so that the tolerances given in clause 8.2 to 8.6 below are respected.

8.1.2 Welding of provisional attachments, tack welds and various tools shall comply with the requirements of "Annexure 6_Welding_Section 5_Production welds" as well as the cleanliness requirements of "Annexure 7_Cleaning and Cleanliness".

8.1.3 The component Manufacturer shall take account of the need for non-destructive examination required by "Annexure 6_Welding_Section 5_Production welds", for the welded joints concerned and, consequently, the alignment tolerances of the surfaces after welding shall be compatible with the correct performance of these examinations.

81.4 Alignments between parts of different thicknesses or rectification of misalignment outside tolerances, shall be performed in accordance with the Engineering Drawing.

8.2 Alignment tolerances for joints welded on both sides or welded one side only but accessible on the root side

8.2.1 The centerlines of the parts to be assembled are aligned to within the fabrication tolerances.

82.2 The internal and external surface alignment tolerances between parts of identical thicknesses are given in Table-2.

Table-2: Alignment tolerance between parts of identical thickness

Tableau RF 4320 : alignment tolerance between parts of identical thicknesses (for class 1, 2 and 3 components)

Section thickness (mm)	Maximum permissible offset
e < 12	$\frac{e}{4}$
e ≥ 12	$\frac{e}{10} + 2$ with a maximum of 8 mm (10 mm in class 3)
e : thickness in mm of joined parts	

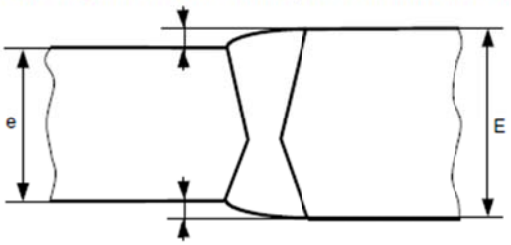
8.2.3 Alignment tolerances for parts of different thicknesses:

(i) The centerlines of two parts of different thicknesses may be offset so that the maximum misalignment of inside surfaces is less than the values given in Table-2, where 'e' is taken to be the thickness of the thinnest part.

(ii) For longitudinal welds, the edge of the thinnest part shall be included in the section defined between the 2 faces of the thickest part (Figure-2 below).

Figure-2: Alignment tolerance for parts of different thickness

Figure RF 4320 : alignment tolerance for parts of different thicknesses



8.3 Joints welded on a single side and inaccessible on the back

8.3.1 Inside surfaces: The maximum offset of inside surfaces shall not exceed e/20 + 1 and a maximum of 3.00 mm.

8.3.2 Outside surfaces: The values specified in clause 8.2.2 and 8.2.3 above shall be applicable.

8.3.3 For parts of different thickness, 'e' shall be the thickness of the thinner section.

84 Dished parts and heads made of welded parts

8.4.1 The weld joints between the component parts of spherical vessels or the constituent elements of dished heads shall meet the alignment requirements for longitudinal joints accessible from the inside.

8.5 Pipes and Piping

8.5.1 For inside misalignment of butt welded counterbored pipe components, the inside diameters of the components shall be offset in accordance with the method given in Clause 8.3, with a locate maximum misalignment of 1.5 mm.

8.5.2 In order to butt weld welded steel pipe and fittings whose thickness-to-diameter ratio is such that the pipe cannot be counterbored and may be subject to deformation, the Manufacturer shall calibrate the end sections of the joint, when necessary, to meet the tolerance requirements given in clause 8.5.1 above.

8.5.3 For longitudinal joints of welded pipe, the internal offset shall not exceed:

(i) 1 mm for $e \leq 20$ mm

(ii) e/20 (in mm) for $20 \text{ mm} < e \leq 40$ mm

(iii) 2 mm for $e > 40$ mm

8.6 Deviation from Tolerances

8.6.1 The alignment tolerances of clause 8 not be exceeded.

8.6.2 When the level differences between accessible surfaces exceed the values given in Clause 8.2 and 8.3, the surfaces shall be joined over a length equal to four times the height of the level difference (or 3 times for circular joints), in accordance with the requirements of Engineering drawing.

8.6.3 The transition made in accordance with 8.6.2 above may be either by removal of metal from the thicker part or by weld deposition of the metal on the thinner part. In this case, the inspection procedures shall cover the areas where metal is removed or deposited. Metal removal from the thicker part is only authorized if this operation does not induce unacceptable stresses. If this is not the case, the deposition of weld metal is authorized.

9. Mechanical Assembly

9.1 General

Mechanical assemblies comprise bolted flange assemblies for piping, equipment outlets and closures as well as all assemblies using screws, studs or threaded rods.

The design, choice of the bolted assemblies and the materials have been defined in the engineering drawing. These requirements shall be complied with.

9.2 Procedure

All mechanical assembling operations must be covered by a procedure specifying:

- The checks to be made before assembly (type of joints, condition of seating surfaces, condition of threads, surface treatment possibly required, etc.),
- The type of lubricants used,
- The tightening torque (possibly the overtightening value) or the value of elongation required,
- The torque or elongation measurement method,
- The bolt tightening sequence and the type of tools to be used.

9.3 Assembly requirements

9.3.1 Procedure

(i) The personnel in charge of assembly is supplied with:

- Written instructions detailing the assembly procedure.
- The tools stipulated by this procedure.

(ii) Before assembly, the following must be checked:

- The condition of the threads, bores and bolting (no damage and foreign matter).
- Absence of radial scratches or traces of impact on gasket seatings, in accordance with the requirements stipulated by the gasket Manufacturer.
- The condition and dimensions of gaskets before installation.
    - Cleanliness as per "Annexure 7_Cleaning and Cleanliness"

(iii) Before installation of the gaskets, clean gasket grooves and seatings (dry lint free cloth or non-chlorinated products such as acetone).

(iv) Fit the gaskets dry or soaked in appropriate grease according to the case (according to the procedure).

(v) After installation of the gasket, when assembling piping, the faces of the flange seatings are brought together and held in place (after ensuring that they are parallel).

(vi) Rods and nuts are installed after lubrication of threads where applicable (according to the procedure).

(vii) Nuts are brought into contact with the support faces by hand tightening.

(viii) The nuts are then tightened in accordance with the sequence stipulated in the procedure (an initial tightening of all nuts to 20% of the specified torque is recommended followed by complete tightening still following the specified sequence). Bolted assembly of the NB Vessels shall be performed according to Bolt torque values specified in ITER_D_YRHXVY - Analysis Report Final Design HNB Vessels V3.0 and ITER_D_3RZKQV - DNB Vessel Analysis Verification (Values / Reports shall be provided at the time of contract execution).

(ix) After the operation, successively check the tightening torque of each bolt or nut using the method specified by procedure, so that any loosening due to the interaction of the bolts is eliminated.

9.4 Lubricants Requirements

Requirements of clause 10.1.5 shall be fulfilled.

9.5 Thread Requirements

(i) The threads of bolts and rods are preferably obtained by rolling treated steel.

In the case of highly stressed bolts, the head must be obtained by dye stamping. The thread may be obtained in a single rolling operation and the direction of maximum extension must not be "cut" at the thread root.

In the case of die stamped non stainless steel blanks, it is recommended that all traces of decarburization be removed from the seating face of the head, on the head/shank fillet zone and from the threads.

The least amount of material possible should nonetheless be removed in order to retain the direction of maximum extension, in particular in the head/shank fillet zone. The depth of decarburization for a 25 mm diameter bolt should not exceed about 0.4 mm on the rough head surfaces.

The threads on machined bolts and rods are accepted. Threads obtained with a screw chaser are prohibited.

Tappings must be protected by plugs if painting and fabrication operations are likely to cause foreign bodies to enter.

9.6 Flange Requirements

Machining lines on the gasket seating faces are concentric. All spiral machining is prohibited.

- 9.7 Surface Treatment of Bolting Materials / Coating
- Any surface treatment on the bolts shall be subjected to approval of ITER-India and IO. The complete details of the surface treatment procedure along with the materials used for surface treatment shall be provided along with the proposal.
- Surface coatings for VQC1 shall be subject to qualification and acceptance at the MRR stage.
- The assessment of the coating shall include the different considerations mentioned in ITER Vacuum Handbook.
- ASC (Anti-Size Coating) is required on threaded components to aid assembly/disassembly by preventing seizing of parts. Consequently, the risk of seizing a bolt and nut of similar material, in contact, is high. Coating will prevent seizing resulting from high pressure on the contact surfaces of any component under vacuum.
- The material of bolts, washers and inserts under vacuum (660 grade steel) shall be treated with Copper Anti-Size Coating as mentioned in the bill of material.
- The material of bolts, washers and inserts under atmospheric pressure (42CrM04) shall be treated with Manganese Phosphate coating as mentioned in the bill of material.
- For all the parts, in 660 grade to be copper coated, that are mentioned in the Bills of Material, Bidder shall provide a technical specification for Copper Anti-Size Coating to be accepted by ITER-India / IO.
- For all the bolts, washers and inserts in 42CrMo4, to be coated, that are mentioned in the Bills of material, Bidder shall provide a technical specification for coating to be accepted by ITER-India / IO.
- The Manganese Phosphate coating shall be compliant RCC-MR requirements coming from section RF5220 of RCC-MR 2007.
- Identification of all components shall be prepared according to ITER_D_U344WG - Procedure for Identification and Controls of Items

9.8 Standards Relating to Bolting Materials for Bolted Flange Assembly

- Threads: NF ISO 261 and NF ISO 262.
- Thread tolerances: NF ISO 965-1 and 2.
- Dimensional tolerances: NF EN ISO 4759-1.
- Nuts: NF EN ISO 4032, NF EN ISO 4034, NF E 25-403, NF E 25-4

10. Fasteners and Fixings

(IVH requirements)

10.1 Tapped Holes

10.1.1 Blind tapped holes shall be avoided as far as possible, since in addition to being a source of virtual leaks (see Section 10), they provide a potential trap for contaminants. Where the use of blind holes is unavoidable, holes shall be tapped with flat bottoms and vented screws or bolts shall be used.

10.1.3 Tapped holes shall be cut using only the approved cutting fluids listed in "Appendix_4_Accepted_Fluids_2ELN8N_v1_14".

10.1.4 Cutting fluids not listed in"Appendix_4_Accepted_Fluids_2ELN8N_v1_14"may be accepted in advance by the ITER Vacuum RO and submitted for inclusion through ""Acceptance Request Form". Where an insertion is used to provide a screw thread in a plain hole (e.g. Helicoil™ inserts), the material used shall be consistent with those listed in Appendix 3.

Surface Finish and surface roughness

(IVH requirements)

Metallic components shall be supplied with the maximum average surface roughness listed in below table. Surface roughness is defined in accordance with ISO 4287: 2000.

Classification	Maximum average Surface Roughness Ra (μm)	Measurement Technique
VQC 1	6.3	Electric stylus

Generally, where the base material is not produced with an acceptable surface finish, such surface finishes may be achieved using techniques including:

- Machining.
- Electropolishing.
- Bead Blasting in a slurry in a water jet with alumina or glass beads.
- Surface Passivation / Pickling (see "Annexure 8_Pickling and passivation")

All processes on vacuum surfaces shall be followed by appropriate cleaning of the surface (see "Annexure 7_Cleaning and Cleanliness").

The finishing of the vacuum exposed surfaces as reported on the Built-To-Print drawings shall be respected.

11. Trapped Volumes

(IVH requirements)

For VQC 1, the design of any vacuum component shall avoid trapped volumes in vacuum spaces which could result in virtual leaks.

Communicating passages should be made between any potential trapped volume and the pumped volume. The design of welded and brazed joints shall be such as to avoid the risk of trapped volumes.

Bolts in vacuum should have a drill hole in the axis in order to remove trapped volume.

Care should be taken to avoid large areas of surface contact which, through imperfect flatness, can provide a trap for gas and impurities. Such surfaces, if required, should be channelled.

Where relief holes are necessary, these should preferably be in the “fixed” part of the work piece, rather than relying on, for example, the use of a vented screw which may be missed on assembly.